1969 ELECTRONICS FOR MEASUREMENT · ANALYSIS · COMPUTATION

SCIENCE · INDUSTRY · MEDICINE · EDUCATION

HEWLETT hp PACKARD

HEWLETT hp PACKARD

About this reference catalog.

This catalog is presented to you to simplify selection of quality equipment and accessories for solving your measurement, analysis, and computation tasks.

In addition to the pages outlining the capabilities, features, and specifications of HP products, there is applications material, technical information, and selection charts.

As indicated by the charts to the right Hewlett-Packard provides a wide variety of equipment for many technical phases of Science, Industry, Medicine and Education.

How to use this reference . . .

Go to the *Alphabetical Index* on the following pages to find the product of interest, and turn to the page(s) indicated. Or, if you know the Model Number turn to the index commencing on page 665.

For assistance, call your Sales and Service Office; see pages 16 through 22 for addresses and telephone numbers.

GENERAL PURPOSE

SCIENTIFIC

COMPUTATION

SYSTEMS

MICROWAVE

COMMUNICATIONS

SOLID STATE CIRCUIT DEVICES

Printed in U.S.A.

ELECTRONICS SHOP
RM. 48 NOYES

Amplifiers
Ammeters
Attenuators
Bridges
Calibrators
DC Power Supplies
Distortion Analyzers

Electronic Counters
Filters
Frequency Standards
Loudness Analyzer
Mixers
Modulators
Multifunction Meters

Network Analyzers
Ohmmeters
Oscilloscopes
Pseudorandom Noise Generator
Q-Meters
Recorders
Signal Sources

Spectrum Analyzers
Sweepers
Time Standards
Transducers
Ultrasonic Detectors
Voltmeters
Wave Analyzers

ANALYTICAL

AA Photometer
CHN Analyzer
Digital Integrator
Gas Chromatographs
MRR Spectrometer
Osmometers
Quartz Thermometer
Viscometers

MEDICAL

Cath Lab Recording Systems
Diagnostic Instrumentation
Patient Monitoring Systems
Physiological Recording Systems
Transducers

NUCLEAR

Alpha, Beta, and Gamma Counters
Gamma-Ray Spectrum Analyzer
Multichannel Pulse Height Analyzer
Nuclear Instrument Modules
Scalers and Timers
Scintillation Detectors

STATISTICAL/ DIGITAL

Multichannel Analyzer
Random Noise Generator
Signal Analyzer/Averager

ACOUSTIC

Impulse Sound Level Meters
Loudness Analyzers
Spectrum Analyzer

COMPUTING CALCULATOR

DIGITAL COMPUTERS

TIME SHARE COMPUTING SYSTEM

COMPUTER PERIPHERALS

Analog-to-Digital Converter
Disc Memory
Magnetic Tape Units
Mark Sense Readers

Multiverter
Power Supply Programmer
Punched Tape Reader
Tape Punch
Teleprinters

CUSTOM-BUILT SYSTEMS

Automatic Test and Calibration
Stimulus/Response Testing

STANDARD SYSTEMS

Data Acquisition and Manipulation
Frequency Measuring

Frequency Standard
Logic Module Testing
Automatic Network Analyzer

Nuclear Counting
Recording

Amplifiers
Attenuators
Coaxial Instrumentation
Detectors
Directional Couplers
Frequency Meters

Impedance Meters
Microwave Link Tester
Mixers
Network Analyzers
Noise Figure Meters
Noise Sources

Phase Shifters
Power Meters
Power Supplies
Signal Generators
Solid State Devices
Spectrum Analyzers

Sweepers
SWR Indicators
Transistor Chips
Vector Voltmeter
Waveguide Instrumentation

Cable Fault Locators
Cable Testing
Distortion Analyzers

Leak Detectors
Microwave Link Analyzer
Spectrum Analyzers

Telemetry Instrumentation
Telephone Test Sets
TV Monitors

TV Waveform Monitors
Wave Analyzers

Amplifiers
Displays
Hot Carrier Diodes
Infrared Sources

Integrated Circuits
Light-Coupled Isolators
Light Emitting Diodes
Limiters

Microwave Transistors
Mixers
Photochoppers
Photo Diodes

PIN Modulators
Step Recovery Diodes
Switches
Transistor Chips

ALPHABETICAL INDEX — A TO COMMUNICATIONS

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ORDERING INFORMATION | ABOUT HEWLETT-PACKARD

GENERAL INFORMATION

Hewlett-Packard products are manufactured in factories located throughout the free world. The Hewlett-Packard field sales office, representative, or distributor in your area is equipped to handle all your needs for information on any Hewlett-Packard product, and for parts or service on Hewlett-Packard products you are already using. A worldwide listing of field offices, representatives and distributors commences on page 16.

Order by model number

When you order, please specify the catalog model number and name of instrument desired. For example, "Model 180A Oscilloscope." To prevent misunderstanding, include significant specifications. Whenever you want special options or features such as special color, non-standard power line voltage, etc., include specific instructions.

Many Hewlett-Packard instruments are supplied in cabinets along with easily attached hardware for direct mounting in 19" equipment racks. Other Hewlett-Packard instruments are available in cabinets for bench use or with 19" panels(for example, "180AR") for rack mounting. Catalog listings indicate the availability of cabinet or rack mounting arrangements. Please be sure your order indicates which you desire.

Price and delivery information

The illustrations and product information herein were current at the time this catalog was approved for printing. However, in order to continue to offer the finest instrumentation available, Hewlett-Packard Company reserves the right to change specifications, designs, models or prices without notice and without liability for such changes. Prices listed are F.O.B. USA factory or warehouse, except as indicated. Consult your nearest field sales office to confirm prices at your location and to obtain current delivery information.

Local technical assistance

Technical assistance in selecting equipment and preparing orders is available, without charge, from field engineers at sales offices in the USA and in principle areas throughout the world.

FOR CUSTOMERS IN THE USA

Where to send your order

Your order should be made out to the Hewlett-Packard Company and sent to the Hewlett-Packard office nearest you. Each field office has special communication channels to the Hewlett-Packard factories to assure prompt and efficient handling of your order. For Delcon products see page 316.

Shipping methods

Shipments to destinations in the USA are made directly from local factories or warehouses. Unless specifically requested otherwise, express or truck transportation is used, whichever is less expensive and most serviceable to you. Small items are sent parcel post. If rapid delivery is needed we will gladly ship by the more expensive methods of air freight, air express, or air parcel post when specified on your order. In many parts of the USA a consolidated air freight service provides the speed of air transport at surface rates. Ask your field engineer for details.

Terms

Terms in the USA are 30 days net. Unless credit has already been established, shipments will be made C.O.D., or on receipt of cash in advance.

Quotations

Upon request, quotations including destination prices, will be furnished to you by your local Hewlett-Packard sales office.

FOR CUSTOMERS OUTSIDE THE USA

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In many countries, your order can be placed directly on your local Hewlett-Packard distributor or representative. If there is none, as yet, in your area, your order should be placed directly on the office indicated for your part of the world.

Shipping methods

Shipments to customers outside the USA or Western Europe are made from the appropriate Hewlett-Packard facility by either surface or air, as requested. Sea shipments usually require commercial export packaging at a nominal extra charge.

Terms

Terms for orders from countries outside the United States of America which are placed on the Hewlett-Packard Company, Hewlett-Packard S.A., or Hewlett-Packard Inter-Americas, are irrevocable letter of credit or cash in advance, unless other terms have been arranged previously. Terms for orders placed on authorized Hewlett-Packard distributors are mutually determined between the customer and the distributor.

Quotations and pro forma invoices

FAS, CIF, C&F, etc. quotations or pro forma invoices, as well as exportation and importation assistance, are available on request from local authorized Hewlett-Packard sales office or representative.

ABOUT HEWLETT-PACKARD — MANUFACTURING OPERATIONS

"Advancing the state of the art" and "contribution" are expressions often heard in Hewlett-Packard's 18 research and development laboratories across the United States and around the world. The expressions accurately reflect the philosophy on which the company was founded in 1939 and which today guides the development of new products used in rapidly increasing numbers to test, to measure and to compute.

Other expressions are heard, too. These include "finest craftsmanship" and "highest quality" in the company's 18 manufacturing plants. "Service" is another. It is the watchword of the sales engineering staffs. With "fast" and "expert" added, it becomes the motto at HP's customer service facilities.

All these expressions could be merely hollow words. At Hewlett-Packard they aren't. Our aim is to bring to our valued customers the best products available, well designed, well made, well maintained.

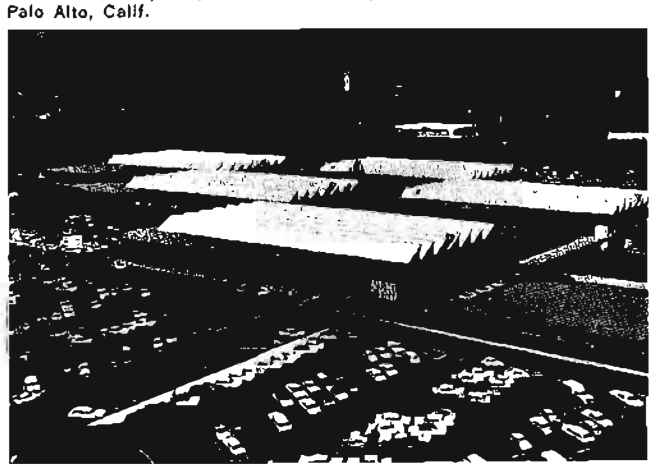
We aren't perfect, but we try to be.

Fifty-thousand customers know us and our 2,000-plus products, which broadly cover the fields of electronic, medical and analytical instrumentation, data acquisition and processing equipment, digital computers and electronic calculators. They sell at better than a quarter-billion-dollars-a-year clip.

Hewlett-Packard has 1,500 engineers and scientists dedicated to helping you solve your problems. Over the years, their contributions to technology have been numerous: the first stable audio oscillator . . . first high-speed electronic counter . . . atomic-controlled frequency standards, clocks accurate to a second in 30,000 years . . . this century's most significant development in thermometry, a quartz thermometer precise to 1/10,000th of a degree Centigrade . . . many important innovations in oscilloscopes . . . leadership in voltmeters . . . a desk-top calculator that can outperform some small computers . . . versatile digital computers designed to interface easily with measuring instruments . . . gas chromatographs able to detect and identify quantities as minute as a million-millionth of a gram . . . patient-monitoring systems that markedly reduce the mortality rate for cardiac patients . . . and many others. Tomorrow there will be still more.

Hewlett-Packard Corporate Headquarters, Palo Alto, Calif.

Microwave, Frequency & Time, and Corporate Headquarters, Palo Alto, Calif.



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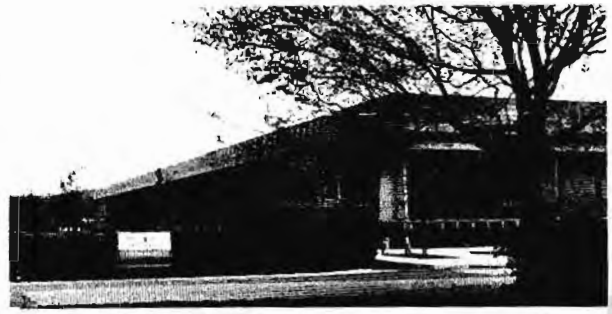

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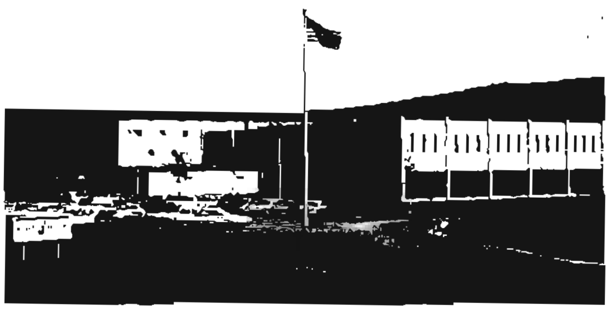

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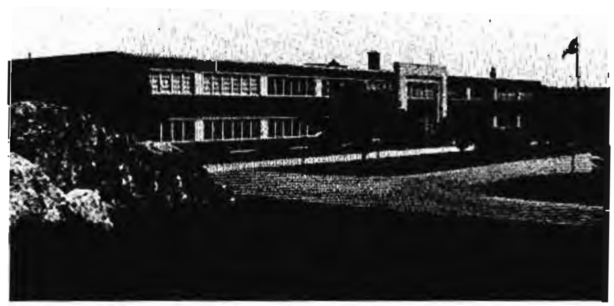

Waltham, Massachusetts

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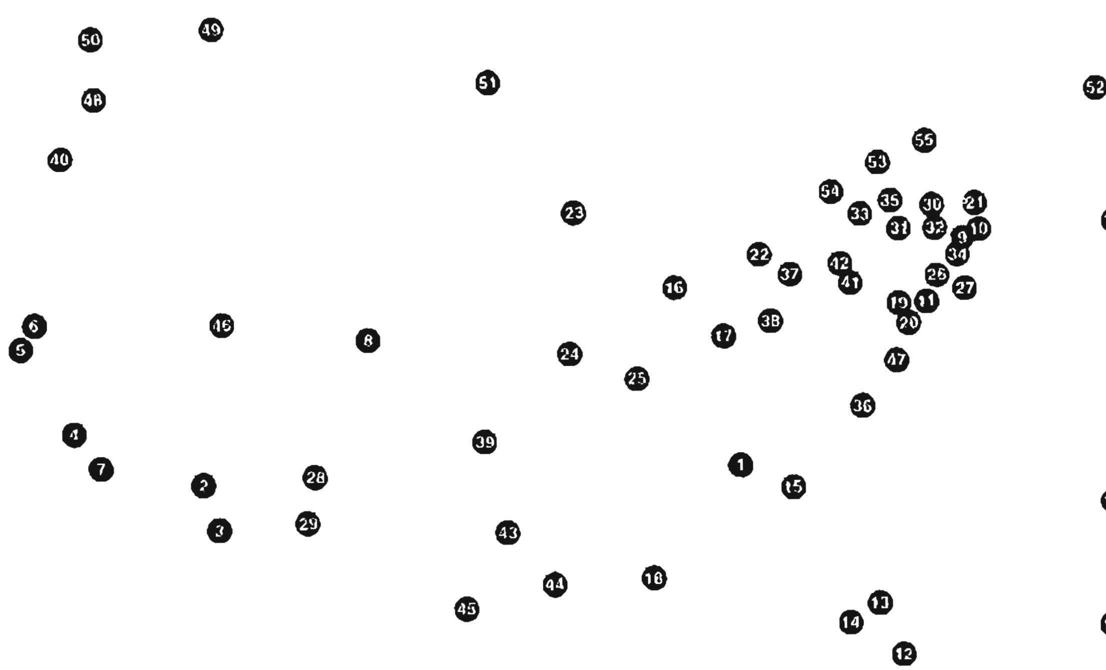

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Offices handle all catalogued products except as noted:

- Handles analytical products Pages 34-52
- Handles medical products Pages 53-67
- Handles all other products Pages 68-664

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Telex: 1598

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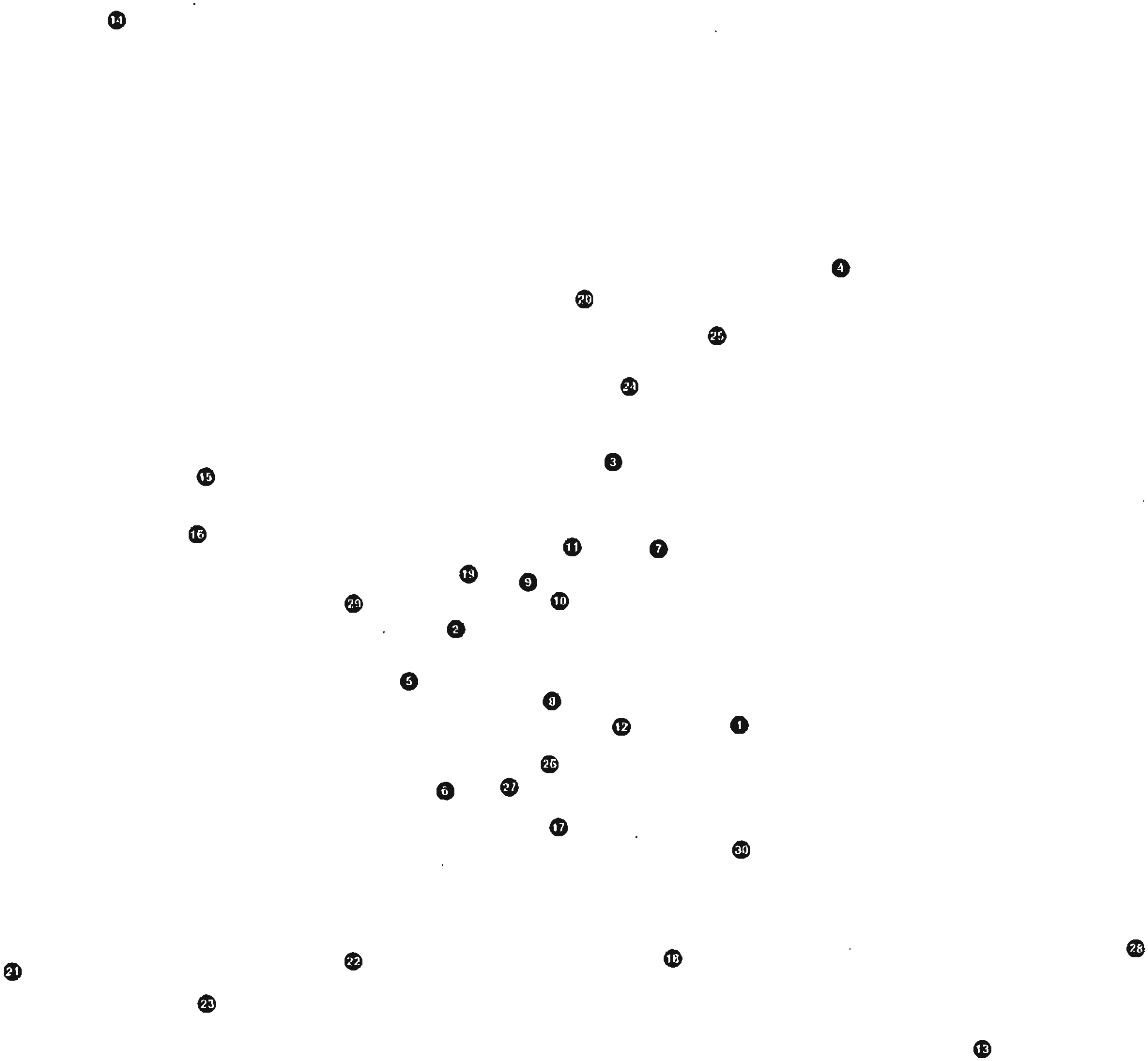
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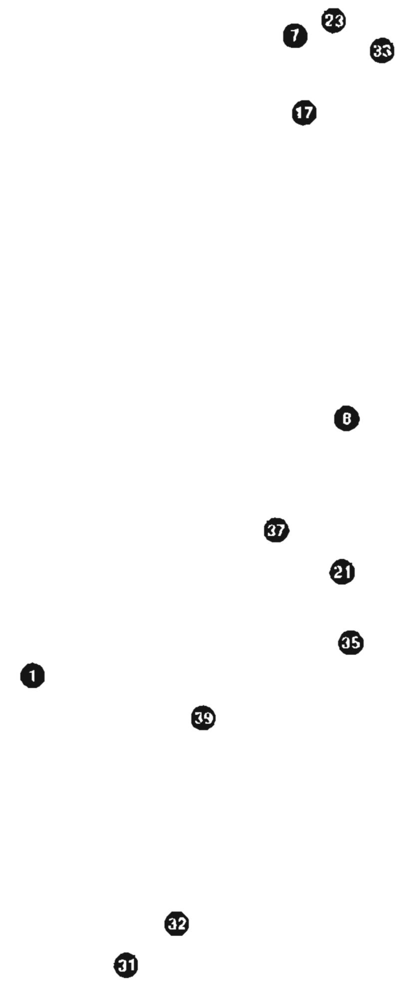
SALES & SERVICE OFFICES — AFRICA, ASIA, AUSTRALIA



Offices handle all catalogued products except as noted:

- Handles analytical products Pages 34-52
- Handles medical products Pages 53-67
- Handles all other products Pages 68-664

ANGOLA

1 Telectra Empresa Técnica
de Equipamentos Eléctricos S/
Rua de Barbosa Rodrigues
42-1°
Box 6487
Luanda
Cable: TELECTRA Luanda

AUSTRALIA

2 Hewlett-Packard Australia Pty. Ltd.
22-26 Weir Street
Glen Iris, 3146
Victoria
Tel: 20.1371 (4 lines)
Cable: HEWPARD Melbourne
Telex: 31024

3 Hewlett-Packard Australia Pty. Ltd.
61 Alexander Street
Crows Nest 2065
New South Wales
Tel: 43.7866
Cable: HEWPARD Sydney

4 Hewlett-Packard Australia Pty. Ltd.
97 Churchill Road
Prospect 5082
South Australia
Tel: 65.2366
Cable: HEWPARD Adelaide

5 Hewlett Packard Australia Pty. Ltd.
2nd Floor, Suite 13
Casablanca Buildings
196 Adelaide Terrace
Perth, W.A.

CEYLON

6 United Electricals Ltd.
P.O. Box 681
Yahala Building
Staples Street
Colombo 2
Tel: 5496
Cable: HOTPOINT Colombo

CYPRUS

7 Kypronics
19-19D Hommer Avenue
P.O. Box 752
Nicosia
Tel: 6282-75628
Cable: HE-I-NAMI

ETHIOPIA

8 African Salespower & Agency Private Ltd., Co.
P. O. Box 718
58/59 Cunningham St.
Addis Ababa
Tel: 12285
Cable: ASACO Addisababa

HONG KONG

9 Schmidt & Co. (Hong Kong) Ltd.
P.O. Box 297
1511, Prince's Building
10, Chater Road
Hong Kong
Tel: 240168, 232735
Cable: SCHMIDTCO Hong Kong

INDIA

10 The Scientific Instrument Co., Ld.
6, Tej Bahadur Sapru Road
Allahabad 1
Tel: 2451
Cable: SICO Allahbad

11 The Scientific Instrument Co., Ld.
240, Dr. Dadabhai Naoroji Road
Bombay 1
Tel: 26-2642
Cable: SICO Bombay

Pioneer Equipment Co., Pvt. Ld.
Seksaria Chambers
139, Nagindas Master Road
P.O. Box 1909
Fort, **Bombay** 1
Tel: 25-1882
Cable: PIOMETAL Bombay

12 The Scientific Instrument Co., Ld.
11, Esplanade East
Calcutta 1
Tel: 23-4129
Cable: SICO Calcutta

Pioneer Equipment Co., Pvt. Ld.
3, Esplanade East
Calcutta 1

13 The Scientific Instrument Co., Ld.
30, Mount Road
Madras 2
Tel: 86339
Cable: SICO Madras

Pioneer Equipment Co., Pvt. Ld.
22, Royapettah High Road
First Floor, North Wing
Madras 14

14 The Scientific Instrument Co., Ld.
B-7, Ajmeri Gate Extn.
New Delhi 1
Tel: 27-1053
Cable: SICO New Delhi

Pioneer Equipment Co., Pvt. Ld.
36-B, Nizamuddin West
New Delhi 13

INDONESIA

15 Bah Bolon Trading Co. N.Y.
Djalah Merdeka 29
Bandung

IRAN

16 Telecom, Ltd.
P. O. Box 1812
240 Kh. Saba Shomali
Teheran
Tel: 43850, 48111
Cable: BASCOM Teheran

ISRAEL

17 Electronics & Engineering
Div. of Motorola Israel Ltd.
16, Kremenetski Street
Tel-Aviv
Tel: 35021 (4 lines)
Cable: BASTEL Tel-Aviv
Telex: Bastel Tv 033-569

JAPAN

18 Yokogawa-Hewlett-Packard Ltd.
Nisei Ibaragi Bldg.
2-2-8 Kasuga
Ibaragi-Shi
Osaka
Tel: 23-1641

19 Yokogawa-Hewlett-Packard Ltd.
Ito Building
No. 59, Kotori-cho
Nakamura-ku, **Nagoya City**
Tel: 551-0215

20 Yokogawa-Hewlett-Packard Ltd.
Ohashi Building
59 Yoyogi 1-chrome
Shibuya-ku, **Tokyo**
Tel: 370-2281
Telex: 232-2024YHP
Cable: YHPMARKET TOK 23-724

The Nissho Company Ltd.
Nissho Building
10, Nihonbashi-Edobashi, 1-chome
Chuo-ku, **Tokyo**
Tel: 273-5111
Cable: NISSHOCONY Tokyo

KENYA

21 R. J. Tilbury Ltd.
P. O. Box 2754
Suite 517/518
Hotel Ambassadeur
Nairobi
Tel: 25670, 26803, 68206, 58196
Cable: ARJAYTEE Nairobi

International Aeradio (E.A.), Ltd.
Nairobi Airport
P.O. Box 19012
Nairobi
Tel: 82222
Cable: INTAERIO Nairobi

KOREA

22 American Trading Co., Korea, Ltd.
P.O. Box 1103
Dae Kyung Bldg.
170 Sejong Ro
Chongro Ku
Seoul (4 lines)
Tel: 75-5841
Cable: AMTRACO Seoul

Asia Science & Company
International P.O. Box 1250
23-15, 1-KA, Choongmoo-ro
Choong-ku, **Seoul**
Tel: 28-1431
Cable: ASIASCIENC Seoul

LEBANON

23 F. Makhlouf & Co.
P.O. Box 983
144, Damascus Avenue
Beirut
Tel: 226221, 242662
Cable: MAKHLOUFCO Beirut

Constantin E. Macridis
Clemenceau Street
Clemenceau Center
Beirut
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

MALAYSIA
24 MECOMB Malaysia Ltd.
2 Lorong 13/6A
Section 13
Petaling Jaya, **Selangor**
Cable: MECOMB Kuala Lumpur

NEW ZEALAND
25 Hewlett-Packard (N.Z.) Ltd.
32-34 Kent Terrace
P.O. Box 9443
Wellington, N.Z.
Tel: 56-409
Cable: HEWPACK Wellington

Dental & Medical Supply Co., Ltd.
P.O. Box 1994
128 Wakefield Street
Wellington, C. 1
Tel: 70-769
Cable: DENTAL Wellington

PAKISTAN (EAST)
26 Mushko & Company, Ltd.
31, Jinnah Avenue
Dacca
Tel: 80058
Cable: NEWDEAL Dacca

Dodhys Agencies
9-H, Motijheel
Dacca 2,
Cable: DODHYS Dacca

PAKISTAN (WEST)
27 Mushko & Company, Ltd.
Oosman Chambers
Victoria Road
Karachi 3
Tel: 51027, 52927
Cable: COOPERATOR Karachi

28 Dodhys Agencies
2, McLeod Road
Lahore 6
Tel: 66180
Cable: DODHYS Lahore

PHILIPPINES
29 International Industrial Investment
P.O. Box 2511
Plazza de Binondo
No. 417 J Luna Street
Manila 12133
Tel: 4-26-08, 4-81-52
Cable: THREE-I Manila

Electromex Inc.
2129 Pasong Tamo
Makati, Rizal
P.O. Box 3419
Manila
Cable: ELEMEX

SINGAPORE
30 Mechanical and Combustion
Engineering Company Ltd.
9, Jalan Kilang
Singapore, 3
Tel: 642361-3
Cable: MECOMB Singapore

SOUTH AFRICA
31 Hewlett Packard (Pty.), Ltd.
Hill House
43 Somerset Rd.
Cape Town
Tel: 2-9711
Cable: AUTOPHONE Cape Town
Telex: 7038CT

32 Hewlett Packard (Pty.), Ltd.
607 Pharmacy House
80 Jorissen Street
Braamfontein, **Johannesburg**
Tel: 724-4172
Telex: 0025 JHB

SYRIA
33 Sawah & Co.
Place Azmé
B.P. 2308
Damascus
Tel: 16367, 19697, 14268
Cable: SAWAH Damascus

TAIWAN
34 Hwa Sheng Electronic Co., Ltd.
P. O. Box 1558
Room 404
Chia Hsin Building
No. 96 Chung Shan
North Road, Sec. 2
Taipei
Tel: 555211
Cable: VICTRONIX Taipei

TANZANIA
35 International Aeradio (E.A.), Ltd.
P.O. Box 861
Dar-es-salaam

R. J. Tilbury Ltd.
P.O. Box 2754
Suite 517/518
Hotel Ambassadeur
Nairobi
Tel: 25670, 26803, 68206, 58196
Cable: ARJAYTEE Nairobi

THAILAND
36 The International
Engineering Co., Ltd.
P. O. Box 39
614 Sukhumvit Road
Bangkok
Tel: 910722
Cable: GYSOM Bangkok

Chalermmas
39 Praplthuck Road
Bangkok
Tel: 27508
Cable: CHALERMMAS Bangkok

UGANDA
37 International Aeradio (E.A.), Ltd.
P.O. Box 2577
Kampala
Cable: INTAERIO Kampala

R. J. Tilbury Ltd.
P.O. Box 2754
Suite 517/518
Hotel Ambassadeur
Nairobi
Tel: 25670, 26803, 68206, 58196
Cable: ARJAYTEE Nairobi

VIETNAM
38 Landis Brothers and Company,
Inc.
P.O. Box H-3
216 Hien-Vuong
Saigon
Tel: 20.805
Cable: LANBROCOMP Saigon

ZAMBIA
39 R. J. Tilbury (Zambia) Ltd.
P.O. Box 2792
Lusaka
Zambia, Central Africa

FOR AREAS NOT LISTED, CONTACT:
Hewlett-Packard Export
Marketing
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 326-7000
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461

SALES & SERVICE OFFICES

CENTRAL AND SOUTH AMERICA

Offices handle all catalogued products except as noted:

- Handles analytical products Pages 34-52
- Handles medical products Pages 53-67
- Handles all other products Pages 68-664

ARGENTINA

1 Hewlett-Packard Argentina S.A.C.e.I
Lavalle 1171 - 3°
Buenos Aires
Tel: 35-0436, 35-0627, 35-0431
Telex: 012-1009
Cable: HEWPACKARG

Lutz, Ferrando y Cia. S. A.
Florida 240 (R.5)
Buenos Aires
Tel: 46-7241, 48-1635
Cable: OPTICA Buenos Aires

BRAZIL

2 Hewlett-Packard Do Brasil I.e.C Ltda.
Rua Coronel: Oscar Porto, 691
Sao Paulo - 8, SP
Tel: 71-1503
Cable: HEWPACK Sao Paulo

3 Hewlett-Packard Do Brasil I.e.C. Ltda.
Avenida Franklin Roosevelt 84-grupo 203
Rio de Janeiro, ZC-39, GB
Tel: 32-9733
Cable: HEWPACK Rio de Janeiro

CHILE

4 Hector Calcagni P.
Casilla 13942
Estado 215 - Oficina 1016
Santiago
Tel: 31-890, 490-505

General Machinery Co., Ltda.
Paraguay 486
Casilla 13910
Santiago
Tel: 31123, 31124
Cable: GEMCO Santiago

COLOMBIA

5 Instrumentacion
Henrik A. Langebaek & Kier Ltda.
Carrera 7 #48-59
Apartado Aereo 6287
Bogota, 1 D.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota

General Electric de Colombia, S.A.
Apartado Aéreo 6799 y 3744
Kilo Metro 7 Caratera a Bosa
Bogota
Tel: 38-2040
Cable: GELCOLSA Bogota
Telex: 044-704, 044-809

COSTA RICA

6 Lic. Alfredo Gallegos Gurdián
Apartado 3243
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR

7 Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 12496
Cable: HORVATH Quito

J. A. Vizcaino V. & Cía.
García Moreno No. 1224
Casilla 2925
Quito
Tel: 213697; 217034
Cable: VIZCAINO Quito

EL SALVADOR

8 Electrónica
Apartado Postal 1589
27 Avenida Norte 1133
San Salvador
Tel: 25-74-50
Cable: ELECTRONICA San Salvador

GUATEMALA

9 Olander Associates Latin America
Apartado 1226
7a. Calle, 0-22, Zona 1
Guatemala City
Tel: 22812
Cable: OLALA Guatemala City

HONDURAS

10 Roberto L. Rodríguez
Apartado Postal No. 4
Tegucigalpa, D.C.
Tel: 2-2871
Cable: RODRIGUEZ Tegucigalpa

MEXICO

11 Hewlett-Packard Mexicana, S.A. de C.V.
Apartado Postal 12-832
Eugenia 408, Dept. 1
Mexico 12, D.F.
Tel: 43-03-79, 36-08-78

NICARAGUA

12 Roberto Terán G.
Apartado Postal 689
Edificio Terán
Managua
Tel: 3451, 3452
Cable: ROTERAN Managua

PANAMA

13 Electrónica Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel: 30833
Cable: ELECTRON Panama City

PERU

14 Fernando Ezeta B.
Avenida Petit Thouars 4719
Miraflores
Casilla 3061
Lima
Tel: 50346
Cable: FEPERU Lima

Compañia Electro Medica S.A.
Casilla 1030
Lima
Cable: ELMED Lima

PUERTO RICO

15 San Juan Electronics, Inc.
P.O. Box 5167
Ponce de Leon 154
Pda. 3-Pta. de Tierra
San Juan, P.R. 00906
Tel: (174) 725-3342
Cable: SATRONICS San Juan
Telex: SATRON 3450 332

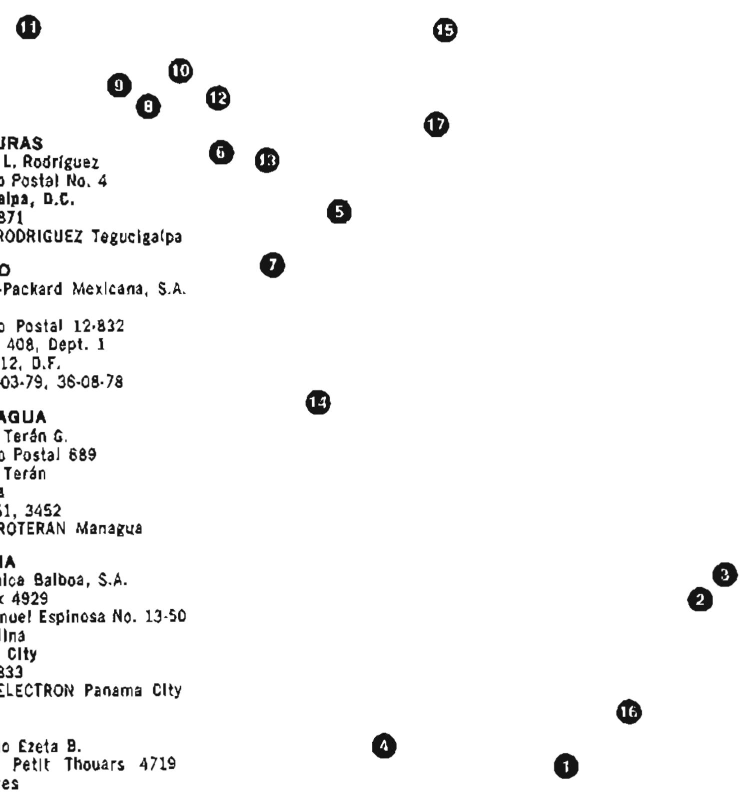
URUGUAY

16 Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA

17 Hewlett-Packard De Venezuela C.A.
Edificio Arisán Office No. 6
Avda. Francisco de Miranda
Apartado del Este 50933
Chacaito
Caracas
Tel: 71.88.05, 71.88.69, 71.88.76
Cable: HEWPAK Caracas

FOR AREAS NOT LISTED, CONTACT:
Hewlett-Packard Inter-Americas
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 326-7000
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8461



TOTAL SERVICE--PROVIDED WITH EVERY HEWLETT-PACKARD INSTRUMENT

For nearly three decades, users of measuring instrumentation have found that they can rely on the integrity of Hewlett-Packard. This customer confidence has built Hewlett-Packard into one of the world's foremost manufacturers of electronic and scientific measuring instruments.

Companies making sophisticated measuring instruments have a special responsibility to their customers because of the highly critical ways in which instruments of this kind are often used. Whether the use is found in the maintenance of international communications, in the control laboratory of a petroleum refinery, or in a hospital operating room, it is essential that the equipment's performance meet its advertised specifications.

In recognition of this responsibility, Hewlett-Packard firmly adheres to the philosophy that its obligation to you as a customer does not end when your new instrument is delivered. In purchasing an HP measuring instrument, you are purchasing a way to do a job. You have the right to expect that your instrument will continue to do this job today, tomorrow, next week, and for a reasonable number of months and years in the future.

Hewlett-Packard implements this philosophy in two ways: (1) by initially making sure that it designs and builds for HP customers the finest, most reliable instruments possible, and (2) by backing up those instruments with a customer service program which can respond with speed and completeness to HP customers' needs.

This customer service program is one of the most important facets of Hewlett-Packard's worldwide operations. Directly involved in it at present are some 850 people located throughout the company.

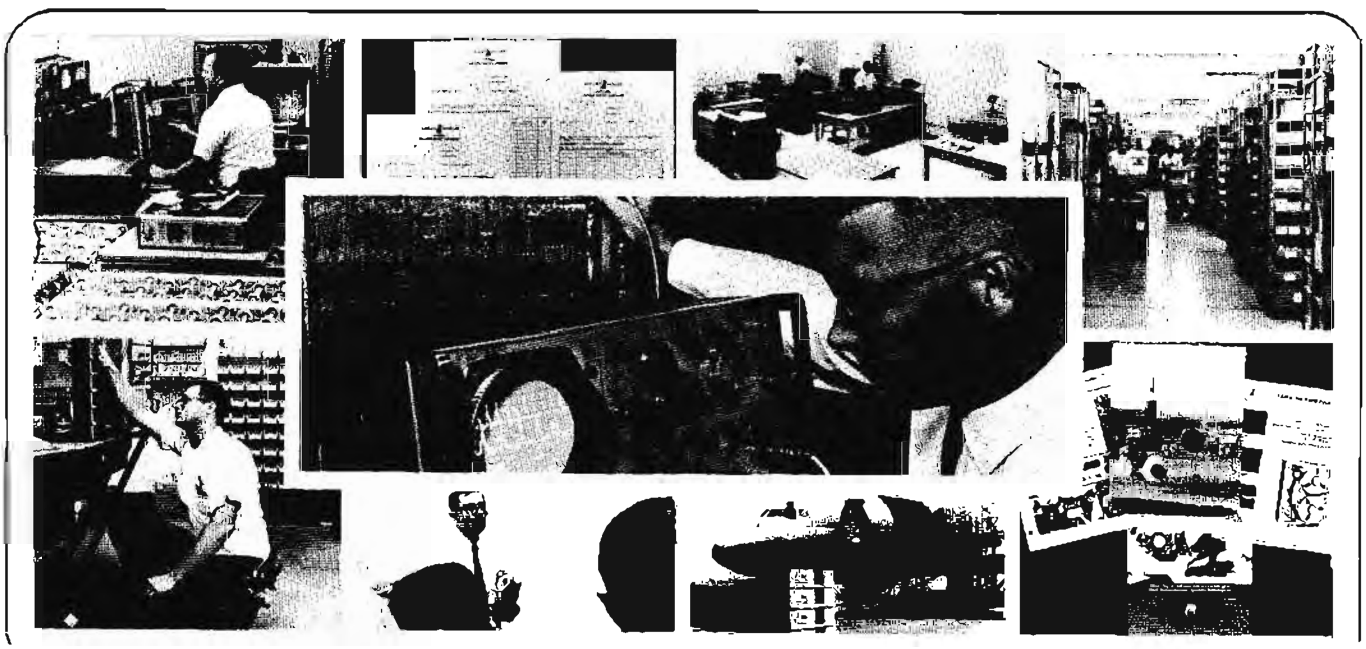
... HP's customer service begins during the instrument design phase. Service engineers in each manufacturing division work closely with design and manufacturing engineers to assure that every instrument is as easily serviceable as possible.

... More than 100 HP field sales offices located in North America and abroad provide rapid and convenient service for Hewlett-Packard instruments. You need not correspond with a factory several thousand miles away for repair service, replacement parts, and technical assistance.

Backing up these local offices are regional repair centers and major service centers with extensive replacement parts inventories and facilities for major overhauls and large calibration and repair operations. Serving HP's customers are five repair centers and one service center in the U. S. and Canada, and one service center in Europe.

Listed below are the elements of Hewlett-Packard's customer service program. The following pages briefly describe some of the benefits available to you as an HP customer under each of these headings:

- THE HEWLETT-PACKARD WARRANTY
- PRE-SALE PRODUCT INFORMATION
- TECHNICAL PUBLICATIONS
- TECHNICAL TRAINING PROGRAMS
- CUSTOMER SERVICE AGREEMENTS
- REPLACEMENT PARTS
- REPAIR SERVICE
- RECALIBRATION AND STANDARDS CALIBRATION



Hewlett-Packard gears its entire operation to one goal—the satisfied customer.

*THE HEWLETT-PACKARD WARRANTY

When you buy a Hewlett-Packard instrument, you can count on receiving an instrument built with quality materials and workmanship. You can be sure that this instrument will perform as reliably and consistently as possible for a sophisticated piece of equipment.

The Hewlett-Packard warranty is an expression of confidence in the ability of HP instruments to measure up to this standard of performance.

The following warranty is the heart of an important and enduring Hewlett-Packard aim—to satisfy you initially and to keep you satisfied. It guarantees you an instrument which will perform the way you expect it to perform. It is backed by nearly 30 years of experience in the manufacture of precision measuring instruments:

Certification

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

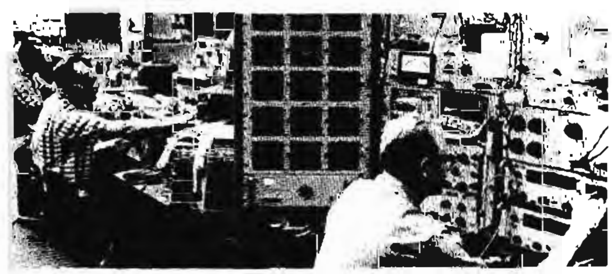
Warranty and assistance

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard. No other warranty is expressed or implied. We are not liable for consequential damages.

Service contracts or customer assistance agreements are available for Hewlett-Packard products that require maintenance and repair on-site.

Ease of service is an important consideration during the various instrument design stages.

Production lines are designed to provide optimum worker accuracy and efficiency.



Every instrument manufactured is subjected to a thorough mechanical test.

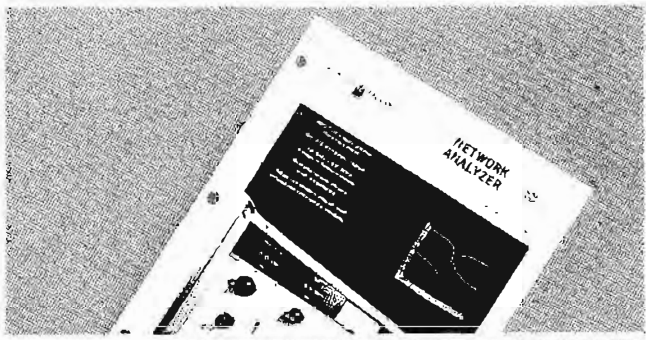
A complete electrical test is also made to ensure that each instrument meets its published specifications.

Modern packing procedures minimize damage in transit.

Hewlett-Packard offers a wealth of technical information to help you select and use Hewlett-Packard products.

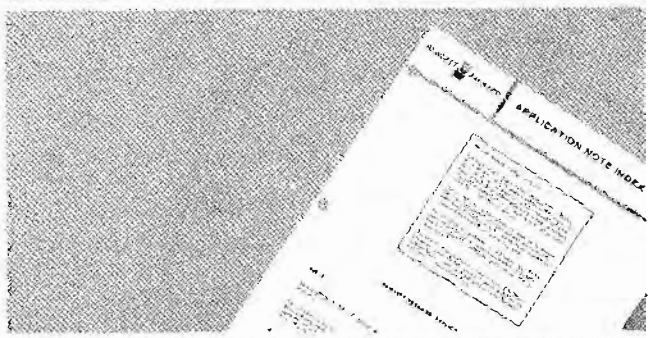
Technical data sheets

For the greatest possible detail on any individual Hewlett-Packard products, ask for the data sheet. Elaborate data is there on performance, dimensions, capabilities, options, and prices.



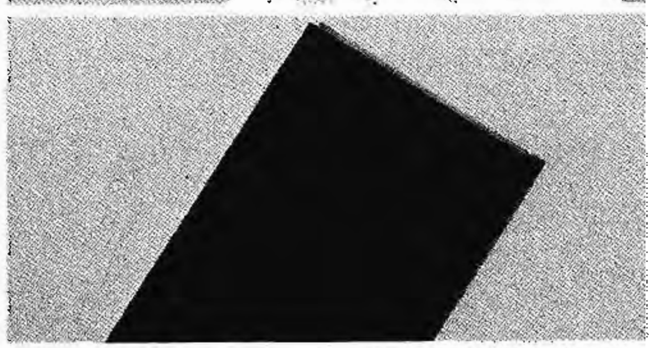
Application notes

From the Hewlett-Packard engineering laboratories which originate the products, you may also have a wide variety of technical information on using Hewlett-Packard products. More than 80 such Application Notes are described in the current Application Note Index. Ask your local Hewlett-Packard field engineering office for a copy, or write Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, California 94304.



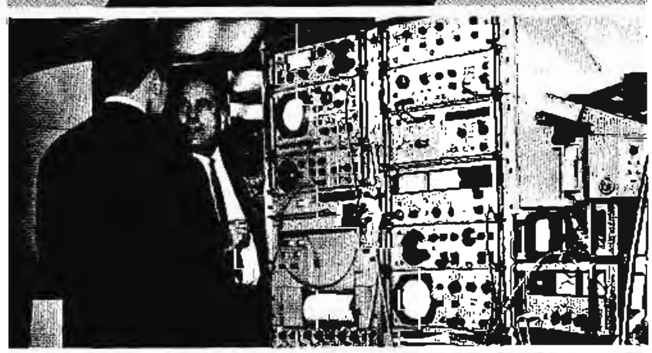
New product information

From time to time through the year, recently-introduced Hewlett-Packard products are described in summary in brochures which will supplement the information in this catalog. For a copy of the most recent issue, get in touch with your local Hewlett-Packard field engineering office or write Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, California 94304.



Hewlett-Packard Travelabs

Touring exhibits of Hewlett-Packard products are brought by bus, ship, and airplane to much of the world. Demonstrating equipment conveniently near you, these visits are scheduled by local Hewlett-Packard offices. The office nearest you has details.



Participation in professional shows

Almost every day in the year Hewlett-Packard shows and demonstrates equipment at a professional conference somewhere in the world. Often those who developed the products on display are on hand to talk with you about uses and capabilities.

SERVICE PUBLICATIONS

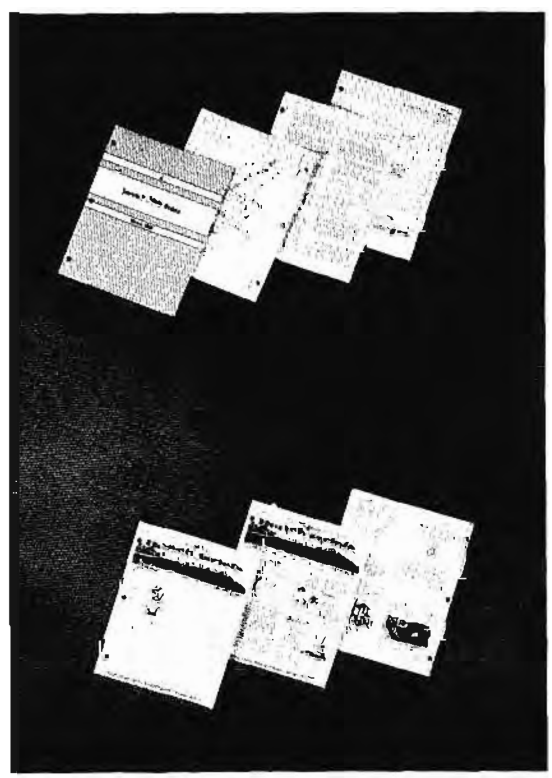
Sophisticated measuring instruments are very often rather intricate pieces of hardware. To take full advantage of the capabilities of these instruments, users generally have to familiarize themselves with a considerable amount of highly technical information. The primary source of this information for a particular instrument is the written material supplied by the manufacturer of that instrument.

Recognizing this responsibility, Hewlett-Packard devotes unusual attention to developing and distributing to its customers the most informative, readable, and generally useful written material of any manufacturer of measuring instrumentation.

Operating and Service Manuals

Hewlett-Packard's Operating and Service Manuals are outstanding technical publications—logically organized, well written, containing ample photographs, diagrams, and illustrations, and compatible with several publications standards. Included in each manual are operating instructions, maintenance and calibration information, and a table of replacement parts.

A manual is supplied with each new instrument. As a further service, extra manuals for all current Hewlett-Packard instruments, as well as for many older instruments, are also available at reasonable cost.



Service Notes

This series of technical publications is intended primarily as a vehicle for disseminating repair and maintenance information on Hewlett-Packard instruments. Acting as a convenient means of updating customers' Operating and Service Manuals, Service Notes cover such topics as new or special calibration techniques, instrument modifications, and special repair procedures—all written in a detailed manner. Ask your local field specialist for a copy of the Service Note Index so you can order those Service Notes of interest to you.

Bench Briefs

This newsletter briefly describes new Service Notes and other service publications as they become available. Servicing tips and suggestions which may be helpful to you are also included. Your local Hewlett-Packard field sales office will be happy to place your name on the regular Bench Briefs mailing list.

TECHNICAL PUBLICATIONS AND PERIODICALS

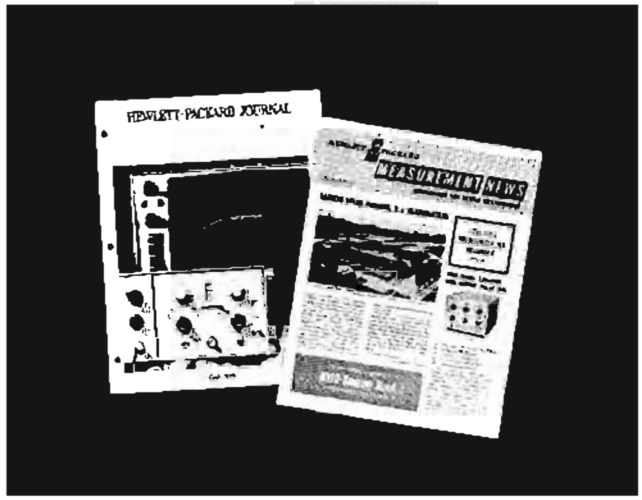
SERVICES

Each month engineers and scientists of the various Hewlett-Packard laboratories report new developments in electronic measurement in the *Hewlett-Packard Journal.*

To receive the publication, ask any Hewlett-Packard field office or write: Editor, *Hewlett-Packard Journal,* 1501 Page Mill Road, Palo Alto, California 94304.

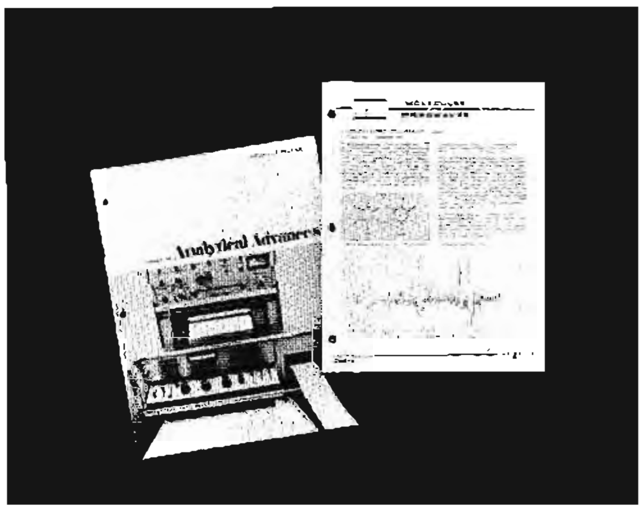
Your local Hewlett-Packard field office reports on its activities and on new Hewlett-Packard products in *Measurement News,* six times each year. A convenient card accompanies each issue, to request new literature, application notes or other desired information.

Ask your local Hewlett-Packard field office to place you on the *Measurement News* mailing list.



Analytical Advances is a quarterly journal of technical information on analytical measurement techniques, including gas chromatography, atomic absorption photometry, and vapor pressure osmometry. Successor to *Facts and Methods,* the new publication reports new findings from the Hewlett-Packard chemical applications laboratories as well as new engineering developments. Subscriptions are available for the asking from any Hewlett-Packard field office, or write *Analytical Advances,* 1501 Page Mill Road, Palo Alto, California 94304.

In *Molecules and Microwaves,* scientists of the Hewlett-Packard MRR (molecular rotational resonance) laboratory report new developments and findings in microwave spectrometry. *Molecules and Microwaves* is issued from time to time, as findings emerge. To add your name to the subscription list, get in touch with your local Hewlett-Packard field office, or write *Molecules and Microwaves,* 1501 Page Mill Road, Palo Alto, California 94304.



Measuring for Medicine and the Life Sciences is a quarterly publication of the Hewlett-Packard Waltham Division's biomedical technical staff. It regularly reports on actual field practice in medicine and the life sciences, with techniques and results of applying new measurement methods. To add your name to the subscription list, ask any Hewlett-Packard field office, or write to *Measuring for Medicine,* 1501 Page Mill Road, Palo Alto, California 94304.

More than seventy Hewlett-Packard *Application Notes* are available. Each covers a special aspect of measurement in considerable depth. Copies are distributed only on request, which will gladly be received by any Hewlett-Packard field office, or may be sent to Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, California 94304. An index of currently-available Hewlett-Packard *Application Notes* is available from the same sources.

TECHNICAL TRAINING PROGRAMS

What subjects		Seminar locations		
Applications How to use Instruments	**Service** How to Repair HP Instruments	At your local HP field sales office	At HP manufacturing plants	**Corporate Product Training**

Contact your local HP Field Sales Office for seminar information

CUSTOMER SERVICE AGREEMENTS

Many Hewlett-Packard customers have found that an HP Customer Service Agreement is the best way to optimize their instrumentation maintenance expenditures. Each agreement is shaped to best meet each individual customer's needs and at the same time, save him money.

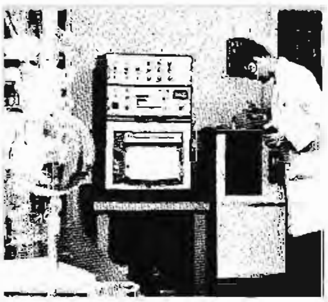
HP Service Agreements offer a well-tested service program that can reduce your costs by ensuring reliable operation, minimum downtime, and maximum useful life for your instruments. For a fixed annual cost; you can let HP assume all or part of your maintenance responsibilities.

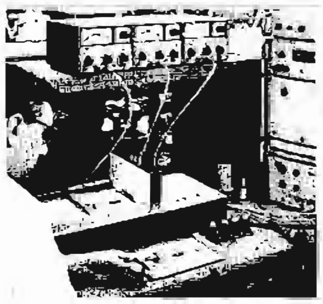
Some of the services you may choose to include in your agreement are: 1) regularly scheduled and documented calibration and preventive maintenance; 2) a fixed number of emergency repair service calls; 3) an unlimited number of emergency repair service calls; 4) the replacement of any worn or defective parts; 5) service to be performed at your location or at HP facilities; 6) pick-up and delivery of your instruments; 7) the use of the HP standards lab for your special requirements. This list by no means defines all of the service options you may choose under an HP Service Agreement to best meet your maintenance needs.

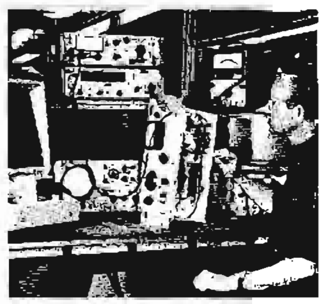
An additional benefit under most HP instrument Customer Service Agreements is that new HP instrumentation you purchase during the course of the Agreement may be included under the Agreement at no additional charge.

Hewlett-Packard's Customer Service Agreement program is based on years of detailed maintenance information on each HP instrument. By taking advantage of this information you can improve the usefulness and efficiency of each of your instruments, and do it at a fair price. You may find, as many other satisfied customers have, that a Hewlett-Packard Customer Service Agreement is the best answer to your maintenance needs.

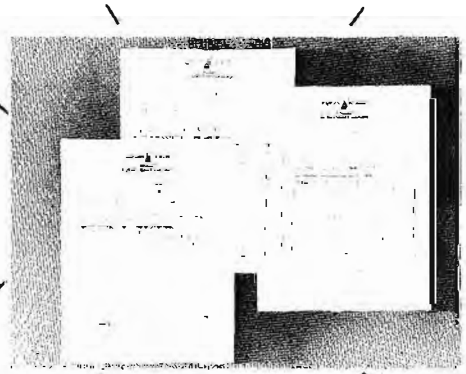
Contact your local HP field office for more information.


Maximum equipment use


Minimized downtime


Trained repair specialists

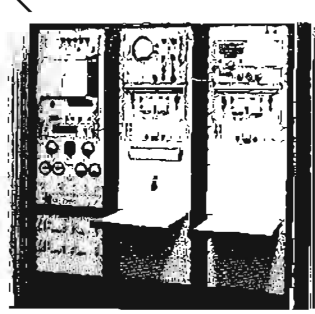

Known annual cost




New instruments added free


On-site service


Defective parts replaced free


Standards lab calibration

REPLACEMENT PARTS

Inventories

Prompt instrument maintenance, done either in your facility or by Hewlett-Packard, depends on the immediate availability of replacement parts. For this reason, HP maintains extensive parts inventories at its field sales offices in many locations. These field sales offices are backed up by service centers, which maintain full factory level inventories, including many parts for older HP instruments.

Parts Identification

As mentioned earlier, every HP instrument manual has a "Table of Replacement Parts" to make it easy for you to identify parts you wish to replace.

If you need further help in identifying replacement parts, be sure to call your Hewlett-Packard field sales office. Each office maintains extensive technical files to help identify parts rapidly and further support is given each office by the service centers which have complete microfiles including many of the older products. This capability provides complete information in a matter of seconds.

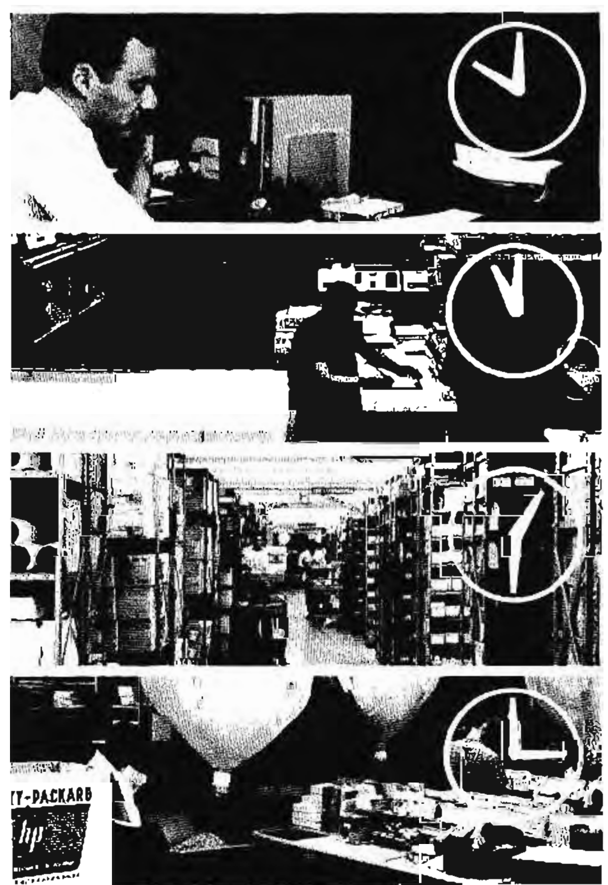
Delivery Time

When it comes to replacement parts, customers have a right to expect product quality and fair value from their supplier. From Hewlett-Packard, this is exactly what they receive. Customers also have a right to expect fast delivery. With its extensive distribution of field sales offices and convenient local inventories, HP is uniquely qualified to provide fast delivery.

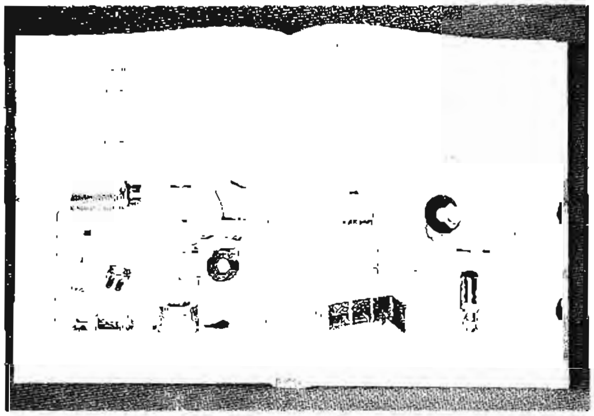
Normally, a replacement part order received by a USA field sales office will be filled and shipped the same day. Even if the office does not have the part in stock, this speed is not lost thanks to a computerized dataphone communications system linking each field office and service center.

In the USA if a field sales office receives an order for a part which it cannot supply, the order will be instantly relayed to a service center via the dataphone link. The order is then filled and shipped directly to the customer by the service center.

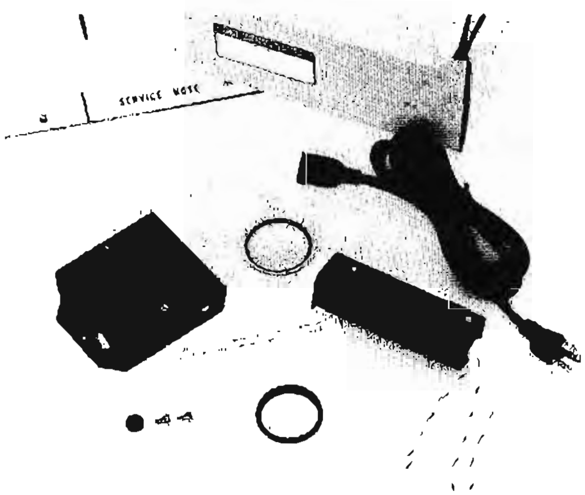
Hewlett-Packard can in this way offer unusual speed in the delivery of replacement parts.



AT LEAST 90% OF THE ORDERS FOR REPLACEMENT PARTS RECEIVED BY AN HP FIELD SALES OFFICE WILL BE SHIPPED THE SAME DAY — EITHER FROM THE SALES OFFICE ITSELF OR FROM A SERVICE CENTER.



A wide variety of instrument accessories are always available for Hewlett-Packard Products.



Shown here is the modification kit for the internal light source of the model 196A oscilloscope camera.

These items make up a spare parts kit for the model 417A VHF detector.

Other Supplies

In addition to the usual replacement parts, *Accessories and Operating Supplies* are also in stock ready for immediate delivery.

Modification Kits may also be ordered from your nearby field sales office. Two publications from HP Customer Service, "Service Notes" and "Bench Briefs" (referred to earlier under TECHNICAL PUBLICATIONS), keep you abreast of modifications which are available.

Several types of *Spare Parts Kits* are available to sustain continuous operation from your HP instruments when they are being used in an isolated area, or where loss of the instrument's use would be extremely critical. "Running Spares" and "Isolated Service Kits" offer varying degrees of completeness, and you can choose the kit that most nearly satisfies your requirements.

Ordering Procedure

When ordering a replacement part or supply item, please specify: (1) the HP stock number for the part, and (2) its complete name as indicated in the "Table of Replacement Parts" in your Operating and Service Manual. Since the characteristics of a given component may have been altered in subsequent production changes, you should be sure to take this information from the Operating and Service Manual you originally received with the instrument.

As indicated above, your local field sales office can also provide help in parts identification. If you do place an order for a part without a stock number, please include the instrument model number, its serial number, a complete description of the part, its function, and its location within the instrument.

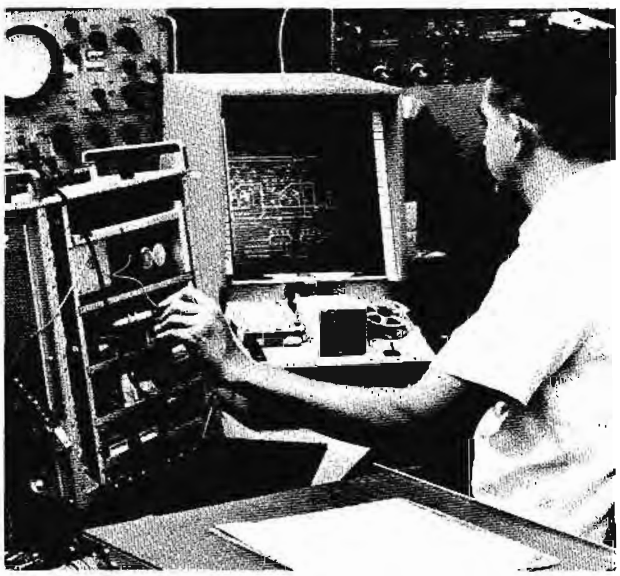
REPAIR SERVICE

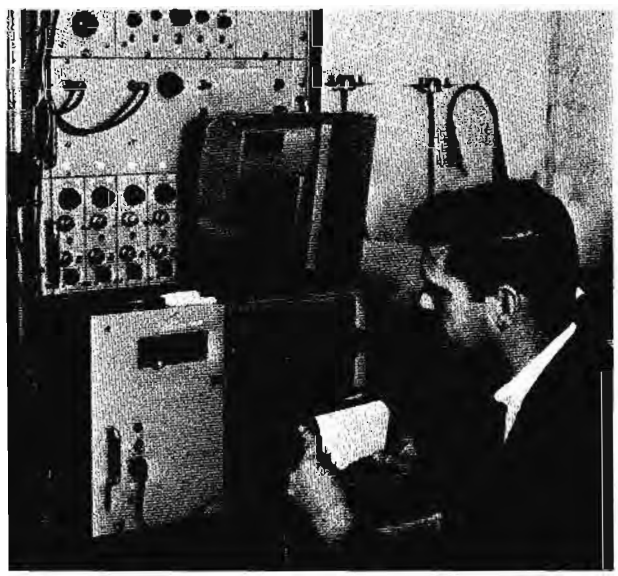
Hewlett-Packard is always prepared to back its products with the best possible repair service at a fair price.

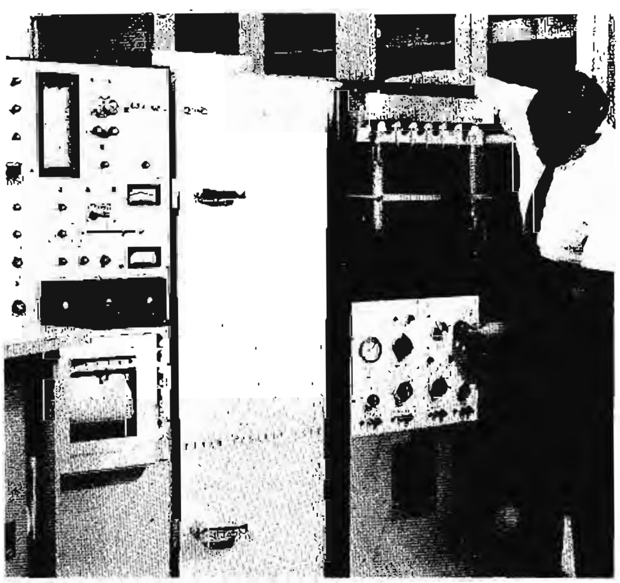
To this end, most HP field sales offices throughout the world have repair and maintenance groups. These offices are backed by regional repair centers and service centers which have complete maintenance facilities, sophisticated test equipment, factory trained specialists, and a full line of replacement parts. You are thus able to deal with one local HP sales office for all your instrumentation needs.

Service is always provided at a price which reflects a fair value for the work actually done and is consistent with what customers reasonably expect to pay for the benefits received. In addition to needed repairs, HP performs calibration, preventive maintenance, and both mechanical and electrical inspection to ensure satisfactory operation and a prolonged life for your HP instruments.

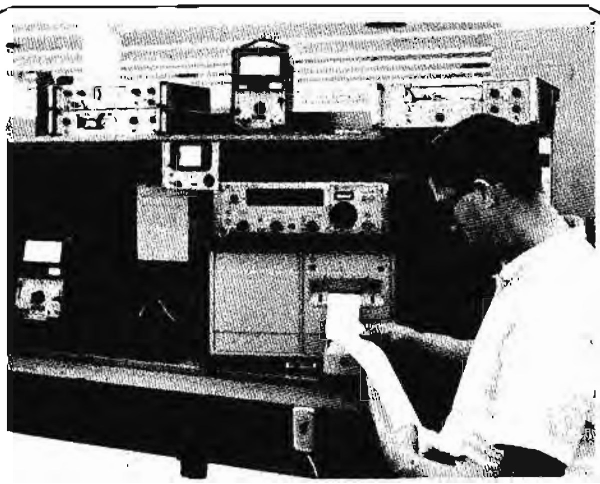
HP also offers extensive overhaul services for older instruments. These models can often be rebuilt to meet the specifications of the current production models. If a model is no longer manufactured, an overhaul will restore the instrument to its original usefulness.







RECALIBRATION AND STANDARDS CALIBRATION



Recalibrations are performed by factory trained technicians at local field service facilities

HP's flying clocks are used by major world time keeping centers to calibrate their time standards.

To insure that an electronic instrument continues to perform reliably, its operation should be routinely verified from time to time. Each Hewlett-Packard operating and Service Manual provides the information you need to recalibrate instruments in your own facility. If you prefer, the local HP sales office will be happy to arrange your recalibration for you.

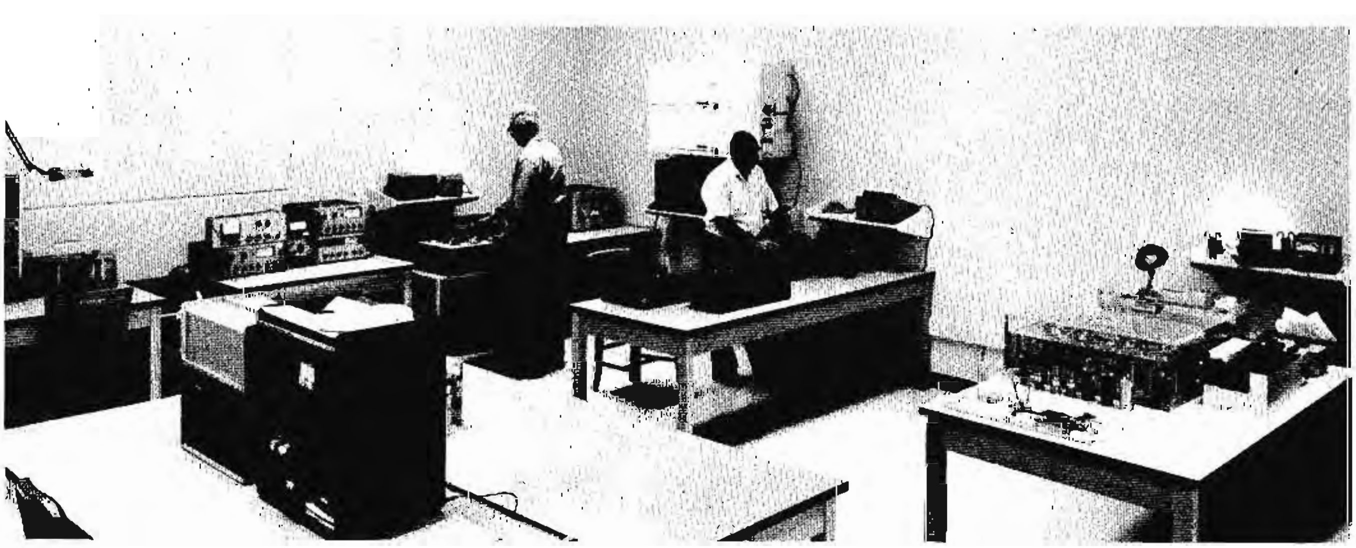
In addition to this normal recalibration service, Hewlett-Packard also offers a standards calibration service for a wide variety of components, instruments and systems.

A standards calibration generally consists of obtaining the necessary corrections to be applied so that an instrument can be used with improved accuracy. In other cases, the standards calibration report is evidence of compliance with requirements for traceability to the National Bureau of Standards, important in government contracts.

The calibration report issued on every calibration gives the measurement conditions, a brief description of the technique used, the measurement uncertainty, the statement of traceability, and the actual test data, expressed in the most useful form. HP's standards capabilities cover almost all of the usual electronic quantities, at frequencies from dc to 40 GHz. An instrument of any manufacture can be calibrated, provided only that it is in good condition and shows the requisite stability.

Most customer standards calibrations are done by the Measurement Standards Laboratory at HP's headquarters in Palo Alto, California. As a further service, however, many of the HP field sales offices have been equipped with standards calibration capabilities for selected types of measurements.

Contact your local Hewlett-Packard field sales office for more information on the recalibration and standards calibration services available to you from HP.



The DC Room in HP's Palo Alto Standards Laboratory has temperature controlled within ±0.03°C.

INTRODUCTION

Long recognized as the foremost supplier of electronic measuring instruments for the engineer, Hewlett-Packard has more recently become an important source of analytical instrumentation for the chemist and research scientist.

Gas chromatographs

Easily the most popular instrument in chemical laboratories around the world, the gas chromatograph (GC) has had a revolutionary effect on analytical chemistry because of its almost universal application, great speed and low cost.

Hewlett-Packard offers as complete a line of analytical and preparative gas chromatographs as any manufacturer anywhere in the world.

Analytical GC. Hewlett-Packard manufactures three basic types of analytical GC's: Series 5750 "research" instruments incorporating all the state-of-the-art advances in design to permit the highest possible level of performance for a great variety of analyses; Series 700 "laboratory" instruments, modular in design, available with only the basic equipment that is required to perform a particular class of analyses; and Series 402 "high-efficiency" instruments whose primary advantage is a large oven that accommodates U-tube glass columns for the analysis of sensitive materials. The choice between these three types should be based along functional lines.

Preparative GC. Automative preparative GC's are used to isolate components of complex chemicals and collect them as pure fractions. There is a choice of two Hewlett-Packard instruments in this category: Series 775/776 large-scale preparative GC's that accommodate any size column up to 4 inches OD; and the Model 5795A preparative attachment for converting analytical GC's to fully automatic small-scale preparative work.

Spectrometers

The *HP Model 5960A Atomic Absorption (AA) Photometer* is a fast and accurate way to detect the presence of metallic elements in *ppm* and often *ppb* concentrations. The 5960A is fundamentally faster and easier to use than other AA instruments because it employs push-button-selected resonant wavelength filters rather than the traditional monochromator. It produces reliable six-element analyses as fast as 60 seconds, reading out the results directly in concentration. Because of its unique resonant line isolation and dual wavelength compensation, it is capable of routine operation at the highest degree of repeatability.

The *HP Series 8400B Microwave Spectrometer* provides a means of measuring the total amount of information (frequency, intensity and line width) available from gas-phase microwave spectroscopy absorption lines. Research scientists use this measurement to provide information in such areas as molecule identification, molecular concentration, bond distance, bond angle, molecular vibrational levels, barriers to internal rotation, equilibrium constants, molecular collision rates, and reaction kinetics.

Specialized instruments

The *Model 185 Carbon Hydrogen Nitrogen Analyzer* performs a complete elemental analysis of organic materials simultaneously and automatically in less than 10 minutes.

In the few years since its introduction, the 185 has already gained considerable acceptance among microchemists. The reason is its ability to perform, even under difficult circumstances, elemental analyses whose accuracy is well within the accepted allowable error of ±0.3%, at a speed advantage of 4 to 8 times over classical methods. In addition to being faster than the classical methods, the Model 185 also requires a much smaller laboratory investment because it enables a technician with only a minimum of microanalytical training and experience to obtain reliable results under normal laboratory conditions.

The *Model 2801A Quartz Thermometer* is an entirely novel temperature measurement technique. It employs a small quartz disc transducer that operates within a protective probe housing as a piezoelectric resonator for a sensor oscillator. The resonant frequency of the quartz crystal varies as the temperature of the probe in such a manner that the frequency of the sensor oscillator output signal is a linear function of temperature. Probe temperature is displayed as a direct digital readout in °C or °F. A bcd output is also provided for input to computers and other data handling systems.

The 2801A operates over the range of −80 to +250°C (−112 to +482°F) with measurement resolution to 0.0001°. It is equipped with two sensing probes and can indicate the absolute temperature of either probe or the difference between them.

Molecular weight instruments

Hewlett-Packard offers the polymer chemist a choice of three instruments to help him make fast and accurate molecular weight determinations of all sizes of molecules: the Model 302B is a vapor pressure osmometer for number-average molecular weight determinations between 50 and 25,000; Series 500 Membrane Osmometers provide the same type of determination between 10,000 and 1,000,000; and the Model 5901B Auto-Viscometer gives viscosity-average molecular weight determinations and intrinsic viscosity measurements. At one time or another, the polymer chemist needs the kind of information that each of these Hewlett-Packard instruments is capable of producing for him. He may even want to make molecular weight measurements according to the classical cryoscopic or ebulliometric methods. If so, he can simplify his job by using the Model 2801 Quartz Thermometer, described earlier. Once again, the choice between the various types of Hewlett-Packard instruments should be based on functional considerations.

Data handling

The *HP Model 3370A Integrator* is an electronic digital integrator that automatically provides accurate quantitation of a GC analysis and presents the results on a built-in printer and, if desired, on an optional 8-digit visual display. A unique internal programming feature gives the operator a choice of four push-button-selected programs to optimize the integration of different sample types and peak shapes.

The *HP Model 7127A/7128A Strip Chart Recorders* are available with plug-in modules for a variety of uses including GC, osmometry, temperature and multiple-span measurements. They are compact, solid-state recorders with 10-inch calibrated charts, ½-second full-scale pen speed and ±0.2% calibrated accuracy.

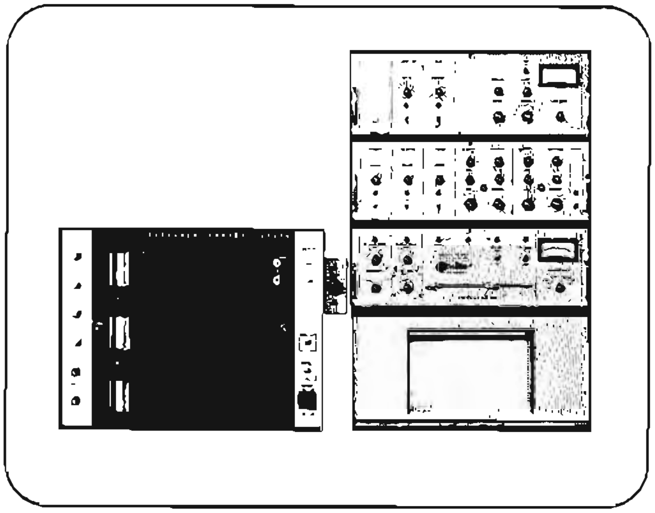
Hewlett-Packard manufactures a broad line of other data handling instruments including digital computers, magnetic tape recorders, oscillographic recorders and X-Y recorders.

Accessories

Often the effectiveness and utility of Hewlett-Packard instruments can be significantly extended through the use of an accessory that has been specially engineered for that purpose. The most important ones are described in the Analytical Instrumentation section of this catalog. Complete information on these and many other useful accessories is given in the Columns and Accessories Catalog, available on request.

RESEARCH GC
Automated, multiple-detector for top performance
5750B Series

GAS CHROMATOGRAPHY



Series 5750 Gas Chromatographs are automated yet fully versatile instruments whose performance is equal to the strictest research requirements. They are a 'top-of-the-line' instrument incorporating improvements that are available in no other gas chromatograph. Behind these improvements stand some quiet but important advances in the state-of-the-art that have made gas chromatography an even more useful tool than it was just a few years ago when the 5750's predecessor was introduced. Parallel advances in design make the 5750 still the most useful gas chromatograph around.

Specifications, Series 5750B

Detectors

Flame ionization
Dual detector unit.
Isolated jet, operating potential 350 vdc.
Extended linear operating range of over 10^7 with hydrocarbon sample.
Sensitivity: 40 millicoulombs/gram of carbon with hydrocarbon sample and oxygen as combustion gas.
Operating temp.: ambient to 500°C.
Voltage-stabilized power regulator.
Flame igniter standard.

Thermal conductivity
Dual detector unit.
Operating temp.: ambient to 450°C.
Carrier gas: helium, 5-200 ml/minute.
High-sensitivity, spiral flow-thru tungsten-rhenium filament.
Noise: ±1/4% at 150 ma, detector 350°C, isothermal oven, helium carrier gas.
Drift: ±4% per hour at 150 ma, detector 350°C, isothermal oven, helium carrier gas.
Power-proportioning temp. controller.
Relatively insensitive to flow changes.
"Detector protector": carrier gas pressure reduction automatically cuts off filament current.

Electron capture
Pulsed voltage: 5, 15, 50 and 150 microsecond intervals.
Electron source:
(1) 200 millicuries tritium.
operating temp.: ambient to 220°C ±5°.
(2) 2 millicuries Ni^{63}
operating temp.: ambient to 355°C ±5°.
Integral overheat protection.
Carrier gas: argon-methane or helium with purge.
Purge gas: argon-methane.
Voltage-stabilized power regulator.
Parallel plate configuration.

Micro cross-section*
Electron source: 200 millicuries tritium.
Operating temp.: ambient to 220°C ±5°.

Oven
Temperature range: ambient to 500°C with detectors and injection port at 100°C. 80°C is minimum oven temperature possible with detectors and injection port at 275°C to 300°C.
Isothermal gradients: ±0.5% max. (measured in air).
Programmed gradients: ±1.0% at 10°C per minute to 400°C (measured in air).
Max. heating rate: 50° to 400°C in 10 minutes with 120 Vac across the heaters and without columns.
Cooling rate: 400°C to 50°C in 8 minutes without columns.
Linear programmer: 10 rates from 1° to 60°C/minute.
Simultaneous installation of up to 3 detectors.
Capacity: up to 150 feet of 1/4 inch OD column and proportional lengths of 1/16", 1/8" and 1/2" OD columns.
Power-proportioning temperature controller.
Automated programming cycle including cooling.
Installable accessories: injection splitter, effluent splitter, heated collection vent, gas sampling valve, backflush valve.

T. C. bridge
Continuous current adjustment and readout (0-300 ma).
Coarse and fine zero controls.
Attenuator for bridge output (12 positions to 1024).
Output polarity switch.
Separate output for electronic integrator.
Line-operated power supply.

Electrometer
Single and dual-channel models.
Input (each channel): dual flame ionization, single flame ionization, electron capture or micro cross-section detectors.
Sensitivity: 1.0 x 10^{-12} A full scale output on a 1 mv. recorder at range 1, attenuation 1.
Dynamic range: 100,000 to 1 on all range resistors.
Total linear range of 4.0 x 10^{-14} to 10^{-5}A.
Noise: 2.0 x 10^{-14} A peak to peak (cables disconnected at the electrometer).
Drift: 5%/hr on most sensitive range (cables disconnected at electrometer).
Coarse and fine zero controls, with background suppression of 1.0 x 10^{-10} A on all ranges.*
Separate input and output attenuation controls.
Line-operated power supply.
Output impedance: to recorder ≤1.28 kΩ; to integrator = 11.5 kΩ.

How to order

5751B	Dual flame detector instrument with single-channel electrometer.	$4200
5752B	Dual thermal conductivity detector instrument with bridge.	3750
5753B	Electron capture detector instrument with single-channel electrometer.	3800
5754B	Dual flame and dual thermal conductivity detector instrument with single-channel electrometer and bridge.	5600
5755B	Dual flame and electron capture (tritium) detector instrument with dual-channel electrometer.	5000
5756B	Dual flame, dual thermal conductivity and electron capture (tritium) detector instrument with dual-channel electrometer and bridge.	6700

*Additional suppression at 1.0 x 10^{-8} A possible, with some degradation of noise and drift.

GAS CHROMATOGRAPHY

HIGH EFFICIENCY GC

Multi-detector, dual U columns, all-glass system

Series 402

Designed specifically for the analysis of thermally sensitive, polar and other hard-to-chromatograph materials, Series 402 High-Efficiency Gas Chromatographs incorporate a number of unique instrument characteristics that minimize or eliminate the decomposition or absorption of unstable materials.

Performance

Even with the most sensitive materials—pesticides, steroids, vitamins, organo metallics, polyfunctional industrial organic chemicals—the 402 produces a chromatogram that bears all the marks of a high-efficiency instrument:

peak symmetry so fine that there is no trace of tailing even at picogram levels of detection;

column efficiency so high (often exceeding 700 theoretical plates per foot) that even the most difficult separations are completed on as little as 12 feet of column;

elimination of component loss so complete that steroids give accurate quantitative response, even at the nanogram level;

sensitivity so high that picogram quantities of many materials are detected without even extending the detector;

Specifications

Gas flow system

Facilities for handling four gases:

(1) Carrier gas: dual differential flow controllers and needle valves; dual matched 3-inch rotameters sized for helium flow range of 0-250 cc/min at 40 psig; drying tube.
(2) Hydrogen: dual needle valves; dual matched 3-inch rotameters sized for flow range of 0-100 cc/min.
(3) Air: dual needle valves; dual matched 3-inch rotameters sized for flow range of 0-700 cc/min.
(4) Purge: needle valve, drying tube.

Column system

Dual on-column injection with removable flash heaters.

Dual columns, each 4 or 6-feet, glass U-shaped with 3 mm ID and 6 mm OD (longer glass columns of paper clip configuration and metal columns may also be used).

Oven: stainless steel shell with double insulation 1½" thick; two low-mass heaters each 800 watts; two blowers; thermal fuse.

Effluent splitter (optional): annular split design; made of glass with Teflon✣ insert for min. sample contact with metal: infinitely variable split ratio of approx. 1:1 to 20:1.

Detectors

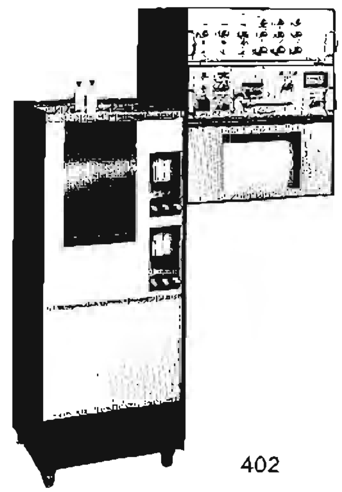
Dual flame ionization (standard): low-mass design; minimum sample contact with metal.

Twin flame: for independent operation of both sides of the dual flame detector.

Electron capture: choice of tritium cell for operation up to 220° ±5°C and nickel cell for temperatures up to 355° ±5°C: tritium cell has 200 millicuries source and nickel cell, 2 millicuries; pulsed voltage type with variable pulse interval of 5, 15, 50 and 150 microseconds; built-in overheat protection, tritium cell of Teflon✣ and stainless steel; nickel cell made of ceramic and stainless steel; venting required; requires *specific* AEC license.

Micro cross-section: 200 millicuries tritium source; dc voltage type; no purge gas required; built-in overheat protection; made of Teflon✣ and stainless steel; no venting required below 150°C; requires *specific* AEC license.

✣ Dupont's registered trademark for flourocarbon resin



402

Electrometers

Sensitivity: 4.0×10^{-12} A full scale on 1 mV recorder.

Linear dynamic range: 4×10^{-14} to 1×10^{-6} A.

Background suppression: 10^{-8} A. supplied by battery.

Input attenuation: 4 powers of 10.

Output attenuation: 8 multiples of 2.

Output for potentiometric recorders: 0-1 mV.

Temperature controls

Oven: power-proportioning controller and linear programmer with 12 rates from 0.5 to 30°C/min.; max. temp. of 400°C; max. temperature gradient of 2°C; max. heating time from ambient to 400°C is 40 min., cooling from 400°C to 50°C in 15 min.; program delay timer variable 0-20 min.

Injection port: voltage-stabilized power regulator; max. temp. of 450°C.

Flame detector: voltage-stabilized power regulator; max. temp. of 425°C.

Auxiliary detector: voltage-stabilized power regulator; max. temp. of 225°C, or 360°C.

Readout: indicating pyrometer and five-position selector switch.

How to order

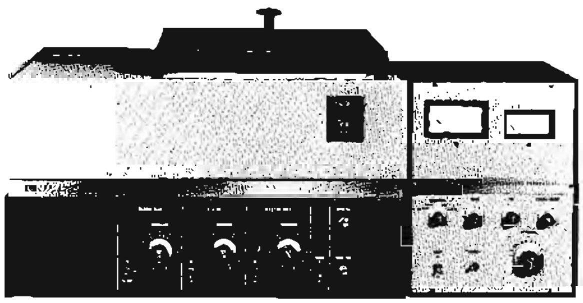
402	Basic dual flame ionization detector instrument with single-channel electrometer, 115 V, 50 or 60 Hz (specify)	$4000.00

Options

01	Adds second electrometer channel (for alternate or simultaneous operation of two ionization detector systems, or for independent operation of both sides of a dual flame detector)	825.00
02	Adds detector and all necessary hardware for electron capture (tritium foil) detection	650.00
03	Same as Option 02 except that detector contains a high-temperature Ni^{63} foil	1000.00
04	Two-way effluent splitter	95.00
21	230 V, 50 Hz operation	100.00

LAB GAS CHROMATOGRAPH

Low-cost modular dual-column GC
Series 700



Series 700

The basic Series 700 unit is an isothermal gas chromatograph with a flexible two-column design that permits single column, series or parallel two-column operation as well as dual column compensation. The 700 is also capable of manual temperature programming and high-temperature operation, with independent control of injection port, detector, and oven to 400°C. Injection can be either directly onto the column or into a flash vaporizer. All Series 700 oven modules are equipped with a voltage-stabilized power regulator. An adapter plate and switch permit bypassing the standard power regulator and allows the plug-in use of either a Model 220 Temperature Controller or a Model 240 Temperature Programmer for oven control. Except for Model 700-00, all Series 700 instruments are equipped with flow controllers.

Series 700 specifications

Detectors

Four interchangeable detectors:

(1) Thermal conductivity:
- dual detector
- four-wire hot filament type, 300 mA range
- W or WX filament standard

(2) Flame ionization:
- dual detector
- low-mass design on cast aluminum base
- manual flame igniter

(3) Electron capture (tritium or N^{63})
- pulsed voltage type with variable interval of 5, 10, 50 and 150 microseconds
- 200 millicuries tritium or 2 millicuries of N^{63} source with integral overheat protection
- no venting required below 150°C
- specific AEC license required

(4) Micro cross-section:
- DC voltage type
- 200 millicuries tritium source with integral overheat protection
- no venting required below 150°C
- specific AEC license required

T. C. bridge

Continuous current adjustment and readout
Coarse and fine zero adjustment
Attenuator (12 positions to 1024)
Output polarity switch

Power requirements:
for W filaments—15 V dc, 300 mA
for WX filaments—30 V dc, 300 mA

Electrometer

Input: HP dual flame ionization, electron capture or micro cross-section detectors.

Sensitivity: 1×10^{-11} A full scale.

Linearity: ±1.5% full scale over entire range.

Time constant: less than 1 second at full sensitivity.

Noise: less than 10^{-13} A.

Drift: less than 1% full scale per hour.
Live zero and background suppression.

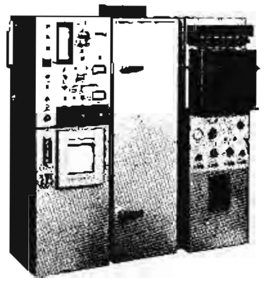
Power requirements: self-powered from integral 135 V battery supply; no ac.

How to order

700-00	Dual thermal conductivity detector (TC) instrument.	$1200.00
700-0019F	Dual TC instrument with power supply and dual flow controllers.	1600.00
700-0119F	Dual TC instrument with power supply, dual flow controllers and proportioning oven temperature controller.	2025.00
700-2419F	Dual TC instrument, with WX filaments, power supply, dual flow controllers and proportioning detector temperature controller.	1850.00
700-021	Dual TC instrument with power supply, dual flow controllers and linear programmer	2300.00
700-231	Dual TC instrument with WX filaments, power supply, dual flow controllers, proportioning detector temperature controller and linear programmer	2550.00
700-1099F	Dual flame ionization detector (FI) instrument with dual flow controllers.	1900.00
700-1199F	Dual FI instrument with dual flow controllers and proportioning oven temperature controller.	2350.00
700-12	Dual FI instrument with dual flow controllers and linear programmer.	2600.00
700-3099F	Electron capture detector (EC) instrument with dual flow controllers. Option 04 for N^{63} Electron Capture Detector, add $275.	$2050.00
700-3199F	EC instrument with dual flow controltrollers and proportioning oven temperature controller. Option 04 for N^{63} Electron Capture Detector, add $275.	2500.00
700-4099F	Micro cross-section detector (MCS) instrument with dual flow controllers.	1850.00
700-4199F	MCS instrument with dual flow controller and proportioning oven temperature controller.	2300.00
700-42	MCS instrument with dual flow controllers and linear temperature programmer.	2600.00

AUTOMATIC AND MANUAL PREP GC

Models 775 and 776



Model 775 Automatic PREP GC

An all-purpose preparative gas chromatograph, the Model 775 accommodates with equal ease, both the "long-narrow" columns of 3/8, 1/2 or 3/4 inch OD and the new "short-wide" columns of 2 1/2 and 4 inches OD. Because of this unique capability, it is equally capable of making high-capacity, high-resolution and trace component separations.

Specifications, Model 775

Injection system

Sample reservoir: pressurized; can be filled, emptied and flushed without removing from instrument; 300 ml capacity standard, optional 1000 and 2250 ml available.

Prep injection: three types provided.

1. Septum-port for manual syringe.
2. Auto-injector for automatic injection adjustable 1/4 to 12 ml.
3. Timed system for automatic injection adjustable 0 to 125 ml.

Column system

Oven: 12 in. wide by 6 1/2 in. deep by 53 in. high; accommodates up to 400 feet of 3/8-in. OD column, or up to 80 inches of 4-in. OD; also accepts proportionate length of 1/4, 3/4 and 2 1/2-in. OD column.

Thermal conductivity detector: (standard)-four-filament type with high-capacity design (no splitting required); integral power supply and bridge controls.

Collection system

Component selector: automatically selects for collection up to six components in a sample containing up to 17 components.

Manifold: seven positions; heated up to the trap, to prevent condensation; check valves prevent diffusion; plugs provide access for cleanout.

Bath: accommodates up to seven 50 ml traps; adjustable and removable; optional refrigeration unit and bath for cooling down to −15°C.

Traps: seven 50 ml glass spiral traps standard; optional 50 ml glass thermal gradient, 10 ml and 2 ml glass traps and 1 liter stainless steel traps also available.

Complete instrument

Model 775 Automatic Preparative GC with thermal conductivity detector, one 300 ml sample reservoir, seven 50 ml glass spiral traps, 48" of 1/4" OD stainless steel column, 80" of 3/4" OD stainless steel column and ElectroniK 18 recorder. $11,000.00

The Model 776 Preparative Gas Chromatograph offers an economical alternative to the Model 775, with the same true prep-scale capacity but without the automatic features. It accepts any prep column between 3/8 and 4" OD, handles up to 125 ml/injection, with a demonstrated collection efficiency of 90-98% at purity levels approaching 100%. The 776 also has an integral analytical gc capability.

Model 776 Specifications

Columns

Preparative: accepts up to 80 inches of 4" OD; proportionate lengths of 1/2", 3/8", 3/4" and 2 1/2" OD.

Analytical: 1/4" OD.

Detector

Unique flame ionization detector design avoids back flow of flame gas, permits nitrogen as carrier gas.

Integral electrometer.

Temperature control

Controllers: independent indication and control of injection port and manifold to 350°C, and column oven to 300°C.

Safety limit controller: hi-limit oven temperature cut-off prevents accidental overheating of columns; interlock prevents operation of column oven heater without fan.

Sample injection

Semi-automatic: gas-operated injector for 1.00 to 125 ml injections.

Manual: septum type.

Vaporizer: high-capacity heat sink supplies 664 calories per °C temperature drop for sample vaporization.

Sample reservoir: 75 ml pressurized reservoir.

Sample collection

Traps: five 50 ml glass traps and cooling bath; manually selected bypass.

Recorder

Optional strip chart recorder.

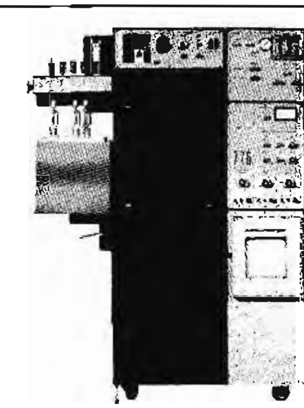
Flow measurement

Rotameter: for continuous indication of carrier gas flows; needle valves for control.

Manometer: for measurement of detector gas flows.

Complete instrument

Model 776 Manual Preparative GC with Flame Ionization Detector, including 75 ml sample reservoir, five 50 ml glass spiral traps and cooling bath, 80" of 3/4" OD stainless steel prep column, and 48" of 1/4 OD stainless steel analytical column. $5,300.00



Model 776 Manual PREP GC

PREP GC ATTACHMENT
Automatic prep accessory for analytical GC
Model 5795A

The Model 5795A Preparative Attachment automates analytical gas chromatographs for reliable small-scale preparative work. Easily installed in less than an hour, the 5795A converts an analytical GC to fully automatic preparative work without interfering in any way with the instrument's ability to perform as an anlytical GC. The 5795A offers the chromatographer an unusually economical avenue to reliable automatic preparative GC because it does not involve a wasteful duplication of the basic gas chromatograph. It also introduces mechanical simplicity and advanced electronic circuitry to small-scale prep GC instrument design and so eliminates the uncertainty and unreliability that have plagued previously designed instruments. The 5795A can be installed on any H-P Series 5750 and 810 Gas Chromatographs. It can be readily adapted to other H-P Gas Chromatographs and most competitive instruments.

Three modes of operation

In the *automatic* mode, the 5795A performs continuous cycles of sample injection and fraction collection until stopped by the operator. It can be used with temperature-programmed instruments capable of automatic re-equilibration and with isothermally-operated GC's.

The *semi-automatic* mode provides a single cycle of automatic sample injection and fraction collection. It can be used for "scouting" runs, and in temperature-programmed runs with instruments that cannot re-equilibrate automatically.

Manual operation can also be used for "scouting" runs, or when the operator wants to cut the peaks at his discretion.

Three compact components

The 5795A programs, actuates and controls repeated cycles of sample injection and sample collection until stopped by the operator. To perform these operations automatically, it employs three compact units.

The *control unit* permits setting the operating mode and trap program. It programs the peaks to be collected, those to be bypassed and the recorder signal level at which peaks are cut. The unit also counts the peaks, signals the end of a cycle, and starts a preset delay period before the next automatic injection.

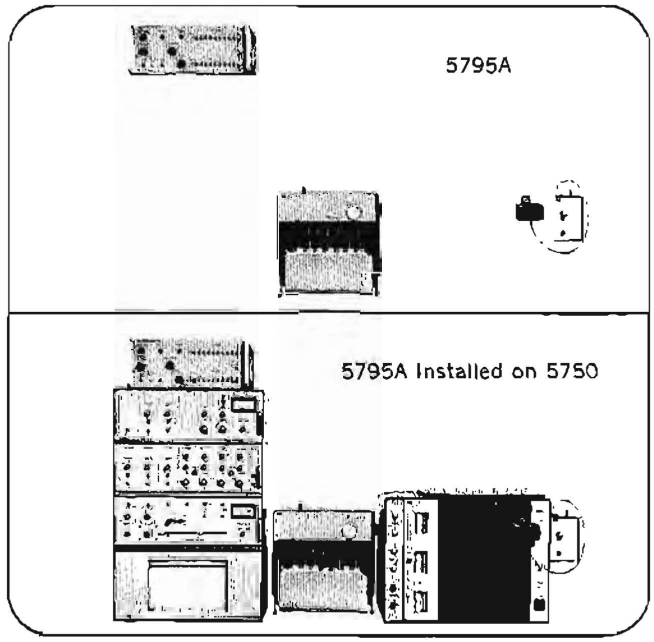
The *injection unit* meters the desired sample volume and performs a true "slug" injection into the analytical GC. Its unique action provides a short blast of carier gas a few milliseconds after the sample injection to purge the unit of sample, eliminating dribble and consequent ghost peaks.

The *collection unit* directs the effluent from the analytical GC to one of six collection traps or to a bypass trap. A 12-position collection valve, programmed by the control unit, establishes a flow path for the column effluent through a manifold to the appropriate trap thus preventing flow to all other traps.

Advanced design features

True slug-injection, achieved by a unique control logic for the 5795A's metering pump, eliminates band spreading during the injection.

Pressurized sample reservoir eliminates the possibility of vapor lock in the injection mechanism and maintains uniform sample composition by preventing volatilization of low-boiling sample components.



Positive displacement pump for sample injection provides injection repeatability of better than ±5% or 5 μl. Its carrier gas-operated floating piston design introduces a new standard of reliability for unattended operation.

Easy, thorough cleaning prevents sample contamination; all liquid-contact surfaces (stainless steel and Teflon) in the injection mechanism can be cleaned-in-place with solvent and then purged dry with carrier gas.

Simplified collection manifod has no moving parts yet positively prevents cross-contamination from trap to trap.

Snap-action collection valve changes trap connections instantly, thus permitting complete collection of desired sample components. The valve is located down-stream of the traps where it operates at lower temperature to optimize reliability.

Solid-state control circuitry increases reliability and minimizes maintenance. An electronic commutator eliminates stepping switches in the control circuit, for example, and a power interrupt system prevents automatic startup after power failure to avoid contamination of previously collected fractions.

Performance

Without discounting the importance of good instrument design and convenience features, no automatic preparative gas chromatograph is really worth its purchase price unless it excels in two performance categories: (1) reliable automation, i.e., it does its job unattended not only during the working day, but overnight and weekends when there's no one around to supervise it; (2) purity of collection, i.e., it collects the separated components without contaminating them with adjacent components because of faults in the injection or collection system. A series of tests has proved that the 5795A excels with regard to both of these performance criteria.

Automatic prep accessory for analytical GC
Model 5795A

Specifications

Control unit

Operation modes: four-position switch for selection of desired mode:
1. automatic—continuous recycling with automatic injection and collection
2. semi-automatic—automatic injection and collection for a single cycle
3. manual—pushbutton-actuated injection and operation of collection valve
4. standby—used during setup

Trap program: twenty 3-position slide switches plus a 2-position Last Peak switch; permit automatic collection of any number of peaks up to a maximum of 6, in a sample that contains up to 20 (as sensed by peak level sensor), automatically bypassing all others.

Peak level selector: sets peak height at which trap program operates; receives signal from retransmitting potentiometer in chromatograph recorder; adjustable 0 to 100% of recorder full scale.

Pre-injection time delay: 0 to 40 minutes in 2-minute steps.

Manifold temperature control: continuously adjustable from ambient to 300°C

Power interrupt system: prevents automatic startup after power failure to avoid contamination of previously collected fractions

Dimensions: 6¾″ high, 16¾″ wide, 18⅜″ in. deep

Injection unit

Type: positive-displacement pump, carrier-gas operated

Sample reservoir: stainless steel, pressurized with carrier gas; 30 ml capacity standard, 75 ml optional; can be filled, emptied and flushed without removing

Injection volume: continuously adjustable from 20 μl to 1 ml by micrometer volume selection

Injection volume repeatability: better than $\pm5\%$ or 5 μl

Sample contact surfaces: stainless steel, Teflon

Operating pressure: 50-75 psig carrier gas pressure

Mounting: main assembly (metering pump) mounts on gas chromatograph oven; injection assembly on chromatograph injection port by means of adaptor (provided)

Dimensions: main assembly—8½″ h, 3⅞″ w, 10½″ d
injection assembly—2¼″ high by 3¾″ wide by 3⅛″ deep (not including needle)

Collection unit

Manifold: heated by two 40-watt cartridge elements to prevent condensation; engineered restrictions prevent diffusion; dial thermometer indicates temperature

Collection valve: fast-acting, solenoid-operated valve with positive detents at each of 12 positions; located downstream of traps; automatically synchronized during automatic and semi-automatic operation; position indicator and manual advance

Traps: seven trap positions; all traps seal automatically when pushed in position; 2, 5 and 10-ml traps available

Bath: adjustable and removable

Mounting: adaptor connects to exit port of gas chromatograph; mounting legs adjust to required height

Dimensions: 15½″ high, 16″ wide, 9¾″ deep

Power requirements

Power: 117 V ac, 60 Hz, 5 A (switch for 220 V ac)

Carrier gas: supplied to Injection Unit at 50 psig minimum, 75 psig maximum

Trap cooling: ice, dry ice/acetone, etc, depends on application

Chromatograph requirements

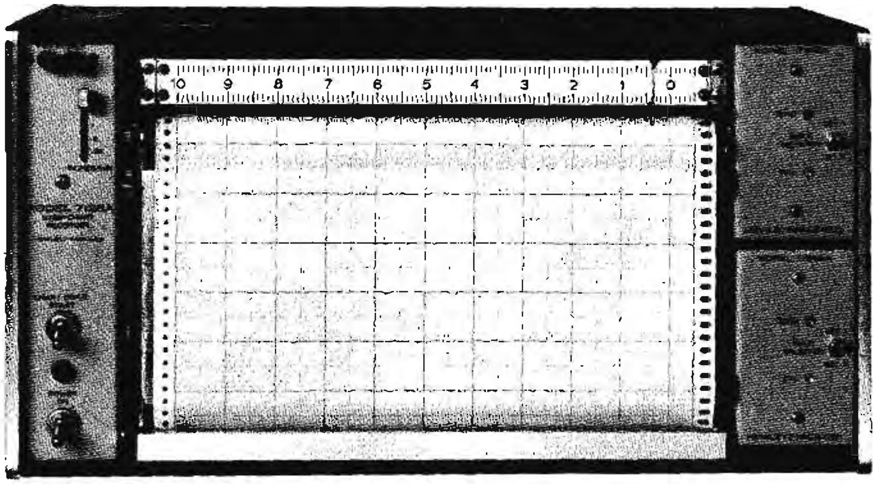
Detectors: thermal conductivity, or flame ionization detector with 10; 1 effluent splitter and heated collection vent

Recorder: requires retransmitting potentiometer, 0-5K ohms

How to order

Ordering No.	Description	Price
	Complete attachment	
5795A	Preparative Attachment for analytical gas chromatographs consisting of: Injection Module with 30-ml sample reservoir, Collection Module with seven conical traps (5 ml) and Control Module (specify one option from Group A and one from Group B)	$2900.00
	GROUP A	
Opt. 06	For use with Series 7620 GC's	n/c
Opt. 07	For use with Series 5750 and 810 GC's	n/c
Opt. 08	For use with Series 700 GC's ....add	110.00
Opt. 09	For use with Model 720 GC's ....add	110.00
	GROUP B	
Opt. 11	Retransmitting potentiometer for HP Recorders ....add	50.00
Opt. 12	Retransmitting potentiometer for Honeywell Recorders ....add	225.00
	ADDITIONAL OPTIONS	
Opt. 04	50 Hz operation	n/c
Opt. 15	Substitute 75-mil sample reservoir ....add	7.00
Opt. 21	Substitute set of seven (7) spiral traps add	70.00
Opt. 22	Substitute set of 7 vigreux traps ......add	28.00
	Individual units	
5796A	*Injection Unit* with standard 30-ml reservoir; adapted for use with 7620, 5750, 810, 720 and 700 GC's	$900.00
Opt. 15	Substitute 75-ml sample reservoir ....add	7.00
5797A	*Collection Unit* (specify one option from Group A)	900.00
	GROUP A	
Opt. 06	For use with Series 7620 GC's	n/c
Opt. 07	For use with Series 5750 and 810 GC's	n/c
Opt. 08	For use with Series 700 GC's ....add	90.00
Opt. 09	For use with Model 720 GC's ....add	90.00
	Additional Options	
Opt. 20	Cable with pushbutton for manual indexing of collection valve and for supplying power to manifold heater ......add	35.00
Opt. 21	Substitute set of seven spiral traps ....add	70.00
Opt. 22	Substitute set of seven vigreux traps ..add	28.00
5798A	*Control Unit* (specify one option from Group A)	1300.00
Opt. 04	50 Hz operation	n/c
Opt. 06	For use with Series 7620 GC's	n/c
Opt. 07	For use with Series 5750 and 810 GC's	n/c
Opt. 08	For use with Series 700 and 720 GC's	n/c
	Accessories	
19150A	30-ml sample reservoir	$ 40.00
19151A	75-ml sample reservoir	47.00
19152A	5-ml conical trap	13.00
19153A	2-ml vigreux trap	17.00
19154A	10-ml spiral trap	23.00
19155A	Retransmitting potentiometer for HP Recorders	50.00
19156A	Retransmitting potentiometer for Honeywell Recorders	225.00
19157A	Cable for manual switching (for use with Collection Unit)	35.00
19158A	Heated collection line for connecting Collection Unit to Series 700 GC's	90.00
19159A	Heated collection line for connecting Collection Unit to Model 720 GC's	90.00

GC STRIP CHART RECORDER
For top performance in gas chromatographs
Models H10-7127A, H10-7128A



H10-7128A

Compact solid-state instruments with a 10-inch calibrated chart and one or two pens, these strip chart recorders are specifically designed for use with gas chromatographs. To insure accurate recording of the chromatogram, they incorporate plug-in input modules whose low-pass filter rejects power line frequencies and the differential noise that is commonly associated with gc detector output.

The Model H10-7127A has one and the H10-7128A has two servo-actuated pens and input modules. All input modules are equipped with a detector selector switch that allows the operator to choose either of two gc detector signals for recording. Both models have a 1 mV full-scale span for each pen; input can be floated up to 500 V above ground with high common mode rejection; zero can be positioned over full span or suppressed up to 100% of full scale.

Standard features:
- One or two servo pens
- Detector selector for each pen
- One-half second full-scale pen speed
- Four chart speeds
- Three-position chart table

Optional features:
- Disc integrator
- 50 Hz operation
- Fully adjustable limit switches
- Event markers

Specifications

Sensitivity: 1 mV full scale.
Response time: 0.5 second max. full scale (0.6 sec. max. 50 Hz).
Accuracy: ±0.2% of full scale.
Linearity terminal based: 0.1% of full scale.
Dead band: 0.1% of full scale.
Pen: capillary type.
Zero: right side.
Chart: 10-inch calibrated width, 120 feet long.
Chart speeds: 1/4, 1/2, 1 and 2 inches per minute.
Interference rejection: 120 dB dc common mode; 100 dB line frequency common mode.
Source impedance: up to 5 kΩ without effect on performance.
Radio frequency interference: meets MIL-I-6181D.
Power: 115 or 230 V ±10%, 60 Hz, 42 va for Model H10-7127A, 65 va for Model H10-7128A.
Dimensions: 16¾ in. long, 8-11/16 in. high, 7¼ in. deep.
Weight: Model H10-7127A, 25 lbs net; 32 lbs shipping. Model H10-7128A, 30 lbs net, 38 lbs shipping.
Accessories supplied: 4 red and 4 blue ink cartridges, balancing pot lubricant and cleaner, ink system cleaner, extra pen for each channel, rear input mating connector, pen cleaning wire, one roll of paper, power cord, instruction manual.
Prices: (basic frame plus input module for each channel).

Single channel, Model H10-7127A		$1100
Dual channel, Model H10-7128A		1650

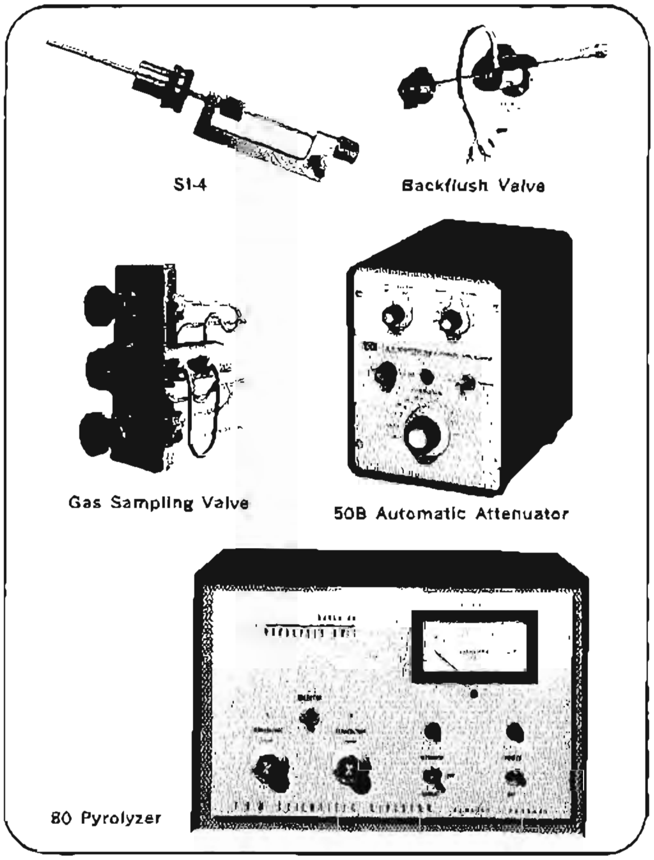
	OPTIONS (factory-installed at time of purchase)	
01	High-low limit switches on Model H10-7127A, and channel one only on Model H10-7128A.	$ 60.00
03	115 or 230 V, 50 Hz operation.	N/C
07	Disc integrator (channel two only on Model H10-7128A).	685.00
09	High-low limit switches on channel two of Model H10-7128A.	50.00
10	High-low limit switches on both channels of Model H10-7128A.	100.00
12	Mounted in cabinet compatible with H-P gas chromatographs.	100.00*

*No charge when ordered with Series 402 or 5750 Instruments.

ACCESSORIES

Extend usefulness, versatility of GC's

Models SI-4, 80, 60, 50B, 19035A, 19034A



SI-4 Backflush Valve Gas Sampling Valve 50B Automatic Attenuator 80 Pyrolyzer

SI-4 Solid Sample Injector

The Solid Sample Injector is ideally suited for introducing exact weights of solid or viscous materials into a gas chromatograph and is adaptable to most makes of chromatographs. It employs a glass melting point capillary to hold and inject sample. Stainless steel, 1 lb SI-4, Solid Sample Injector basic price: $150.

80 Pyrolyzer

The Pyrolyzer extends the scope of GC by decomposing nonvolatile samples semiautomatically and is useful in analyzing large polyfunctional molecules. Suitable for direct connection to HP instruments, these pyrolyzers can be adapted to most other GC makes. 115/220 V, 60 Hz (50 Hz, optional), 16 lbs. 80 Pyrolyzer basic price, including adapters: $400.00.

60 Backflush Valve

The Backflush Valve reverses direction of carrier gas through the column with the twist of a knob. This rapidly clears the column of unwanted components in an analysis; e.g., natural gas analysis, where only low-boilers are of importance. The valve has an integral heater and a replaceable teflon rotor with compression adjustment for leakfree operation up to 225°C and 50 psig. For proper operation the heater requires an auxiliary controller. For prices and ordering information, see table.

For Instrument models	Description	Part No.	Price
Series 700	Backflush valve, with temp controller and pyrometer readout	60C	$465
Series 810	Backflush valve only	60D	$225
Series 5750	Backflush valve only	19030A	$350
Series 810 or Series 5750	Temp controller with pyrometer readout	19045A	$225

50B Automatic Attenuator

Regardless of input signal intensity, the *Automatic Attenuator* holds all peaks on the recorder chart. Eleven positions of binary attenuation factors from 1 through 1024 to infinity are available. The unit attenuates the signal each time the peak approaches 95% of chart width, and scales down each time the peak falls below 35% of width. All peaks are clearly identifiable. Quantitative data are readily calculated by the usual peak height or area method. 50B Automatic Attenuator basic price: $350.00 (*limit switches to adapt for* the various makes of recorders are optional).

19035A Sample Injection Splitter

Specially designed for use with small-diameter, lowflow GC columns the Sample Injection Splitter (not shown) attaches directly to the injection port and provides a variable split ratio to give proper volume of sample injection on these columns. Includes integral heater to keep the system at injection port temperatures. Careful splitter design minimizes the ghosting, nonlinear, and fractionation difficulties often encountered in splitter systems. (For use with Series 5750 Gas Chromatographs only.) 19035A Sample Injection Splitter price: $100.00.

19034A Effluent Splitter

Effluent splitters are for simultaneous operation of two or three detector systems in gas chromatography. They also can be used to divert portions of effluent in a flame or electron capture GC system (which are destructive to samples) to an analytical collection system. For use with Series 810 and 5750 Gas Chromatographs, the 19034A Effluent Splitter converts to either three-way splits (for the Series 5750) or two-way splits (for both series). It comes complete with a set of interchangeable splitters for fixed ratios in all combinations possible with 1:5:10 splits (e.g., 1:5:5, 1:10:5, 1:1:1). All mounting hardware is included for connection to 1/4" outlets. Price: $175.

19055A Total Collection System

For trapping components of a mixture as they elute from an analytical instrument, the total collection system (not shown) traps both carrier gas and component as desired. The system consists of a 300 ml glass flask, a manifold needle valve and a soap-film flowmeter. Useful for small-scale collections needed in further analytical work. Requires adapters for specific instruments. 19055A Total Collection System, basic price without adapters: $120.

GC DIGITAL INTEGRATOR
Features pushbutton-selected internal programs
Model 3370A

The Model 3370A Integrator provides accurate, unattended quantitation of a gas chromatograph (GC) analysis. It operates according to a pre-set program that enables its internal logic to detect the beginning, apex and end of a chromatographic peak; to distinguish noise and reject it; and to provide baseline correction when desired.

The 3370A incorporates important new features that make it easier to use and increase its performance level beyond the state-of-the-art.

Selectable internal programs

The 3370A's unique programming feature allows the chromatographer a choice of four pushbutton-selected sets of analysis parameters.

For the research laboratory, this feature permits selecting precisely the correct program for different sections of a chromatogram, and even changing the program at will in order to optimize the integration of different parts of the chromatogram.

For the control laboratory, selectable programs make it possible to optimize the analysis parameters for each kind of sample, while reducing set-up and integration procedures to simple 1-2-3-4 instructions for technician operators.

One of four pushbuttons is used to activate the desired program. The *Manual Program* pushbutton selects a series of adjustments located on a swingdown panel. Because each of the analysis parameters is easily changed during a run, this mode of operation is ideal for trial runs and one-of-a-kind analyses. In addition to a control for each of the important analysis parameters, the swingdown panel also contains a number of drawings which greatly facilitate the use of the controls by graphically showing how each affects the integration.

The three other pushbuttons activate one of three programs contained on a printed circuit board that plugs into the back of the 3370A. Each program is completely changeable by moving plug-in circuit pins to various positions on the board which correspond to the analysis parameter settings on the swingdown panel.

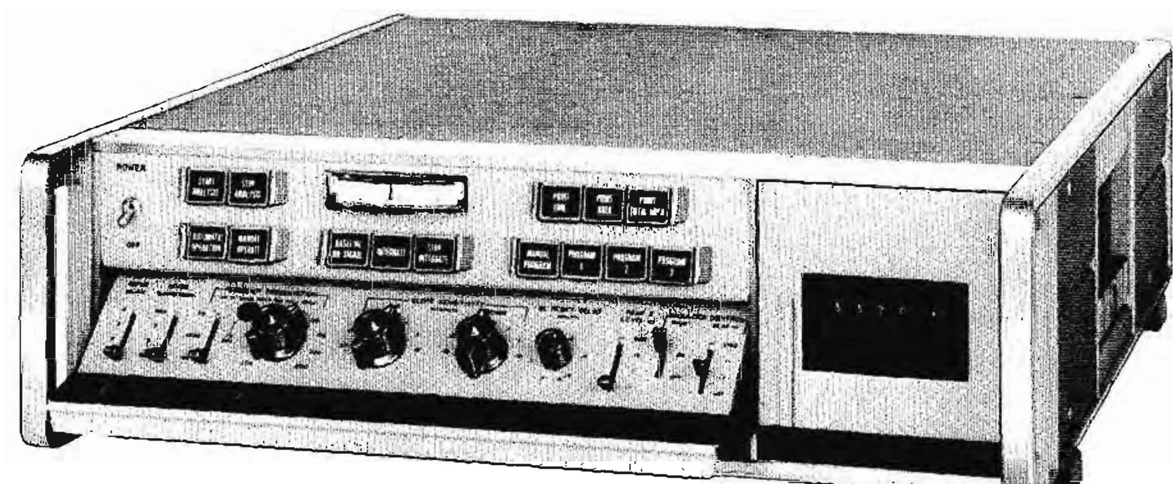
Additional boards can be pre-set and plugged into the 3370A when desired, thus giving it literally an unlimited choice of pushbutton-selected programs to meet changing requirements.

Slope sensitivity controls

When using an integrator that has a single slope control, the chromatographer is forced to compromise the accuracy of integration whenever the *up* slope of a peak differs from the *down* slope. With the 3370A, separate *up* and *down* slope sensitivity controls let the chromatographer optimize the integration of all tailing, overloaded and other imperfectly shaped peaks.

Coded event markers

Coded, superimposed event markers graphically establish the precise relationship of all integrator functions to the recorded chromatogram. The 3370A employs five types of coded markers that positively identify (1) when the analysis starts, (2) when integration starts, (3) when integration stops, (4) when area count is printed and (5) when baseline is reset.



3370A

Features pushbutton-selected internal programs
Model 3370A

Built-in printer

The 3370A has a built-in printer that prints out the area count to a total of 10^9, expressing it to the fourth significant digit, with a floating point notation (data multiplier). It also prints and continuously indicates time to four digits, selectable as hundredths of minutes or seconds.

Calibrated controls

The 3370A controls are calibrated in real terms: *mv/min* for slope sensitivity, *min* for baseline reset delay, etc. Significance to the chromatographer is two-fold: he can *precalculate* the exact settings by making measurements on a sample chromatogram and *pre-set* them precisely in real terms on the 3370A controls.

Top performance specifications

In all three of the most important measures of performance for electronic integrators, the 3370A sets new standards: precision of ±0.05% (vs. ±0.1% state-of-the-art); linearity of ±0.1% (vs. ±0.25%); dynamic range of 1,000,000:1 (vs. 200,000:1).

Specifications

Range

Voltage range: 0-1 V.
Linear dynamic range: $>10^6$.
Resolution: 1 μV-sec.

Performance ratings

Area repeatability: ±[.05% of reading ±1 μV-sec per sec of peak duration + baseline drift error].
Area accuracy: ±[.1% of reading + 1 μV-sec per sec of peak duration + baseline drift error] (only includes area between *start integrate* command and *print area* command).
Recorder presentation accuracy: ±5% of setting.
Accuracy of controls: (slope sensitivity, peak summation and rear shoulder) ±10% of setting.
Baseline drift: <1 μV/min.

Input characteristics

Input terminals: 4 pairs of input terminals selectable remotely or from front swing-out panel; input can be floated or grounded.
Input impedance: >10 MΩ.
Input overload: input overload automatically detected and printed.
Minimum area count: 1 μV-sec.
Maximum area count (single peak): 10^5 μV-sec.
Maximum area count (analysis): 10^9 μV-sec.

Output characteristics

Recorder output: 2 recorder outputs (1 mV and 1 V) isolated from input, are available on rear panel; full-scale recorder output corresponds to 3370A input voltage equal to recorder presentation setting; event markers are coded and superimposed upon recorder output.

Printer output:
Area: 4 most significant digits and data multiplier (floating point notation).
Time: 4 digits of time selectable as hundredths of minutes or seconds.
Rate: 2 peaks/sec maximum.

BCD output: all information printed is simultaneously available in binary coded decimal form (1-2-4-8, "1" state positive).
Voltage to frequency output: V to F output provided for visual display of integration.

Programming

Internal programming: front panel pushbuttons select 1 of 3 sets of 8 programmed analysis parameters.
Remote programming: all front panel controls (except recorder) can be remotely controlled by electrical contact closure.

General

Operating temperature: instrument will operate within specifications from 10°C to 50°C.
Storage temperature: −40°C to +75°C.
Power: 115 V or 230 V ±10%, 50 Hz to 60 Hz, <40 W.
Weight: net 40 lbs (18,2 kg); shipping 50 lbs (22,8 kg).
Dimensions: 16¾" (42.5 cm) wide by 57/32" (13.3 cm) high by 18⅜" (46.7 cm) deep.
Accessories furnished: rack mounting kit

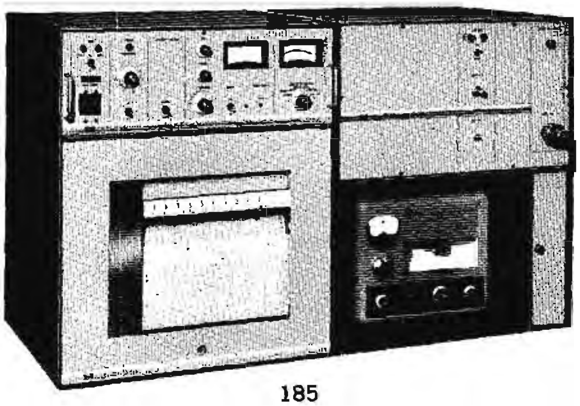
How to order

Ordering No.	General Description	Price
3370A	Electronic Digital Integrator with internal programming and built-in printer; for operation at 115 or 230 V, 50 or 60 Hz	$5000
	OPTIONS	
01*	Visual display consisting of 8-digit nixie tube readout of area count in separate housing (see photograph)	700
02	Total area accumulator (for printout of accumulated count and time at end of run)	300

*Can also be ordered separately as Model No. 18990A; price is $700.

18990A Visual Display

CHN ANALYZER
Simultaneous microdetermination of C, H and N
Model 185



185

The classical Pregl and Dumas methods for the microdetermination of carbon, hydrogen and nitrogen are slow, tedious and expensive. With the Model 185 Carbon Hydrogen Nitrogen Analyzer, the microchemist now has at his disposal an equally accurate and reliable alternate method that is 4 to 8 times faster — the complete 185 analysis takes less than 10 minutes.

In addition to being faster than the conventional methods, the 185 also requires a much smaller laboratory investment because it enables a technician with only a minimum of microanalytical training and experience to obtain reliable results under normal laboratory conditions.

Instrument design features

The Model 185 CHN Analyzer incorporates a number of important design features that are unique among instruments for elemental analysis, the result of Hewlett-Packard's experience in the field which surpasses that of any other manufacturer.

Two-stage furnace for optimum oxidation and reduction: the Model 185 uses a two-stage furnace for sample combustion:

(1) an oxidation furnace, automatically controlled at any temperature between 750 and 1050°C as selected by the analyst for the best oxidation conditions for the sample at hand;

(2) a reduction furnace, automatically held at 400 to 600°C to provide complete reduction of all nitrogen oxides and excess oxygen, thus ensuring nitrogen determinations that are reliable within the allowable error of ±0.3%.

Automatically timed combustion cycle: the peak height response obtained during the chromatography of the oxidation products is dependent upon the time the sample is confined in the combustion chamber. In the 185, the combustion period is automatically and precisely controlled to eliminate analytical error from this source. A flow diversion switch and timer are used for this purpose. In the "Timed" position, carrier gas flows through the furnace until a "Start" button is pushed. When timer is started, carrier gas bypasses the furnace for a precisely timed 20 or 50 second period, at end of which it is automatically re-directed through the furnace, sweeping combustion products into the gas chromatograph.

In the "Manual" position, carrier gas bypasses the furnace. Pilot lights indicate whether carrier gas flow is in "bypass" or "through furnace".

Two-zone oven for consistent GC analysis: the 185's column oven consists of an outer shell and an inner column oven, each equipped with separate and independent temperature control. The outer shell maintains an ambient temperature near that of the oven and keeps column temperature stable. Peak height thus responds to sample composition only and the baseline is stable.

Single-column single-detector GC system: improved column technology led to the single-column, single-detector design of the 185. All three combustion products — CO_2, H_2O, N_2 — are separated in a single pass resulting in a three-peak chromatogram, one peak for each of the combustion products.

Automatic sensitivity selector: an automatic sensitivity selector keeps all three peaks on scale for all types of samples, and allows direct peak height readout of the analytical trace. This feature releases the operator from having to manually attenuate the CO_2 peak on each analytical run, thus providing unattended operation from sample injection to completion of run.

Specifications

Analysis time: 10 minutes total.

Accuracy: comparable to Pregl and Dumas methods. Based on test analyses with NBS standards; the same limitations that apply to the classical method also apply to the 185, especially with regard to samples that are difficult to combust.

Sample range: any solid or liquid material that burns completely at 1050°C or less, including those that contain O, S, P, Cl, Br, I, F, As, Sb, and Sn.

Furnace: two-stage type with oxidation furnace and reduction furnace, each independently temperature-controlled.

Oven: two-zone type with inner oven and outer shell, each independently temperature-controlled.

Temperature control:

1. Oxidation furnace: variable voltage transformer, adjustable to 1050°C.
2. Reduction furnace: variable voltage transformer, adjustable 400 to 600°C.
3. Oven: thermostat controller, adjustable ambient to 150°C.
4. Shell: thermostat controller, adjustable ambient to 150°C.

Temperature readout: pyrometer graduated 0-1200°C and five-position selector switch for readout of 4 positions noted above plus ambient.

Detector: four-filament thermal conductivity type equipped with current adjustment, bridge balance and output attenuation controls.

Carrier gas: automatically timed bypass control; shutoff control, pressure regulator.

Balance: Cahn Ratio Electrobalance.

How to order

Ordering No.	Description	Price
185	Model 185 with Honeywell ElectroniK 16 Strip Chart Recorder and Cahn Ratio Electro-balance	$6600.00
19046A	Gas Purifier	$ 300.00
(Regulator Kit)	Carrier Gas cylinder regulator kit (two-stage pressure regulator, 6 feet of 1/4 in. O.D. copper tubing with appropriate fittings). Specify carrier gas supplier or CGA No. of cylinder outlet	$ 50.00

MRR* SPECTROMETER

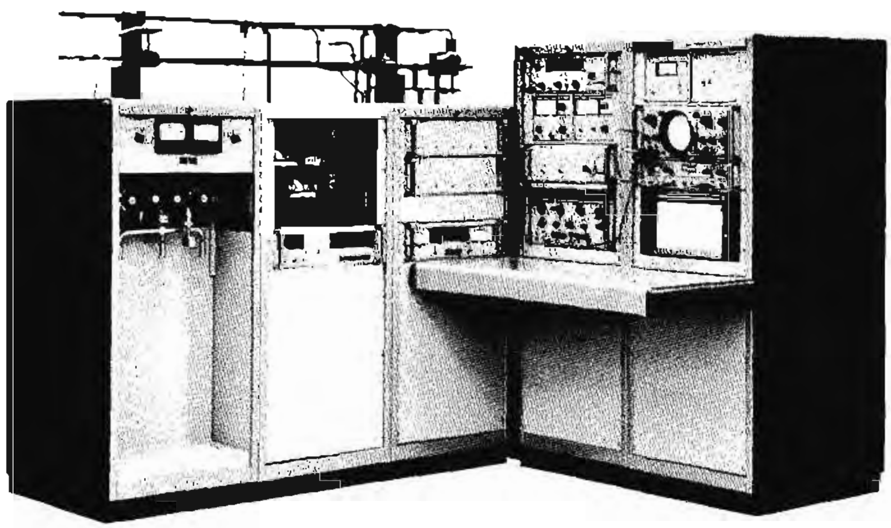
Rotational energy transfer, molecular structure and concentration—Model 8400C

The HP 8400C Series MRR* Spectrometers are designed to measure the function log S vs. log P_0 as well as the frequency, ν_0, of a microwave absorption line. The signal amplitude, S, is due to the resonant absorption of microwave radiation by the gas and can be related to molecular concentration, N. From the power incident on the gas, P_0, the rotational broadening-relaxation time, τ, can be calculated. The frequency measurement, ν_0, provides information on molecular structure.

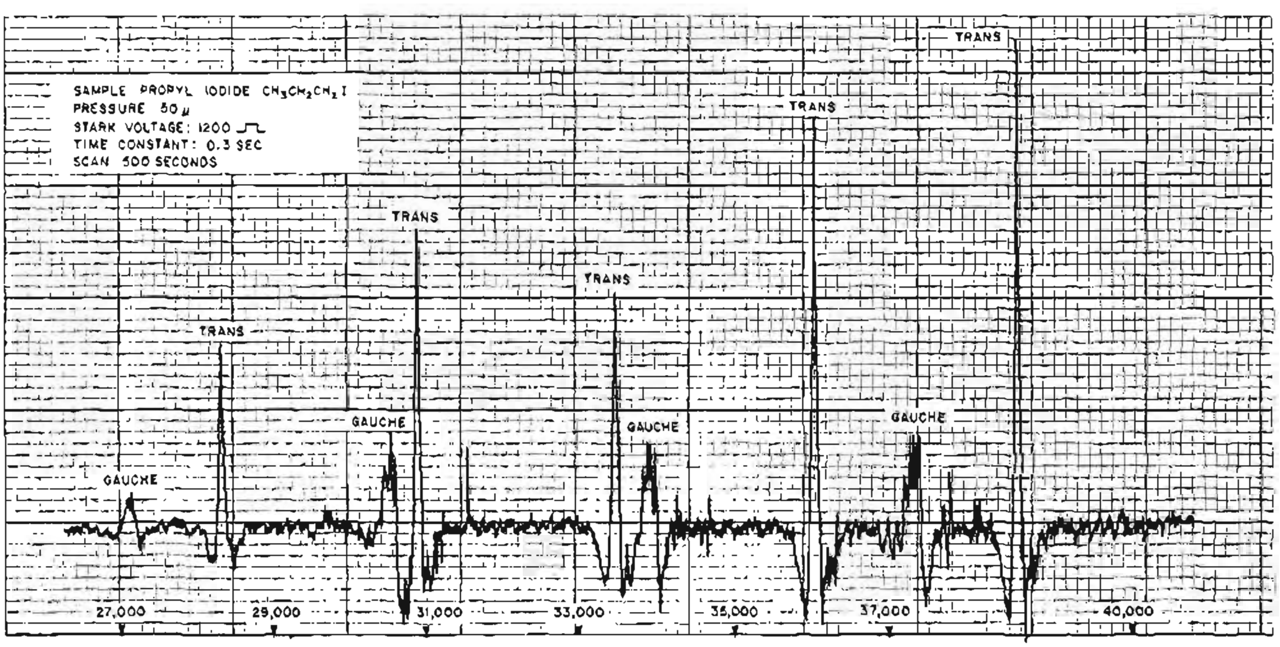
*Molecular Rotational Resonance.

Sensitivity

The signal-to-noise performance of any spectrometer depends on several factors: the bias conditions on the crystal detector, the crystal detector, the frequency stability (long term and short term), the available radiation power, and the Stark Modulator-Stark Cell combination. These factors must be considered over an entire waveguide band. The figure to the right is a slow scan through the $J = 2 \rightarrow 3$ transition of the $O^{18}C^{12}S^{34}$ line in natural abundance in about a 90% pure sample of OCS.



8400C Molecular Rotational Resonance Spectrometer



Broadband sweep of Propyl Iodide

Specifications

Sensitivity

Time constant, 100 seconds

Signal power = 10 x noise power

Sufficient to detect: X-band signal/cm of $10^{-10 \cdot 34}$
P-band signal/cm of $10^{-10 \cdot 14}$
K-band signal/cm of $10^{-9 \cdot 70}$
R-band signal/cm of $10^{-9 \cdot 34}$

Signal calibrator accuracy: ±0.6 dB in the signal amplitude of two lines.

Frequency

Range: four waveguide bands from 8.2 to 12.4, 12.4 to 18.0, 18.0 to 26.5, and 26.5 to 40.0 GHz.

Stability: long term, 2 x 10^{-8}/day; short term, 5 x 10^{-8}/minute.

Sweep width: over any part or all of a frequency band.

Sweep rates: continuously variable from 10 to 10,000 seconds.

Readout: to ±10 kHz.

Modulation

Frequency: 33.333 kHz.

Stark voltage: ground to base, 0 to 2000 V; base to peak, 0 to 2000 V.

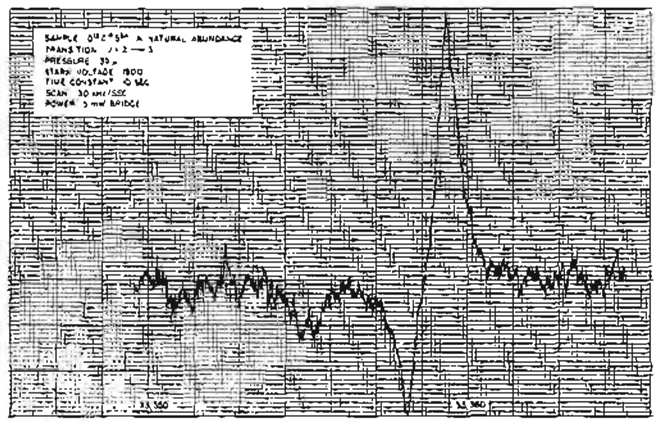
Square wave: rise time, 1.2 μs; fall time, 1.2 μs.

Stark cell

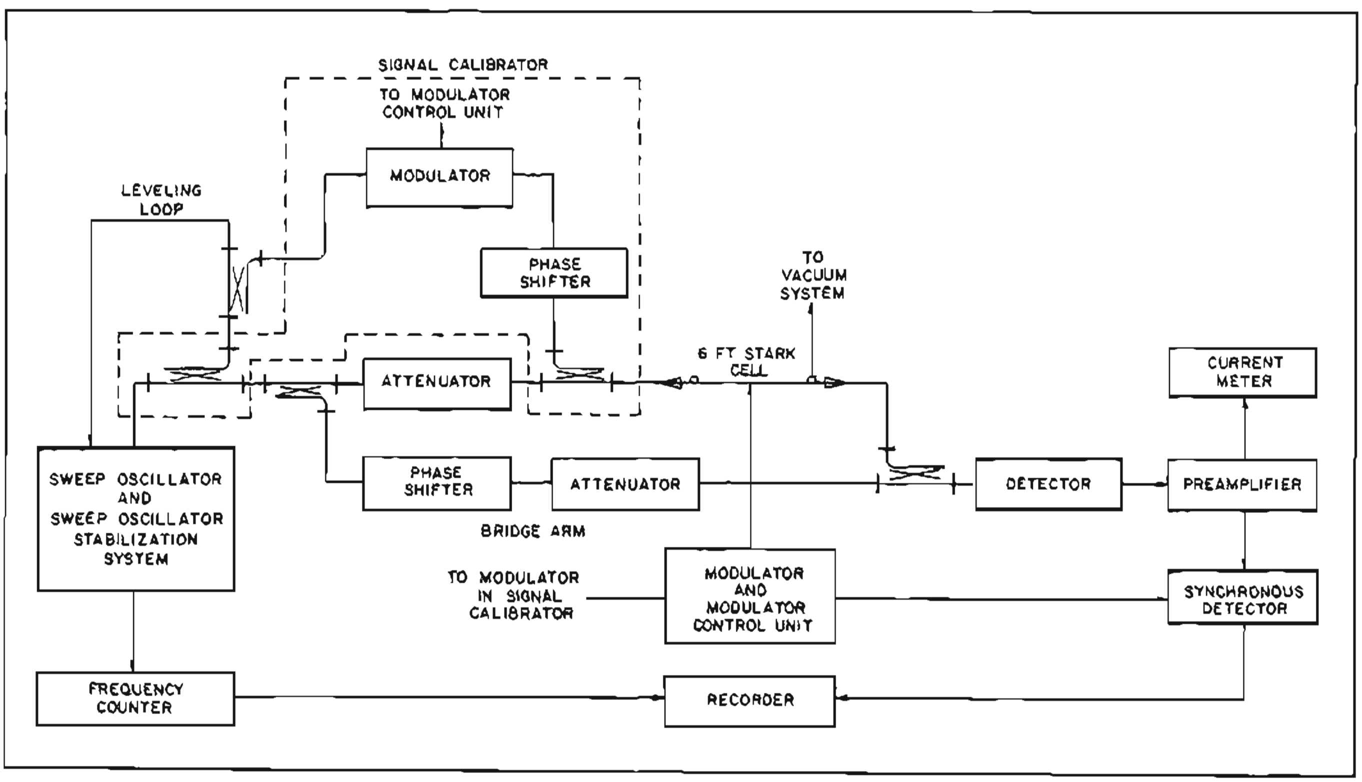
Volume: ≅500 cc (6 feet).

Plating: gold, both septum and walls.

Price: from \$44,000 to \$61,000 per frequency band. Conversion kits also available.



Slow Scan J = 2 → 3 Transition of $O^{16}C^{12}S^{34}$



8400C Molecular Rotational Resonance Spectrometer

AA PHOTOMETER

Fast multi-element atomic absorption analysis

Model 5960A

The Model 5960A Atomic Absorption Photometer is fundamentally faster and easier to use than any of its contemporaries. Other AA instruments employ a monochromator, a sensitive optical device that is better suited to basic research than to routine analysis because it requires careful adjustment at every use, preferably by a trained spectroscopist. In contrast, the 5960A eliminates the monochromator, replacing it with a series of discrete resonant wavelength filters that are instantly and correctly pushbutton-selected by any operator regardless of skill.

Fast six-element analysis

The practical significance of the 5960A design becomes abundantly clear when multi-element analyses are required, as they often are. With all monochromator instruments, a multi-element analysis takes a long time because monochromator, slit and electronic balance must be changed *every time* the element is changed. With the 5960A, a six-element analysis can be performed on a single sample in little more time than it takes to push six buttons.

To perform a multi-element analysis with the 5960A, the operator simply:

a—*rotates element selector wheel* to place any of six hollow cathode lamps in operating position instantly, without adjustment or warm-up;

b—*pushes resonant wavelength selector button* to position the proper narrow bandbass filter, each accurately pre-calibrated and zeroed;

c—*aspirates the sample* and, within a few seconds, reads its concentration directly on a built-in meter or from a recorder;

d—*uses the same sample* for uninterrupted determination of as many as six elements, without adjustments of any kind between elements.

Modular design for easy expansion

The 5960A is delivered custom-equipped for pushbutton analysis of up to any six pre-selected elements. And the modular design of its source and wavelength selectors permits expansion of the instrument's capability beyond the originally specified elements. The conversion which takes no more than a few minutes, involves only the replacement of hollow cathode lamps, and a factory-assembled single filter assembly which locks into place without alignment or adjustment.

Fixed optical system

All optical components are mounted on a massive cast aluminum optical bench. They are permanently related to one another and never need alignment. A unique dual-wavelength technique compensates for instabilities in a *single* pass hence does not introduce the troublesome and slow optical nulling of double-beam instruments. Flame emission is effectively eliminated without source modulation. Wide-range optics are highly efficient from 1900 to 8000Å.

Interchangeable burners

The 5960A can be operated with either of two interchangeable burners: a new laminar flow burner that optimizes performance and is quiet, and a total consumption burner. Either burner mounts on a rigid structural arm that is aligned in the optical path, and is completely accessible from front and back.

Design of the laminar flow burner minimizes explosion hazard by virtue of its extremely small premix volume—0.05 cubic inches, about 1/100th as much as in previous designs. Very economical of fuel and oxidant gas flow, it can be operated with hydrogen-air, acetylene-air and acetylene-nitrous oxide.

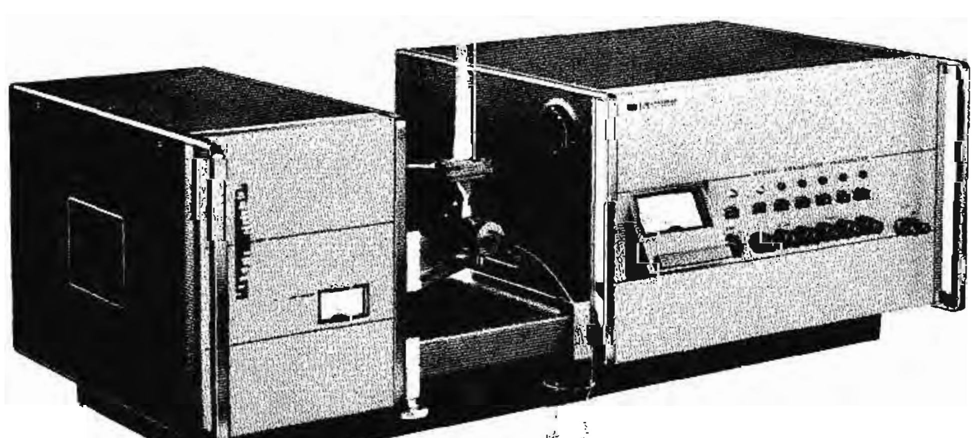
The total consumption burner is a non-clogging type with readily interchangeable aspirator. External gas mixing eliminates the possibility of explosions, and the burner can be operated satisfactorily with hydrogen fuel and air as support gas.

Performance

The salient fact about the performance of the 5960A is its speed: no other instrument can produce reliable results anywhere near as fast. A six-element analysis can be completed in as little as one minute, about ten times faster than contemporary instruments of other makes.

But speed is only one important factor in rating the performance of an AA instrument: the detection limit, linear operating range and precision are equally significant.

Detection limits of the 5960A are considerably greater than the vast majority of analytical applications require, as illustrated below:



5960A

Element	Typical Detection Limit (μg/ml in water)	Linear Operating Range (μg/ml)
Calcium	0.006	0 to 8
Copper	0.08	0 to 10
Gold	0.4	0 to 25
Iron	0.5	0 to 70
Lead	0.8	0 to 60
Lithium(natural)	0.04	0 to 4
Magnesium	0.001	0 to 8
Manganese	0.04	0 to 15
Mercury	2.5	0 to 200
Nickel	0.4	0 to 60
Potassium	0.003	0 to 8
Silver	0.1	0 to 15
Sodium	0.01	0 to 7
Strontium	0.06	0 to 15
Tin	1.2	0 to 250
Zinc	0.06	0 to 2

Linear operating range of the 5960A often exceeds the performance of higher-priced instruments, especially in the case of the more sensitive elements (see table above).

Precision of the 5960A is unsurpassed. No other AA instrument is capable of routine operation at a higher degree of repeatability. The reasons are obvious. *Resonant line isolation,* which is accomplished by discrete narrow bandpass filters in the 5960A, is repeated precisely in the same way at every use. In monochromator instruments, the procedure is subject to variations at every use, even with the same operator, and especially with non-expert personnel. *Dual wavelength compensation* in the 5960A eliminates variations from instabilities in the source and electronics without source modulation. Finally, *direct concentration readout* greatly reduces the chance of error in the calculations.

Specifications

Optical

Single-beam, single-pass fixed optical system.
Dual wavelength compensation (without source modulation.
System range of 1900 to 8000Å (fused silica lenses).
Compensation for scattered light and neutrally absorbed light.
Resonant line isolation by 6 pushbutton-selected narrow bandpass filters.
Filters easily substituted in 6-filter assemblies.
Single wide-range multiplier phototube detector.

Source

Turret holds 6 hollow cathode lamps, all in operating condition.
Lamp selector on front panel.
Solid-state power supply provides regulation to all 6 lamps.
Lamp current individually controlled from 0 to 30 mA dc.
Lamp current indication on milliammeter with 1 mA graduations.

Photometric

Sensitivity of 0.01 absorbance full scale.
Range of 0.01, 0.10 and 1.00 absorbance full scale.
Calibration controls are continuous over full range.
Meter output is linear with absorbance.
Recorder output: 50 mV full scale, 5.1 k ohm output impedance.

Burners

Two directly interchangeable types, both made of stainless steel.
Vertical adjustment by screw knob.
Incidence adjustment: longitudinal or perpendicular to optical path (laminar flow burner).
Sample introduction by aspiration.
Laminar flow burner:
- Quiet.
- Sample aspiration rate: recommend 3-6 Ml/min.
- Path length: 1 inch.
- Fuel: acetylene at 2 ft^3/hr; or hydrogen at 2-4 ft^3/hr.
- Support gas: air or nitrous oxide, at 14 ft^3/hr.
- Premix volume: 0.05 in^3.

Total consumption burner: safe.
- Sample aspiration rate: recommend 3-6 Ml/min.
- Fuel: hydrogen at 4-8 ft^3/hr.
- Support gas: air at 20-30 ft^3/hr.

Physical

40⅛″ long, 16-1/16″ high, 18⅜″ deep; 125 lbs net.

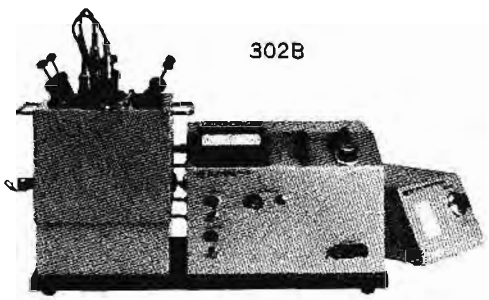
Electrical

105-125 V *or* 210-250 V, 50 or 60 Hz, 285 W.

How to order

Ordering No.	Description	Price
5960A	Atomic Absorption Photometer with Laminar Flow Burner and Support installed; for operation at 115 V-230 V, 50-60 Hz.	$4,400.00
	ELEMENT OPTIONS	
	NOTE: The 5960A is operational only with the addition of at least one element option; it accommodates up to six element options, factory-installed; beyond the first six, options are shipped separately for customer installation. Each element option includes a hollow cathode lamp, filter and holder, pushbutton label and 100 ml of standard solution.	
28	Calcium	add 310.00
33	Copper	add 310.00
40	Iron	add 310.00
45	Gold	add 400.00
48	Lead	add 330.00
49	Lithium (natural)	add 355.00
53	Magnesium	add 310.00
54	Manganese	add 315.00
55	Mercury	add 335.00
58	Nickel	add 310.00
64	Potassium	add 360.00
74	Silver	add 310.00
75	Sodium	add 360.00
76	Strontium	add 360.00
83	Tin	add 350.00
89	Zinc	add 385.00
	ADDITIONAL OPTIONS	
06	Substitute total Consumption Burner	add 100.00
15	Strip Chart Recorder 7127A with 17501A plug-in input module, 10″ calibrated chart, 0.2% accuracy, four-speed chart drive; 115 V, 50 or 60 Hz.	add 1200.00
	BURNER MODELS	
5963A	Total Consumption Burner	add 300.00
5964A	Laminar Flow Burner	add 200.00

Model 302B Vapor Pressure Osmometer
Model 500 Membrane Osmometer



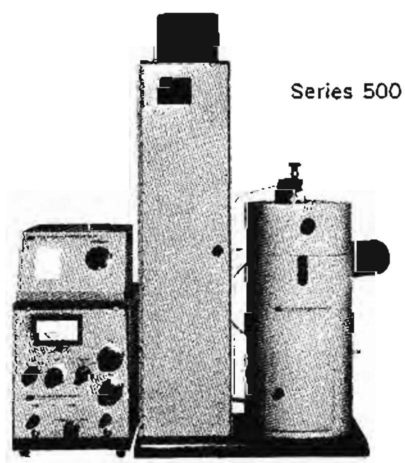
302B

The Model 302 Vapor Pressure Osmometer measures the osmotic concentration of a solution, operating on the principle of vapor pressure lowering. From this data, number-average molecular weights of solute species in solution are determined precisely.

The Model 302 VPO is designed for molecular weight materials in the range of 100 to 25,000 and are effective for both natural and synthetic polymer measurements. It can be operated at 25°, 37°, 50°, 65°, 100°, or 130°C and can operate successfully with sample sizes as small as 10 microliters. It is capable of measuring temperature differential between sample and solvent drops to better than 0.0001°C.

How to order

Ordering No.	Description		Price
302B	Vapor Pressure Osmometer for aquerous and non-aquerous operation at 115/230 V, 50-60 Hz (specify one or more temperature control options and one or more probe options).		$2700.00
	Temperature control options		
06	Fixed thermostat, 25°C	add	$100.00
07	Fixed thermostat, 37°C	add	100.00
08	Fixed thermostat, 50°C	add	100.00
09	Fixed thermostat, 65°C	add	100.00
10	Fixed thermostat, 100°C	add	100.00
11	Fixed thermostat, 130°C	add	100.00
12	Variable temperature controller, 25 to 130°C, with sensor for operation at 60 Hz	add	400.00
13	Variable temperature controller, 25 to 130°C, with sensor for operation at 50 Hz	add	400.00
	Probe options		
20	Probe for non-aquerous operations, 25 to 80°C	add	$190.00
21	Probe for non-aquerous operation, 70 to 130°C	add	190.00
22	Probe for aquerous operation, 25 to 80°C	add	250.00



Series 500

Series 500 Membrane Osmometers are automated instruments for the precise and speedy determination of the number-average molecular weight of natural and synthetic polymers in the range 10,000 to 1,000,000. They operate with aqueous as well as organic solvents, at temperatures between 5°C and 130°C. The 500 measures osmotic pressure with a repeat accuracy of ±0.02 cm of solvent in a range of 20.00 . . . on samples as small as 1 ml.

Based on the dynamic method of measuring osmotic pressure, the 500 reaches equilibrium when no more than 10^{-5} liter of solvent has moved into the membrane.

Individual readings are frequently completed within 10 minutes after the sample has been introduced . . . and a full concentration series, within an hour.

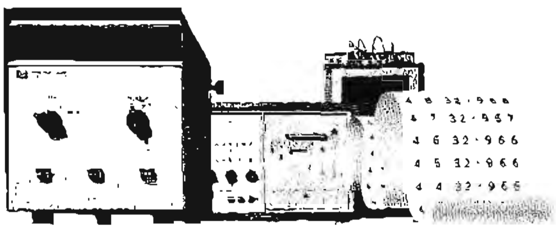
How to order

Ordering No.	Description	Price
501	Standard membrane osmometer, 10 mV recorder output; 115 V, 60 Hz	$4900.00
502	High temperature membrane osmometer, 10 mV recorder output; 115 V, 60 Hz	5750.00
503	Low temperature membrane osmometer, 10 mV recorder output; 115 V, 60 Hz	6250.00
	Options (factory-installed)	
03	For operation at 25°C	100.00
04	For operation at 37°C	100.00
05	For operation at 50°C	100.00
06	For operation at 65°C	100.00
07	Thermostat for operation at 100°C (Model 502 only)	100.00
08	Thermostat for operation at 110°C (Model 502 only)	100.00
09	Thermostat for operation at 130°C (Model 502 only)	100.00
10	Variable Temperature Controller	375.00
11	1 mV recorder output	n/c
12	Thermostat for operation at 5°C (Model 503 only)	100.00
20	50 Hz operation (115 V)	n/c
21	50 Hz operation (230 V)	75.00
	Recorder	
H02-7127A	Moseley strip chart recorder with 17504-80060 plug-in 10 mV input module, 10-inch calibrated chart, 0.2% accuracy, four-speed chart travel; 115 V, 50 or 60 Hz	1050.00

AUTO-VISCOMETER

Automatic programming, recording of efflux time

Models 5901B and 5903A



5901B 5903A

Highest accuracy in determining efflux times yields highest accuracy in final calculations—whether for intrinsic viscosity, kinematic viscosity, or for molecular weight.

The instruments described here—in combination—provide extremely high accuracy and reliability in measuring efflux times. Using the Auto-Viscometer and the Programmer you can expect:

a) 20 times better accuracy than stopwatch techniques.
b) Unlimited and automatic repeat measurements on any viscometer.
c) Automatic sequences for all four viscometers in the system with up to 10 repeat measurements per viscometer.
d) A permanent record of all efflux times measured.

5901B Auto-Viscometer

The Auto-Viscometer measures efflux time in glass capillary viscometers with a transistorized electronic counter using a quartz crystal oscillator as a time base reference. This approach not only makes viscosity measurements more efficient, but produces results at least 10 times more accurate than stopwatch techniques. The electronic counter measures efflux time automatically through use of photocell detectors mounted at upper and lower reference points on the glass viscometer. Positioning screws are provided for spacing adjustments between upper and lower reference points. Each detector consists of a self-contained, miniature light source and photocell in a compact submersible unit. "On and Off" triggering of the time interval counter occurs when the meniscus of the solution drops past the detectors; the time is read on the Nixie® display. This reading remains until intentionally erased by the operator. After the operator records the efflux time, he can either repeat the run or switch to another channel for a new measurement.

5903A Programmer

The repetition of efflux time measurements yields data of high confidence, and final viscometry calculations will have utmost precision. A combination programmer and printer, the 5903A virtually eliminates the tedium of constant monitoring and recording of data, while giving you the capability for unlimited measurements. It attaches to the Auto-Viscometer to automatically program efflux time measurements. The Programmer can control a sequential run from channel to channel (one through four on the Auto-Viscometer) and will repeat the program for as long as the operator wishes. Up to 10 repeat measurements per channel can be made, with 40-second intervals between measurements. Alternately, an unlimited number of repeat measurements can be done on individual viscometers. This automatic printout of efflux times gives you a permanent record of measurements, and is a time-saver. Each reading, moreover, is coded with viscometer number and run number. The printer is identical to HP 562A, described on page 135 in this catalog.

Specifications, 5901B Auto-Viscometer

Range and resolution: up to 1000 seconds ±0.01 second; up to 100 seconds ±0.001 second.

Readout: Neon Nixie® 5-Digit Register with decimal point indicated.

Accuracy: at least ±1 second. Based on reproducibility of typical measurements of efflux time up to 300 seconds using Model 5910A Bath.

Operating temperature: 5°C to 135°C.

Glassware: detectors will accommodate viscometers with 6.5 to 10 mm diameter at point of detection.

Response time: 10 microseconds.

Minimum meniscus speed: 1 inch per minute.

Power requirements: 115/230 V ±10%, 50 or 60 Hz, 60 watts.

Dimensions: 10" high, 8½" wide, 13" deep.

Weight: net 17 lbs; shipping 22 lbs.

5903A Programmer

Printer: see specifications on HP 562A on page 135.

Programmer: sequence and repeat selectors for four viscometer channels.

Power requirements: 115/230 V ±10%; 50 or 60 Hz; 130 watts.

Dimensions: 12½" high, 20¾" wide, 18½" deep.

Weight: 35 lbs.

How to order

Ordering No.	Description	Price
5901B	Auto-Viscometer, complete with pump and 4 sets of detectors	$3400.00
5903A	Programmer, with printer	$4700.00
	Option 01: timer for measurement intervals of 5 to 100 minutes, add	$225.00

QUARTZ THERMOMETER

0.0001 °C or °F resolution, direct measurement

Model 2801A

The method of temperature sensing employed in the 2801A Quartz Thermometers is based on the sensitivity of the resonant frequency of a quartz crystal to temperature change.

Temperature range of the 2801A Quartz Thermometer is −80 to +250°C (−112 to +482°F). The quartz thermometer is considerably more linear than a platinum resistance thermometer: ±.05% of span from −40 to +250°C compared with a typical figure of ±.55% for the same range for platinum thermometers. Linearity of the quartz thermometer is superior to that of thermocouples and thermistors, which have an exponential characteristic. The excellent sensing characteristics of the quartz thermometer are supplemented by the advantages of direct digital readout (no bridge balancing, or reference to resistance or voltage-temperature tables or curves), immunity to noise and cable resistance effects, no reference junction, and good interchangeability between sensing probes.

The 2801A is equipped with two sensing probes for measuring temperature at either probe or the difference between the two. A 6-digit visual readout and recording output with a choice of pushbutton-controlled sample times provides resolution of 0.01, 0.001 or 0.0001°C or F. With Option M40 (100 second sample period) resolutions of 0.001, 0.001 or 0.00001 °C or °F can be obtained. Signal polarity indication is provided. The 2801A includes the capability for operation as a 300 kHz electronic counter.

Temperature sensing probes

Various standard probe configurations are available for the 2801A Quartz Thermometer. Probes from the 2850 series are furnished with the quartz thermometer. Outline drawings for all models appear at right.

Remote operation of probes

Each temperature sensing probe has a quartz-crystal which is resonant at a frequency dependent upon temperature, and is driven by a 2830A Sensor Oscillator. The oscillators are transistorized devices enclosed in small die-cast aluminum housings. They are normally installed in the 2801A flush-mounted in a front panel recess. 12-foot cable connects each probe to its associated sensor probe; this cable forms part of the tuned circuit and cannot be altered in length. However, the sensor oscillators may be unplugged from the instrument and connected to it by standard 75-ohm coaxial cable up to 500 feet in length, with no loss in measurement accuracy. For greater distances, one or two 2831A Amplifiers may be used for a maximum of 4500 feet.

Specifications 2801A

Temperature range: −80 to +250°C (−112 to +482°F with Option M1).

Calibration accuracy: thermometer-probe combination calibrated at factory to within .02°C (.04°F) absolute, traceable to NBS.

Linearity: −40 to +250°C. Better than .15°C (.27°F) referred to best fit straight line through 0°C; −80 to −40°C. Better than 0.7°C (1.26°F) referred to same line as above; 0 to +100°C. Better than .05°C (.09°F) referred to best fit straight line through 0°C.

Stability:

Short term: better than ±.0001°.

Long term: zero drift less than ±.01°C (.018°F) at constant probe temperature for 30 days.

Ambient temperature effect: less than .002°C per °C change.

Display: 2801A: 6-digit in-line readout in C°, or °F. Decimal point, °C (°F), and polarity indication included. Readout and units indication in kc in counter mode of operation. Storage feature holds display between readings.

Digital recorder output: BCD, 4-2'-2-1, positive-true, for each digit, decimal point (exponent), polarity, and operating mode. 8-4-2-1 positive true optionally available.

External programming: selected by contact closures or transistor circuit closures to ground. Measurement initiation, probe selection (T1, T2, or T1–T2), and resolution (.01, .001, or .0001°) programmable.

Counter operation: Frequency Range: 2 Hz to 300 kHz; Resolution: 10, 1, and 0.1 Hz; Sensitivity: 0.5 to 10 V rms; Input Impedance: 1M, 50 pF shunt; Gate Time: 0.1, 1 and 10 sec.

Power required: 115/230 V ±10%, 50 to 60 Hz, 85 W.

Instrument environment: ambient temperatures from 0 to +55°C (+32 to +130°F), at relative humidity to 95% at 40°C.

Weight: net 22.5 lb (10,1 kg), shipping 35 lb (15,9 kg).

Dimensions: 3-15/32" x 16-5/16" x 16-3/4" (88 x 414 x 425 mm).

Price: 2801A Quartz Thermometer, including two 2830A Sensor Oscillators and two (matched) 2850 series Temperature Sensors, $3,800.

HP-2831A Amplifier Specifications

Operating frequency: 28 to 29 MHz approx.

Gain: 40 dB approx.

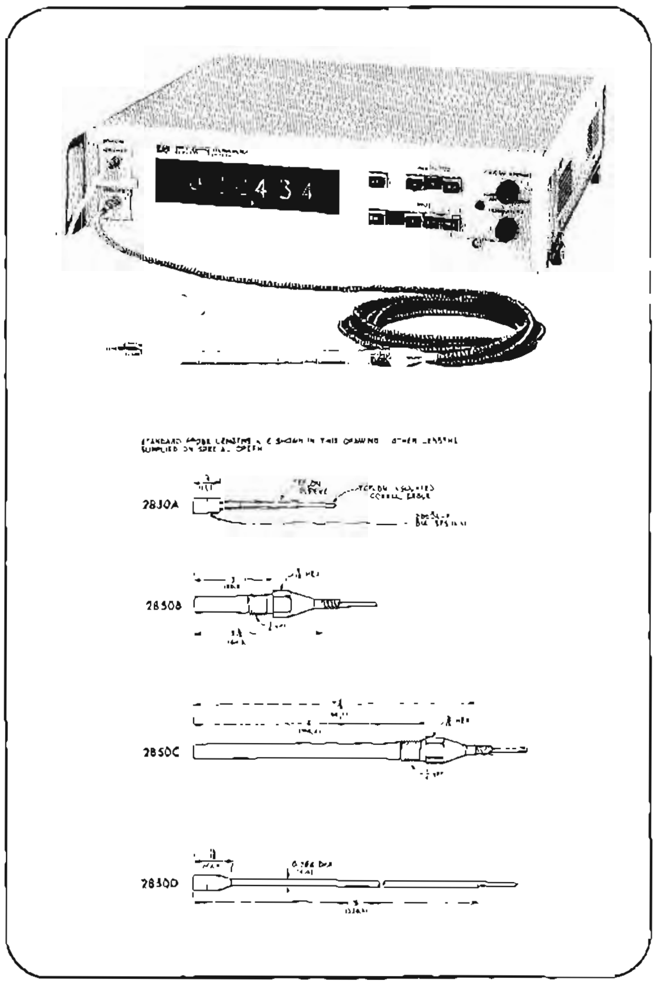
Power required: +12 to +20 V dc, at 8 mA approx. (Normally supplied by HP 2801A.)

Connectors: coaxial output connector mates with HP 2801A Quartz Thermometer.

Operating conditions: same as HP 2830A Sensor Oscillator.

Dimensions, weight, finish: same as HP 2830A Sensor Oscillator.

Price: 2831A Amplifier, $100.



Instruments and Systems for Measuring, Monitoring and Recording Physiological Data: The following pages summarize the main features of the majority of Hewlett-Packard instruments for clinical medicine, clinical laboratory, patient monitoring, resuscitation, multichannel diagnosis and multichannel research. Additionally, references will be made in the following text to various Hewlett-Packard test instruments which are applicable to the medical instrumentation listed.

Two additional publications are available describing Hewlett-Packard's clinical and patient monitoring instruments in full detail. These are the *Diagnostic Instrumentation* catalog and the *Patient Monitoring Compendium*. To receive your complimentary copies, contact the nearest Hewlett-Packard sales/service office (see lists on pages 16-22).

Total system concept

In order to best meet your needs as a customer in the bio-medical field, Hewlett-Packard strives to provide, wherever possible, a total data acquisition system rather than isolated instrument components. Thus Hewlett-Packard's medical customers are assured of obtaining the desired results in the most appropriate form.

A total data acquisition system contains a signal pickup, signal conditioner, readout device and, as required, a data storage unit.

The pickup consists of electrodes for sensing biolectric phenomena and transducers for converting the physical phenomena into electrical signals. The signal conditioner amplifies the signal from the pickup so that there is sufficient drive for readout devices or it may modify the pickup signal to convert the data into a more useful form for readout. The readout device presents the data in a form convenient for monitoring and/or study. The storage device preserves the data for readout at a later time.

The readouts can be in the form of an oscilloscope, XY recorder, visual display, alarm, and/or typewriter output.

Oscillographs are available in four basic types: heated stylus, ink, optical photographic, and optical ultraviolet.

The visual displays consist of various sized single and multichannel oscilloscopes, meters and numerical readouts. The wide choice of Hewlett-Packard instrument components in the categories listed above distinctly equips Hewlett-Packard to provide total data acquisition systems.

Clinical medicine

Hewlett-Packard has developed an extensive group of instruments primarily for clinical applications. These instruments monitor and/or display ECG, VCG, heart sounds, simultaneous fetal ECG and labor contractions, nerve conduction and muscle voltages, and internal body structures.

ECG instruments include the 1500A electrocardiograph (portable use) and the 1511A (a mobile unit). Either Electrocardiograph can be combined with the 1506B Heart Sound Amplifier for heart sound recording. In the heart station, multichannel ECG's can be recorded by systems employing the 1508A (three channel) or 1509A (six channel) ECG Amplifier. The 8020A Cardiotocograph monitors instantaneous fetal heart rate and labor contractions for indication of fetal distress.

For VCG presentation, the 1520A Vectorcardiograph System, which combines a 1507A Vector Programmer with a 780-6A (Option 01) Viso-Scope, provides a degree of lead network flexibility never before available.

The 7214A Diagnostic Sounder and the 1510A Electromyograph are versatile instruments useful in diagnostic, research and teaching applications. Determining the brain midline, observing heart valve motion, detecting pericardial effusion and locating foreign material within the body are some of the applications of the 7214A. The 1510A is used to monitor nerve conduction and the electrical activity of muscle tissue.

Patient monitoring

Patient monitoring has been shown to be of great value in the coronary care unit, intensive care unit and recovery room. Intensive care of patients is aided and indeed enhanced through the use of electronic instruments which continuously observe various physiological phenomena such as ECG, arterial and venous pressures, temperature and respiration. The physiological data is appropriately displayed on readout devices for convenient and effortless monitoring by the medical staff. High and low limits can be set so the nursing staff can be particularly alerted when an abnormal situation occurs which may indicate patient distress.

Hewlett-Packard Company has designed a special series of electronic instruments for the particular function of patient monitoring. The 780 Series of monitoring units offers many possibilities of system variation to satisfy the particular requirements of monitoring in different areas.

780 bedside units are small, compact, selfcontained instruments which are used to monitor various combinations of patient parameters. Signals from these units are available for use at a central station where a number of patients can be conveniently monitored. Ancillary 780 equipment includes the 7810A Mobile Cart, 780-15 Wall Mount Bracket, 780-16 Ear Plethysmograph and the 780-21 Remote Alarm Indicator.

In some areas where patient monitoring is combined with data acquisition for research, such as the operating room, Hewlett-Packard multichannel systems are used with either the 350 or 760 Series of signal conditioners.

Resuscitation

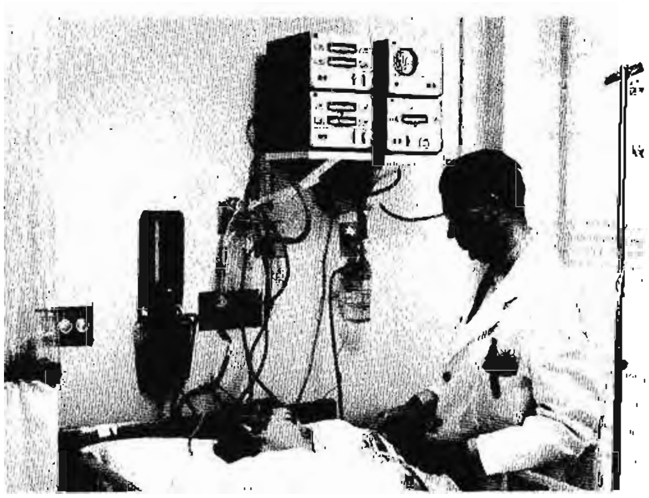
A 7839B Resuscitation System combining a Defibrillator, Pacemaker, Electrocardiograph and Scope on a mobile cart can be used in all areas of the hospital in cardiac emergencies.

Multichannel diagnostic systems

Multichannel systems are used routinely in cardiac catheterization laboratories to record pertinent data, such as cardiac blood pressures, indicator dilution characteristics and the electrocardiogram. In the heart station, multichannel electrocardiograms may be recorded in addition to heart sounds and various pulses. In the pulmonary function laboratory, the recording of respiratory airflows, volumes and pressures is essential in analyzing respiratory diseases.

Test equipment

Throughout the Hewlett-Packard catalog will be found a wide choice of electronic test equipment ideally suited for trouble-shooting, alignment and performance checkout of medical data acquisition systems.



Walter Reed General Hospital, Washington, D.C., is typical of big city hospitals using Hewlett-Packard patient monitoring instruments. At each bedside of the intensive care unit, four wall-mounted 780 Series half modules monitor and/or display systolic and diastolic pressure, central venous pressure, respiration rate, heart rate and ECG. Blood pressures are measured by Hewlett-Packard pressure transducers, respiration rate is detected by a chest expansion transducer and heart rate is derived from either the R-wave of the ECG signal or the 780-16 Ear Plethysmograph.

Monitor these vital parameters with HP 780 Series intensive care instruments:

—heart rate
—peripheral pulse
—ECG
—EEG
—temperature (°C or °F)
—respiration rate
—venous pressure
—arterial pressure
—systolic pressure
—diastolic pressure
—mean pressure
—cardiac arrhythmias

With a Hewlett-Packard ICU system, patient monitoring is effective, economic and easy. Monitoring and data recording are continuous—the patient is effectively never left alone. In case of patient distress, light and audible alarms generated at the central station by the bedside monitors bring a nurse immediately to the patient. This *immediate* knowledge of an alarm condition allows *immediate* investigation and treatment, resulting in more efficient and more effective patient care.

But Hewlett-Packard systems go beyond merely monitoring for patient distress. The continuous information about each patient often enables a crisis to be foreseen and made less severe or completely prevented.

The patient care systems pictured represent an almost unlimited number of combinations of half module and full module units. All units in the 780 Series are electrically and physically compatible. Since each provides one or more specific monitoring, recording or display functions, the desired system can be easily and economically achieved by selecting only the specific modules needed.

Advantages of this building block concept include a cost which reflects only those monitoring capabilities needed and complete flexibility to change or expand the system to monitor more patients, more parameters or a different combination of parameters at each bed.

Reliability, patient safety and comfort, high readability and accuracy of display data, and ease of operation by hospital personnel are foremost in the design criteria of 780 Series instruments. Reliability is provided by all solid state circuitry (except cathode ray tubes) and operation of key components well below rated values. Where monitors make direct electrical connection to the patient, isolation circuits are employed, and cables and transducers are light weight for greatest patient comfort. Visual indicators have large, easy-to-read numerals, and illuminated plaques of contrasting colors distinguish various monitored conditions. Adjustable alarm delays permit the medical staff to select a delay interval which will prevent transients or other events of no clinical significance from triggering an alarm.

Planning, training and service

To ensure that the *right* patient monitoring system is installed in your hospital and that it will provide *continuing* clinical value, every Hewlett-Packard medical instrument salesman is a trained bioengineering consultant, familiar with the needs, objectives and budgets of hospitals like yours. He will discuss your present and anticipated needs with you and recommend the system which most economically and flexibly meets those needs. Comprehensive, written proposals are always supplied prior to contract agreement.

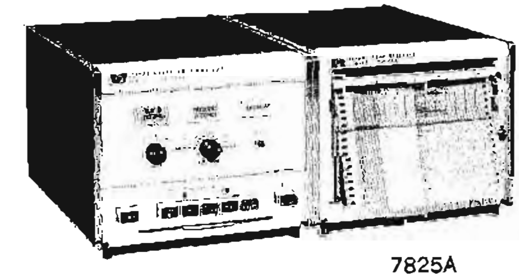
Another benefit is the availability of installation services and responsibility for performance from local Hewlett-Packard sales and service offices. Key features of the new 780 Series warranty (in the United States only) are:

- round-the-clock emergency repair service for the full one year warranty period. Response time will be no greater than twenty-four hours to hospitals within 100 miles of Hewlett-Packard sales and service offices. If you are more than 100 miles from an authorized Hewlett-Packard service facility, a mutually agreeable guaranteed response time will be negotiated.
- three customer assistance calls at approximately 30, 60 and 90 days after the installation (for systems priced at $3000 or more purchased after November 1, 1968). These trips will be made to check on proper operation and understanding of the system, and to perform preventive maintenance using instructions supplied by Hewlett-Packard. A system logbook is provided for the hospital to make note of anything of significance occurring between visits.

Finally, local Hewlett-Packard field office men will train your staff in operating and maintenance procedures using formal hospital seminars and training booklets and informal discussions with the staff.

Patient monitoring compendium

For further patient monitoring systems and service information, ask your local Hewlett-Packard sales and service office (see lists on pages 16-22) for your complimentary copy of the Patient Monitoring Compendium. In it you'll find detailed information about the individual instruments, an ICU systems planning guide and an application section.



7822A 7825A

These two 780 Series patient monitors, with a 1500A ECG Recorder and 7805B Signal Delay, are a complete system for monitoring and recording ectopic beats. The 7822A Arrhythmia Monitor has a run of ectopics alarm (3 or 6 widened beats of ventricular origin without an intervening normal beat) and a frequent ectopics alarm (6 or 12 premature or widened beats/minute). It also controls the ectopic beats recorded on the 1500A ECG Recorder and the 7825A Trend Recorder. In a typical installation, the 7825A plots widened or premature beats/minute in the bar graph mode and heart rate in the analog mode.

Bedside monitors

Model 780B Viso-Monitor. Monitors heart rate and peripheral pulse with visual alarms of distress conditions and signal outputs for central station display/recording; records ECG automatically at preset intervals or manually; delivers pacing current automatically (after preset asystole interval) or manually. $2375.

Model 7803A Monitor Scope. Displays one or two patient parameters on an 8 x 10 cm screen. Scope traces are easy to read with automatic intensity control and safety amber filter. Also used at the central station. $680 (dual-channel); $625 (single-channel, Option 01).

Model 7805B Signal Delay. Records pre-alarm data on an endless tape loop for immediate diagnostic aid upon alarm or later research data. $725 (single-channel); $855 (dual-channel, Option 01).

Model 780-7/7A Patient Monitor. Monitors ECG or pulse and displays derived heart rate; applies pacing stimulus (Model 780-7A without pacing); high and low heart rate limits on front panel meter—visual alarms if limits exceeded. $850 (780-7); $715 (780-7A).

Model 780-8 Patient Monitor. Displays temperature and respiration rate on front panel meters with adjustable high and low alarm limits—visual alarms if limits exceeded. $725.

Model 780-9 Patient Monitor. Displays systolic and diastolic (or mean) blood pressures on front panel meters with adjustable high and low alarm limits—visual alarms if limits exceeded. $910.

Model 780-18 ECG-EEG Preamplifier. Used with a 7803A Monitor Scope as a basic monitoring system in the ICU. The two units are a practical, portable monitor that can be quickly set up at the patient's bedside for routine monitoring or emergency use. $330.

Model 780-19 Patient Monitor. Displays temperature and venous pressure on front panel meters with adjustable high and low alarm limits—visual alarm if limits are exceeded. $910.

Model 7822A Arrhythmia Monitor. This small hybrid computer monitors ECG for premature or widened beats; generates alarms and displays on associated units.

Model 7825A Trend Recorder. Records one to four patient parameters on independent channels capable of producing standard analog traces or plotting bar graphs. Used with the 7822A Arrhythmia Monitor for a long term record of ectopic beats. $925.

Central station modules

Model 780-6A Viso-Scope. Displays patient parameters, such as ECG, pressure and pulse waveforms, on a 5 inch screen. $700 (single-channel); $875 (four-channel, Option 01).

Model 780-11 Patient Selector. Combines visual and audible patient distress alarms with patient signal switching to associated display or recording instruments. $730.

Model 780-12 Patient Alarm Display. Senses alarms from bedside monitors for any of four conditions at up to eight beds, actuates an alarm chime and illuminates a patient-identifying numeral indicating the alarm condition. $1000.

Model 780-13A Signal Switch Expands the capabilities of a 780-11 Patient Selector to additional signals per patient and an automatic mode of signal transfer to associated display/recording instruments. $290 (standard unit); $655 (Option 01 automatic switching); additional $55 per bed (Option 02 relay assemblies).

Model 7824A Analog Display. Displays up to four channels of physiological information on 2.5 inch rectangular meters. $425.

Model 780-800B Remote Monitor. Used with a 780B Viso-Monitor at the bedside, the 780-800B duplicates all visual displays of the 780B, beeps with each QRS complex and has a steady alarm tone in case of patient distress. $340.

Model 5601A Numerical Display. Displays three-digit values of four slowly changing patient parameters—such as blood pressures; heart, pulse and respiration rates; and temperature—on illuminated numerals 0.6 inch high. $2100 (typical four parameter display).

Resuscitation instrumentation

Model 7802B Defibrillator. Provides a dc, capacitor discharge countershock for termination of ventricular fibrillation and, with Option 01 Synchronizer circuit, for conversion of arrhythmias such as atrial fibrillation. Option 02 amplifier is for ECG monitoring. $1135; $1525 (with Options 01 and 02).

Model 7804A Pacemaker. Provides electrical stimulus internally or externally to cardiac patients with atrio-ventricular dissociation, ventricular slowing resulting in reduced cardiac output or cardiac arrest. AC and rechargeable battery-powered models are both available. $520 (AC operation only); $600 (battery and ac line operation).

Model 7839C Mobile Resuscitation System. Consists of a 7802B Defibrillator, 7804A Pacemaker, 1500A Electrocardiograph and 7803A Monitor Scope mounted in a 7810A Cart for quick response in a cardiac emergency.

Ancillary equipment

Model 7810A Mobile Cart. Used as an emergency resuscitation cart for quickly getting all instruments, drugs and supplies to the patient or as a bedside cart for a monitoring system.

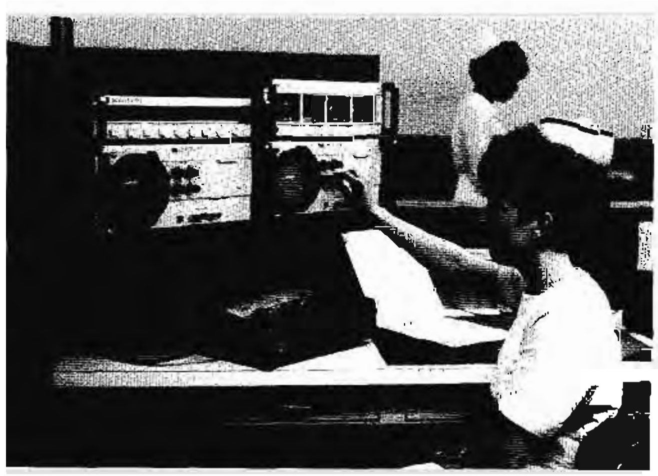
Model 21114A Respiration Transducer. Detects chest expansions/contractions as small as 0.015 inch to monitor respiration rate. Used with a 780-8 Patient Monitor or 760-2200 Respiration Rate Preamplifier. $100.

Model 780-15 Wall Mount Bracket. Holds up to two 780 half modules on a rugged bracket, freeing area around bedside and protecting monitors from possible damage. $35.

Model 780-16 Ear Plethysmograph. Detects blood pressure pulsations with a light-photocell arrangement attached to the ear. Used with a 780-7/7A Patient Monitor or a 780B Viso-Monitor. $100.

Model 780-21 Remote Alarm Indicator. Alerts personnel in corridors, doctors' or nurses' lounge, etc. to distress conditions with a flashing red light and repeating alarm tone. $130.

Model 7837A Central Station Console. Used to mount central station instruments in a single, efficient console; options give a variety of configurations. Minimizes installation time; all equipment—including central junction box—factory-mounted before shipment.



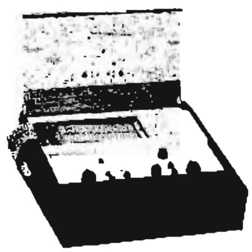
The cardiovascular intensive care unit at Christian Holmes Hospital, Cincinnati, Ohio, makes extensive use of HP monitoring, warning and display instruments. At the central station, the nurse can select and display ECG's on the 780-6A Viso-Scope and monitor patient variables on the 5601A Numerical Display. In cases of patient distress, visual and audible alarms are given by the 780-11 Patient Selector and the alarm patient's ECG is automatically recorded on the strip chart recorder. Bedside modules include ECG, pulse and heart rate monitors and a DC Defibrillator ready for use if needed.

DIAGNOSTIC INSTRUMENTATION

INSTRUMENTS FOR CLINICAL MEDICINE

Clinical applications instruments in the Hewlett-Packard product line are pictured and briefly described below. These units monitor/display ECG, VCG, heart sounds, simultaneous fetal heart rate and labor contractions, nerve conduction and muscle voltages, and internal body structures.

Detailed information on each instrument is found in the Hewlett-Packard 1969 *Diagnostic Instrumentation* catalog. To receive your complimentary copy, simply call or write the Hewlett-Packard sales and service office nearest you (see lists on pages 16-22).



1500A

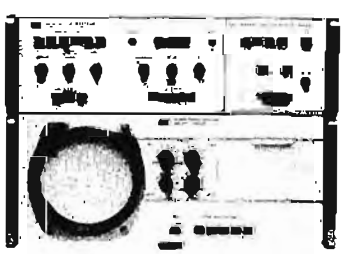
Special features of HP's 1500A portable Electrocardiograph include patient protection from potentially hazardous currents, a quick (10 second) warmup and the high reliability of all solid state circuitry. $850.

1511A

A mobile, hospital version of the Hewlett-Packard Electrocardiograph is the Model 1511A. It has all the patient safety, operating ease and high reliability features of the standard 1500A Electrocardiograph in a cart. $975.

1506B with 1500A

Heart sound recordings of diagnostic quality are provided by the 1506B Heart Sound Amplifier used with the 1500A or 1511A Electrocardiograph. The 1506B is also an independent electronic stethoscope. $450.

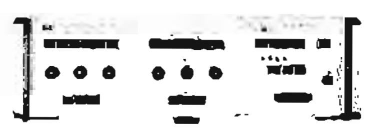


1520A

The 1520A Vectorcardiograph combines maximum versatility of display presentation with ease of operation: isolation of cardiac waveform sections; controlled trace intensity; pushbutton plane selection. $2635.

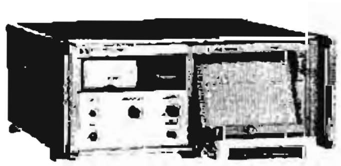
1508A

The 1508A 3-channel ECG Amplifier accepts one of four plug-in lead networks: Frank, Cube-Tetra, McFee Axial or combined ECG-VCG. In systems, it provides simultaneous ECG signals for multiple outputs. $1350.



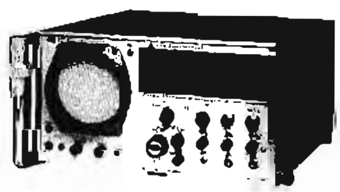
1509A

The 1509A 6 channel ECG Amplifier provides all 12 standard leads with two turns of the selector switch, or the three orthogonal components of the Frank vector system. In systems, it provides ECG signals for chart recording, computer analysis, tape storage, scope display. $2350.



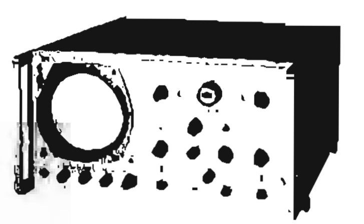
8020A

Studying fetal heart rate and its time relationship to labor activity with the 8020A Cardiotocograph permits diagnosis of fetal distress. External sensor function without disturbance to fetus or mother. $3750 (system).



7214A

Hewlett-Packard's versatile, safe and easy-to-use 7214A Diagnostic Sounder—using high frequency-low intensity ultrasound—has two operating modes: A-scan for measuring fixed distances and Time-Motion for visualizing moving structures. $3900.



1510A

The versatile 1510A Electromyograph is used for diagnosis, teaching and research. With variable persistence, scope viewing of EMG activity is enhanced and displays can be stored for later study or photography. $3750.

TOTAL SYSTEM CAPABILITY

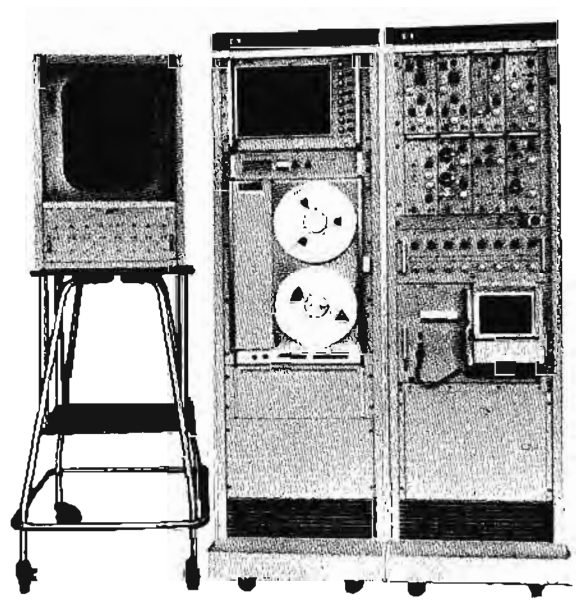
Clinical, Operating Room, Research Recording and Display Instruments

MEDICAL SYSTEMS

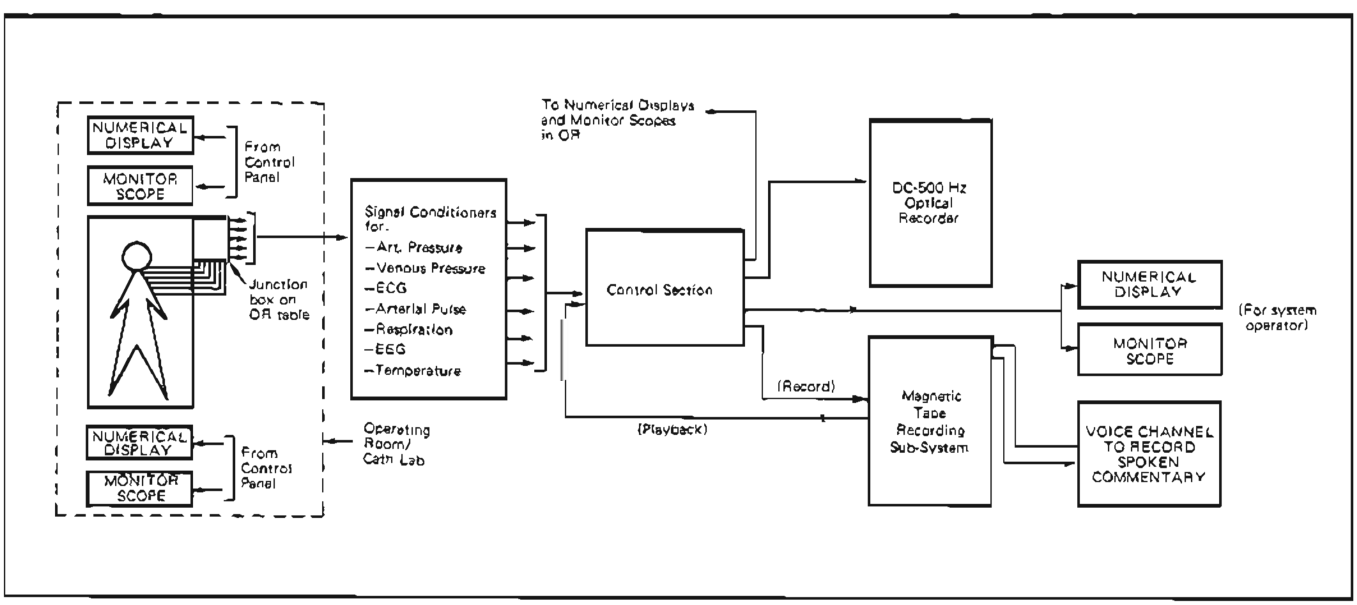
The photograph at the right and the functional block diagram below demonstrate the combination of Hewlett-Packard signal conditioning, recording and display instruments into an integrated system. These two configurations are representative of many different systems, each of which is specifically oriented to the needs of a particular operating room, hospital laboratory or research center. Each system provides its own special advantages through a complete selection of medical electronic instrumentation. Transducers, standard instruments, cabinets and cabling are designed to be electrically and mechanically compatible with each other. Hewlett-Packard provides a single, highly-experienced source of total system design, manufacture, and installation with a responsibility for continued accuracy that is backed up with service attention from people completely familiar with every system element.

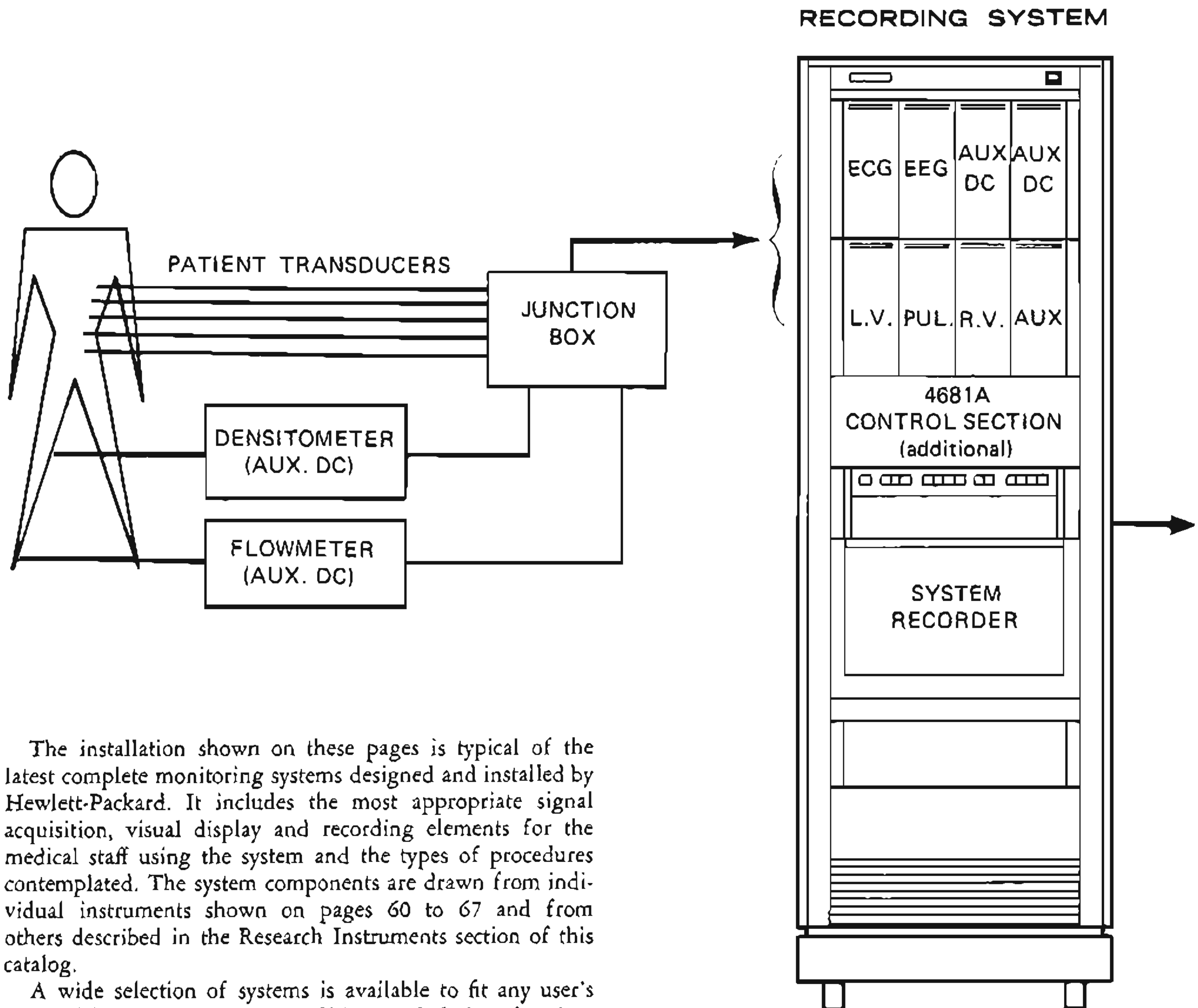
The system shown at the right is designed for the cardiovascular catheterization and research laboratory of an 800 bed hospital. It displays the waveforms of up to eight patient phenomena simultaneously on the 17 inch oscilloscope, photographically records eight variables (from dc to 500 Hz), and records or reproduces seven of these on magnetic tape. One of the system's important features is the Model 4681A Control Section, which enables the operator to select either the signal conditioner outputs or the tape recorded data for display and recording and to regulate each signal for uniform correlation among traces.

The systems engineering capabilities represented by the block diagram are applicable to the monitoring and recording requirements of a catheterization laboratory. Maximum information with minimum equipment and cabling in the catheterization lab itself (dashed outline) are provided by features such as waveform and numerical displays at each end of the room; all patient signals are routed to the main parts of the system in an adjoining room by a junction box near the table. The junction box can transmit up to 10 patient signals. In the block diagram the centrally located control panel affords the operator convenient, complete control of the presentation of patient phenomena.



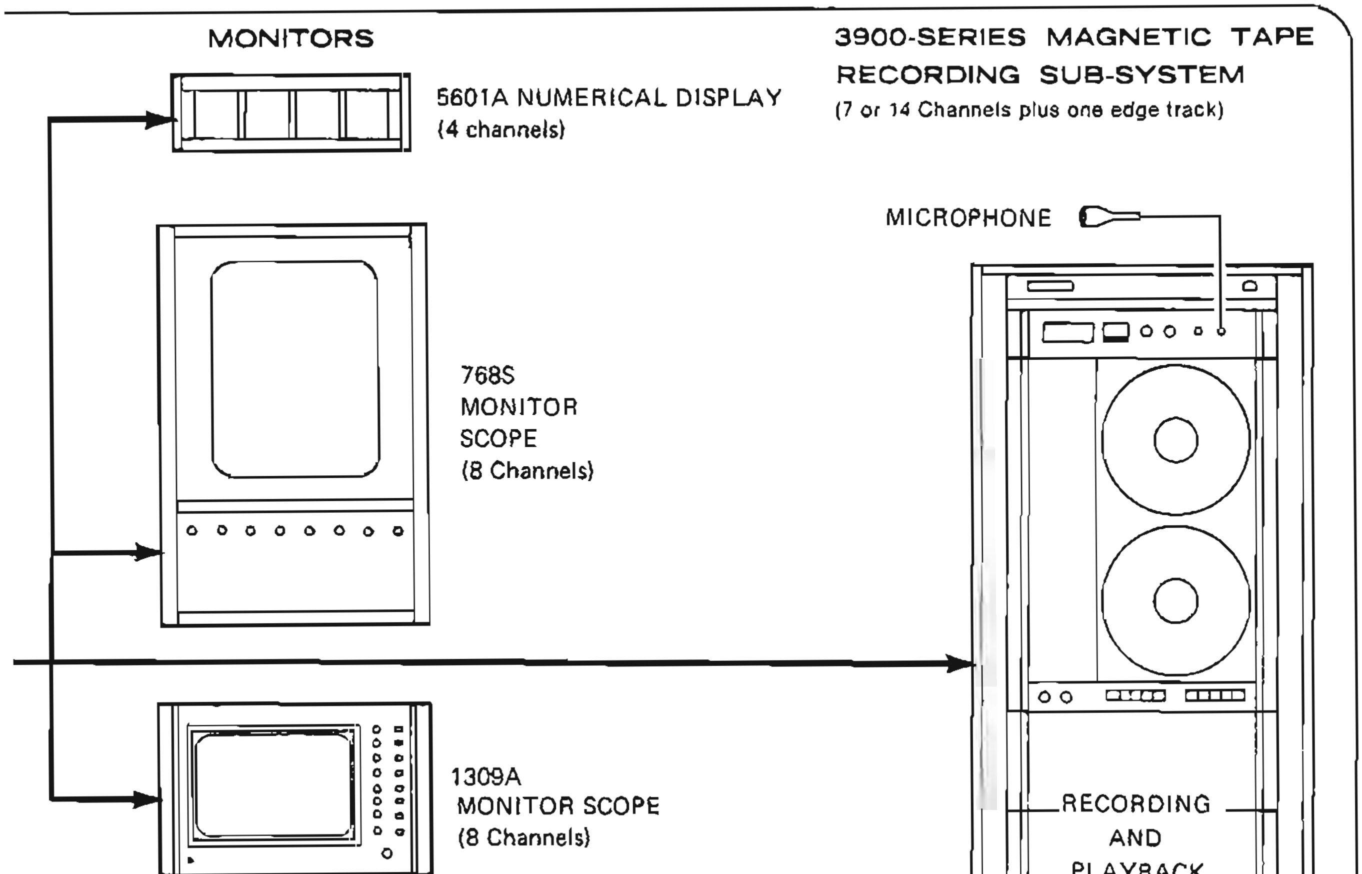
350 Series Dual-Bay System

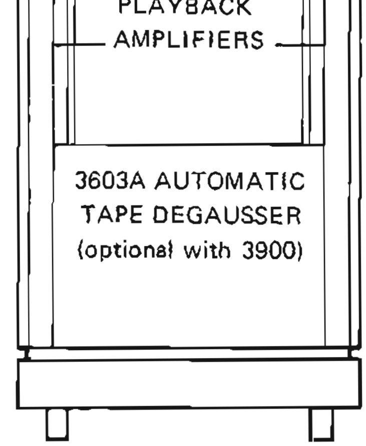




The installation shown on these pages is typical of the latest complete monitoring systems designed and installed by Hewlett-Packard. It includes the most appropriate signal acquisition, visual display and recording elements for the medical staff using the system and the types of procedures contemplated. The system components are drawn from individual instruments shown on pages 60 to 67 and from others described in the Research Instruments section of this catalog.

A wide selection of systems is available to fit any user's physical location, operating conditions and choice of patient phenomena to be monitored. Oscillographic recording equipment can use, for instance, the thermal process for proven reliability, the ink process for dependably clear, crisp traces on Z-fold paper, or the optical process for a high frequency range recording with overlapping traces. For versatile data storage and playback, Hewlett-Packard analog magnetic tape recording subsystems provide the number of direct or FM channels the user needs (from 1 to 14), a voice channel for spoken commentary, and valuable options such as an endless loop for repetitive playback and a remote control unit. Hewlett-Packard tape recording specifications conform to established IRIG (Inter-Range Instrumentation Group) standards so that tapes can be replayed by hospital and research centers





equipped with IRIG standard systems. Other optional capabilities include a dye curve integrator for cardiac output determination, analog-to-digital data conversion units for entering the data into computer storage and oscilloscope and numerical displays. Additional equipment can be incorporated into existing systems at any time, thus permitting the installation to grow with monitoring requirements and advances in instrumentation. Systems are available in single or multiple upright cabinets as shown, less cabinet for mounting in standard RETMA enclosures or in portable cases for transportability.

Hewlett-Packard plans monitoring systems with a true systems engineering approach developed during 20 years of experience. In designing a system, we recognize and stress system performance under actual operating conditions and the degree of operator skill required, provide for servicing and maintenance without disruption of the entire system, and ensure positive safety for patient and medical staff alike. Compatibility of each component in relation to all others is given major attention. For a detailed system proposal and cost estimate, contact your Hewlett-Packard medical field representative. He will be glad to discuss your patient monitoring requirements for general or specialized surgical and research procedures.

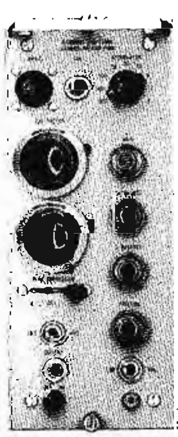
MEDICAL RESEARCH

SYSTEM APPLICATION
Selecting Amplifiers and Transducers
350 and 760 Series

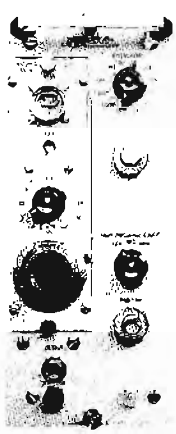
APPLICATION	RECOMMENDED PREAMPLIFIER		COMPATIBLE TRANSDUCERS**
Anesthesia Level	350-2700C 760-2700	High Gain Preamplifier (using 2-lead EEG) High Gain Preamplifier (using 2-lead EEG)	350-2700-C8 EEG Kit, 25 ft cable, electrodes
Apex Cardiogram (ACG)	350-3200A 350-2700C	ECG/General Purpose Preamplifier High Gain Preamplifier	APT-16-1 Pulse Wave Transducer with T41-18 Power Supply, 21050A Contact Crystal Microphone and Adapter 21066A or 21051/B/C/D Pulse Wave Transducer and 21066A Adapter
Auscultation, Aural	350-1700C	Heart Sound Preamplifier no Phonocardio-grams)*	21050A Contact Crystal Microphone
Ballistocardiogram (BCG)	350-3200A	ECG/General Purpose Preamplifier	ASTRO-SPACE LABS Air Bearing Table BOWEN & CO. Ballisto coil and magnet
Blood Density (Dye Dilution using Densitometer)	350-1000B 350-2B 350-2700C 350-3200A 760-1300	DC Preamplifier DC Plug-in (used with 350-1500A) High Gain Preamplifier ECG/General Purpose Preamplifier DC Preamplifier	WATERS Densitometer X250 WATERS Densitometer X300 GILFORD Densitometer 103 or 1031R
Cardiac Output Curve	350-15	Thermal Dilution Plug-in (used with 350-1500A	14012A Thermistor Probe, Model 130 Card. Comp.
Diastolic Pressure	760-3100	Pressure Processor	The 760-3100 must be used with the 760-3000. The readout is generally a 5601A or 7824A.
DC Transducer Applications	Same as Blood Density		Supplied by customer.
Electrocardiogram (ECG,) for adult, animal, child	350-3A 350-2700C 350-3200A	ECG/EEG Plug-in (used with 350-1500A) High Gain Preamplifier ECG/General Purpose Preamplifier (single ECG only)	One channel: 350-3200-C8 ECG Kit, 5 leads, 8 ft with electrodes, straps, Redux creme. Multichannel: Order 1069-04B ECG Panel and 8 wire patient cable 154-1100M-C2, overall length 12 ft.
	760-1600	ECG Preamplifier	Leads 1, 2, 3 only selected on 760-40A and 760-41 Junction Boxes.
Electrocardiogram – Fetal	350-3A 350-2700C	ECG/EEG Plug-in (used with 350-1500A) High Gain Preamplifier	350-2700-C8 EEG Kit, 25 ft cable, electrodes.
Electroencephalogram (EEG) (2-lead EEG only)	350-2700C 760-2700	High Gain Preamplifier High Gain Preamplifier	350-2700-C8 EEG Kit, 25 ft cable, electrodes 350-3200-C8 and 760-40A or 760-41 Junction Box.
Electro Cautery Protection	760-40A 760-41	Junction Box Junction Box	Cautery protection is provided for a 5-wire lead ECG cable and a 2-lead EEG in the 760-40A or 760-41 Junction Box.
Electrometry, Muscle Tissue	350-2700C	High Gain Preamplifier	350-2700-C8 EEG Kit, 25 ft cable electrodes MEDISTOR A-34 Micro-electrode adapter, or similar fast rise time neutralized electrometer.
Electromyogram (EMG), General	350-3700A	Integrating Preamplifier	
Electromyogram, Small Muscle	350-2700C	High Gain Preamplifier	
Electro-oculogram (EOG)	350-2B	DC Plug-in (used with 350-1500A)	350-2700-C8 EEG Kit (connector must be changed, zero suppression required). LEXINGTON INSTRUMENTS EOG electrodes (silver/silver-chloride sponge).
Flow – Air	350-1100CM 350-3700A	Carrier Preamplifier Integrating Preamplifier	270 Transucer, ± 29.4 mm Hg (≈ 400 mm H_2O) with 10 ft cable (pneumotach screen and 1/8 in. ID tube also required – see Respiratory Measurements).
Flow – Liquids	Same as Blood Density		AVIONICS Electromagnetic Flowmeter BIOTRONICS Electromagnetic Flowmeter CAROLINA MEDICAL Electromagnetic Flowmeter.

*Phonocardiograms on Optical Systems only. **Hewlett-Packard Number or alternative commercial source.


350-1000B


350-1100CM


350-1300C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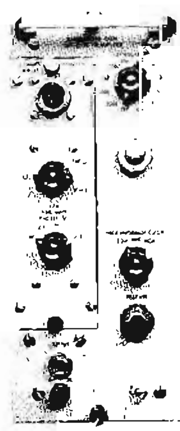
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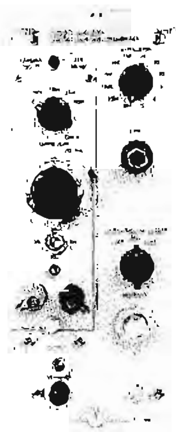
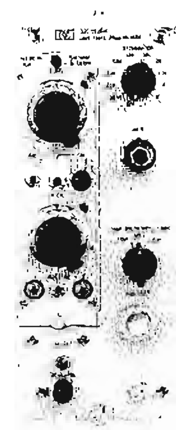
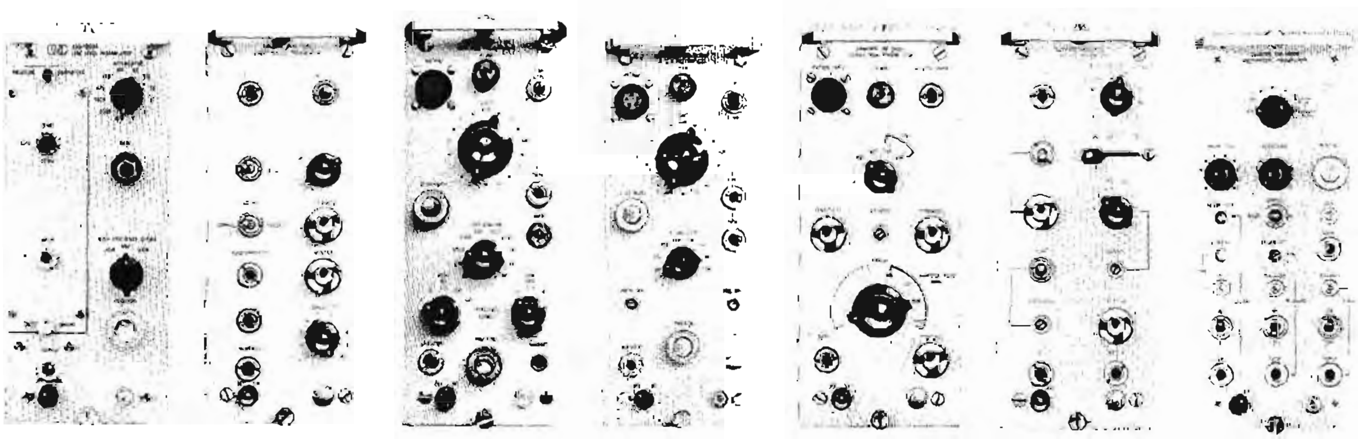

350-1500A/12


350-1500A/15

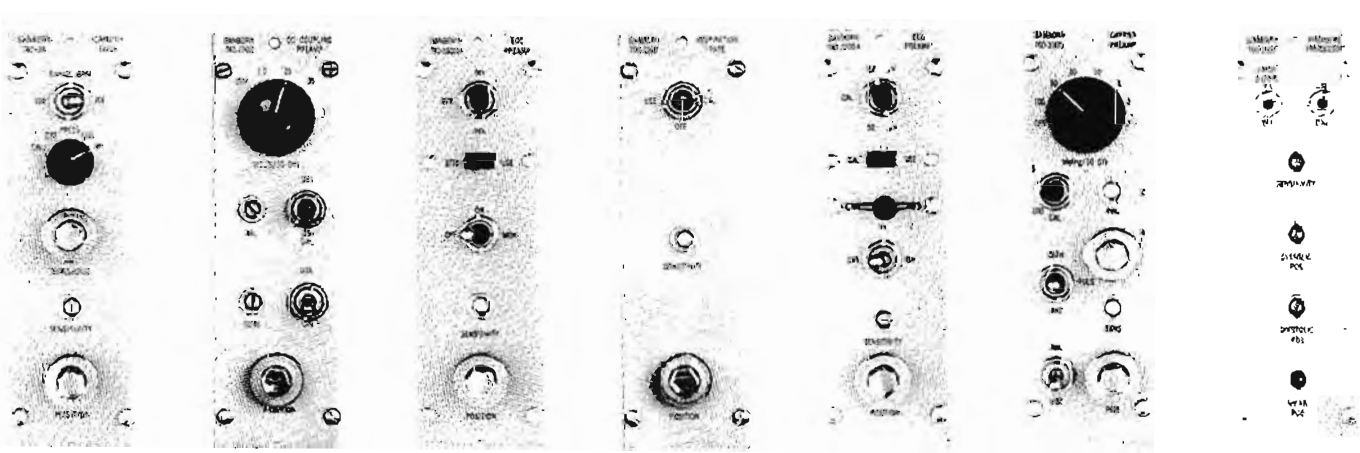
APPLICATION	RECOMMENDED PREAMPLIFIER		COMPATIBLE TRANSDUCERS*
Galvanic Skin Resistance (GSR)	350–12	Galvanic Skin Resistance Plug-In (used with 350–1500A)	(2) 9301–0157 PALMER Skin Electrodes plus (1 ea) 865–7476P1 Cable 865–7476P2 Cable
Gas Analysis	350–1000B 350–1300C 350–3200A	DC Preamplifier DC Coupling Preamplifier ECG/General Purpose Preamplifier	Carbon Dioxide: GODART Capnograph (special cable) Nitrogen: WATERS Nitrogen Gas Analyzer A7 MED-SCIENCE ELECTRONICS Nitralyzer
Heart Rate, Average and Heart Beat Time Interval	350–3400A	Cardiotach Preamplifier	(Direct from ECG) 350–3400–CS ECG Accessory Kit (3 leads) (With simultaneous ECG, or from arterial pressure, requires primary pressure or ECG equipment, plus one listed 8120 cable) 8120–1024, Cable output, 2 ft. 8120–0791, Cable output, 4-1/2 ft. 8120–1022, Cable output, 12 ft. 8120–1023, Cable output, 20 ft.
	760–3A	Cardiotachometer Plug-in (average heart rate only)	Heart Rate determined from ECG 760–1600 to 760–3A Heart Rate determined from Pulse 760-3000 to 760–3A Heart Rate determined from Plethysmograph 780–16 to 760–3A.
Heart Sound	350–1700C	Heart Sound Preamplifier (aural auscultation only)	21065A, Audiophone and either: 62–1500–C16, Microphone (Dynamic) with 14065A Adapter or 21050A, Microphone (Contact Crystal).
Intra-cellular Potentials	350–2700C	High Gain Preamplifier	MEDISTOR Micro-electrode Amplifier A34 or similar fast rise time neutralized electrometer.
Mean Pressure	350–1100CM 760–3000 760–3100	Carrier Preamplifier Carrier Preamplifier Pressure Processor	Carrier Amplifiers may be put in the 'average' mode to read mean pressure. The 760–3100 must be used with the 760–3000. The readout is generally a 5601A or 7824A.
Nerve Potentials	350–2700C	High Gain Preamplifier	MEDISTOR Micro electrode Amplifier A34 or similar fast rise time neutralized electrometer.
Nystagmogram	350–2700C with 350–1500 and 350–3A	High Gain Preamplifier	350–2700–C8 EEG Kit, 25 ft cable, electrodes.
Oxygen Perfusion during Anesthesia	350–2700C	High Gain Preamplifier	350–2700–C8 EEG Kit, 25 ft cable, electrodes.
Physiological Pressures: – Arterial change in pressure over a period of time (DP/DT Differentiator)	350–1500 with 350–16	Low Level Preamplifier DP/DT (Differentiator) Plug-in	350–16 obtains input from arterial pressure channel (350–1100CM Preamplifier) through any 8120-Series cable, see Heart Rate listing.
Physiological Pressures: – Arterial	350–1100CM 760–3000	Carrier Preamplifier Carrier Preamplifier	267AC Single-ended, – 100 to +250 mm Hg, 8 ft cable 267BC Differential – 100 to +250 mm Hg, 8 ft cable 1280B Transparent Dome, Single-ended – 40 to +250 mm Hg, 10 ft cable: extension cables 6, 10, 15, 20, 25 and 50 ft available.
Physiological Pressures: – Venous, Spinal, Gastro-intestinal, Esophageal	350–1100CM 760–3000	Carrier Preamplifier Carrier Preamplifier	268A Single-ended, – 40 to +40 mm Hg, 8 ft cable 268B Differential, – 40 to +40 mm Hg, 3 ft cable 1280C Transparent Dome, Single-ended, – 40 to +250 mm Hg.
Plethysmogram, Body	350–1100CM	Carrier Preamplifier	270 Pressure Transducer (for 1/8 in. ID Tubing).

*Hewlett-Packard Number or alternative commercial source.



350-1500A/16 350-1700C 350-2700C 350-3200A 350-3400A 350-3700A 350-5000B

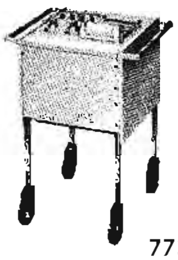
APPLICATION	RECOMMENDED PREAMPLIFIER		COMPATIBLE TRANSDUCERS*
Plethysmogram, Limb-Digit	350-1100CM 350-2700C 350-3200A	Carrier Preamplifier High Gain Preamplifier ECG/General Purpose Preamplifier	PARKS CO. Mercury-filled Tubing with Matching Circuit Adapter PARKS CO. Impedance Type Sensor with Parks Special Interconnecting Cable.
Pneumogram	350-2700C 350-3200A 350-1100CM	High Gain Preamplifier ECG/General Purpose Preamplifier Carrier Preamplifier	Pneumograph Attachment 108 with Pulse Wave Attachment 21051B/C/D Pneumograph Attachment 108 with Pressure Transducer 270.
Pulmonary Function Studies – Flow	350-1100CM 350-3700A	Carrier Preamplifier Integrating Preamplifier	Flow (air): 270 Transducer, 651-Series Pneumo Tach Screens (see Respiratory Measurements). Volume: (1) Use 350-3700A to derive volume from air flow measurements. (2) 108 Pneumo Tach Attachment replaces 651 Series Pneumo Tach. Use 350-3700A to derive volume from 350-1100CM output.
Pulse Wave (carotid)	350-2700C 350-3200A	High Gain Preamplifier ECG/General Purpose Preamplifier	21051B Pulse Wave Attachment (phone plug—use with 760-40A Junction Box) 21051C Pulse Wave Attachment (5-pin A/N connector) APT-16-11 Pulse Wave Transducer (with strap).
Respiratory Measurements	350-5000B and two 350-1100CM	Respiratory Preamplifier Carrier Preamplifier Volume from 350-5000B Flow from 350-1100CM Pressure from 350-1100CM Resistance from 350-5000B Compliance from 350-5000B	Resistance and Compliance can be determined by calculations involving data from simultaneous recording of esophageal pressure and air flow. When using 350-5000B Respiratory Preamplifier, determination can be made directly from a recorder with the following Pneumo Tach Screens; measurements are in liters per minute; 270 Transducer also required, see Flow, Air: Small Animal (Cone) 651-288C, 25L, 0.2 in.^{2}, 0.5 in. H_2O pressure drop. Children (Cone) 651-266C, (Mask) 651-266M, 90L, 1.0 in.^{2}, 0.3 in. H_2O pressure drop. Sedentary Adults (Cone) 651-267C, (Mask) 651-267M, 180L, 2.0 in.^{2} 0.24 in. H_2O pressure drop. Working Adults (Cone) 651-285C, (Mask) 651-285M, 600L, 7.0 in.^{2}, 0.3 in. H_2O pressure drop. Max Breathing Capacity 651-286M, 900L, 12.5 in.^{2}, 0.27 in. H_2O pressure drop.
Respiration Rate	760-2200	Respiration Rate Preamplifier	21114A Respiration Rate Transducer
Systolic Pressure	760-3100	Pressure Processor	The 760-3100 must be used with the 760-3000. The readout is generally a 5501A or 7824A.
Temperature, Body	350-1100CM	Carrier Preamplifier (with 760-53 Temperature Bridge) Carrier Preamplifier	760-53 Temperature Bridge, range of 20°C to 44°C, balanced at 37°C (98.6°F) Full range of compatible probes and cables available, including new Air Temperature Probe, Model 21056A. Please request technial data on 760-53 for complete information on Bridge and Probes. 760-20 Monitor Meter, meter indicator for visual temperature monitoring. Wall or bench mount.

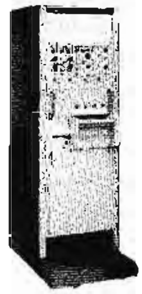


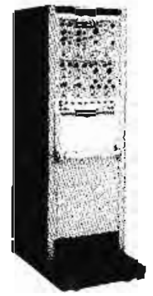
760-3A 760-1300 760-1600A 760-2200 760-2700A 760-3000 760-3100

OSCILLOGRAPH RECORDING

Instantaneous, permanent, rectilinear
Thermal, ink, optical


7714A


7712B


7718A

7712B two-channel recording system

The 7712B two-channel thermal recording system features mobile cart mounting to facilitate clinical and research applications of the system. It is also available in portable case or for rack mounting. Any two of the versatile 350 Series Plug-in Preamplifiers may be used as signal conditioners. Recording channels are 50 mm wide with a frequency response from dc to 125 Hz, unless limited by the preamplifier. Pushbutton selected chart speeds of 1, 5, 20 and 100 mm/sec are standard with 2.5, 5, 25 and 500 mm/sec speeds on Options 10 and 11. Marker on *right margin for* 1-second *timing* is standard; a second optional event marker can be mounted between channels 1 and 2.

Power requirements: 115 V, 60 Hz, 200 watts.
Size: recorder 14" high, 19" wide, 17¼" deep (356 x 483 x 438 mm); cart 39" high, 26¾" wide, 20½" deep (997 x 179 x 520 mm).
Weight: in cart, net 130 lbs (58.5 kg); shipping 172 lbs (77.2 kg); recorder only, 60 lbs (27.2 kg).
Price: HP Model 7712B, less preamplifiers, $1970.

7714A four-channel recording system

The 7714A four-channel thermal recording system for use with any four 350 Series Plug-in Preamplifiers is complete in its fully enclosed upright cabinet. It is also available without cabinet for rack mounting. The system features a horizontal chart table for easier notation on the recording. The four recording channels, each 50 mm wide, provide a recording response from dc to 125 Hz unless limited by the preamplifier. Mechanically selected chart drive speeds of 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec are standard. Right margin time marker provides 1 sec timing marks from built-in timer, manual and remote marking possible; second event marker can be installed between channels 1 and 2 for remote marking; also solid state marker driver amplifiers for dc event marking are available.

Power requirements: 115 V, 60 Hz, 350 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm). 36½" deep with base (927 mm).
Weight: net 473 lbs (214 kg); shipping 569 lbs (256 kg).
Price: HP Model 7714A, less preamplifiers, $3970.

7716A six-channel recording system

The 7716A six-channel Thermal Recording System is designed to operate with any six of the 350 Series of Plug-in Preamplifiers as a single cabinet-mounted system. It is also available in portable cases and for rack mounting. The system features a flush-front recording drive to allow observation of the recording as it is being made. The six recording channels, each 50 mm wide, record from dc to 125 Hz unless limited by the preamplifier. Speeds selected electrically by pushbutton are: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. Right margin time marker provides 1 sec timing marks; provision for manual or remote event marking from external contact closure; "D" version recorders provide 1 sec and 1 min timing markers; optional second event marker can be installed between channels 1 and 2 and actuated by external contacts; also, solid state marker driver amplifiers for dc event marking are available.

Power requirements: 115 V, 60 Hz, 900 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 574 lbs (259 kg); shipping 670 lbs (302 kg).
Price: HP Model 7716A, less preamplifiers, $5325.

7717B six-channel recording system

The 7717B six-channel Thermal Recording System features a visual display facility for one to four channels (HP Model 780-6A Opt 01 Scope) as a unified system complete in one upright cabinet. The system operates with any six of the 350 Series of Plug-in Preamplifiers. Each recording channel is 50 mm wide and provides a response from dc to 125 Hz unless limited by the preamplifier. Speeds selected electrically by pushbutton are: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. Right *margin timer marker provides* 1 *sec timing marks;* provision for manual or remote event marking from external contact closure; "D" version recorders provide 1 sec and 1 min timing markers; optional second event marker can be installed between channels 1 and 2 and actuated by external contacts; also, solid state marker driver amplifiers for dc event marking are available. ECG Input Panel (buffer amplifiers) optionally available.

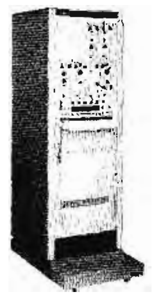
Power requirements: 115 V, 60 Hz, 970 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 590 lbs (266 kg); shipping 686 lbs (309 kg).
Price: HP Model 7717B, less preamplifiers, $6400.

7718A eight-channel recording system

The 7718A eight-channel Thermal Recording System provides the advantages of eight recording channels on one chart with a wide response from dc to 150 Hz unless limited by the preamplifiers. This provides a maximum of recording facilities to add flexibility to both clinical and research applications and furnish a maximum amount of recorded data for any one observation. Each channel is 40 mm wide (50 div). The system operates with any eight of the 350 Series of Plug-in Preamplifiers. Electrically selected speeds by pushbutton are: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. Right margin marker provides 1 sec timing marks; provision for manual or remote event marking from external contact closure; "D" version recorders provide 1 sec and 1 min timing markers; optional second event marker can be installed between channels 1 and 2 and actuated by external contacts; also, solid state marker driver amplifiers for dc event marking are available. The system is also available in portable cases and for rack mounting.

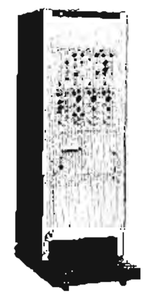
Power requirements: 115 V, 60 Hz, 950 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).
Price: HP Model 7718A, less preamplifiers, $6350.

7719B



7721A

7722B



4568B

7719B eight-channel recording system

The 7719B eight-channel Thermal Recording System features a visual display facility as a standard part of the complete system. This facility is designed around a cathode ray oscilloscope and may be used for the display of vectorcardiographic loops or for showing other physiological phenomena such as ECG, EEG, pulse waves, etc. The entire system is complete in one upright cabinet and includes provisions for inserting any selection of eight 350 Series Plug-in Preamplifiers. Each channel is 40 mm wide (50 div) with a recorded frequency response from dc to 150 Hz unless limited by the preamplifier. Electrically selected speeds by pushbutton are: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. Right margin timer marker provides 1 sec timing marks; provision for manual or remote event marking from external contact closure; "D" version recorders provide 1 sec and 1 min timing markers; optional second event marker can be installed between channels 1 and 2 and actuated by external contacts; also solid state marker driver amplifiers for dc event marking are available.

ECG Input Panel (buffer amplifiers) optionally available.

Power requirements: 115 V, 60 Hz, 950 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).
Price: HP Model 7719B, less preamplifiers, $7325.

7720A eight-channel recording system

The 7720A eight-channel Thermal Recording system operates with any eight 350 Preamplifiers. The system features a horizontal chart table for easier notation on the recording. Multichannel recording furnishes maximum comparative information on its chart for clinical or research measurements. Recording channels are 40 mm wide (50 div), with a recorded response from dc to 150 Hz, unless limited by the preamplifier. Electrically selected chart speeds are 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. An ECG Input Panel with buffer amplifiers is optional.

Power requirements: 115 V, 60 Hz, 950 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).
Price: HP Model 7720A, less preamplifiers, $6650.

7721A six-channel recording system

The 7721A six-channel Thermal Recording System operates with any six 350 Preamplifiers. The system features a horizontal chart table for easier notation on the recording. Multi-channel recording furnishes a maximum amount of information on the chart for clinical or research measurements. Recording channels are 50 mm wide (50 div), with a recorded response from dc to 125 Hz unless limited by the preamplifier. Electrically selected chart speeds are 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. An ECG Input Panel with buffer amplifiers is optional.

Power requirements: 115 V, 60 Hz, 950 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).
Price: HP Model 7721A, less preamplifiers, $5620.

7722B eight-channel recording system

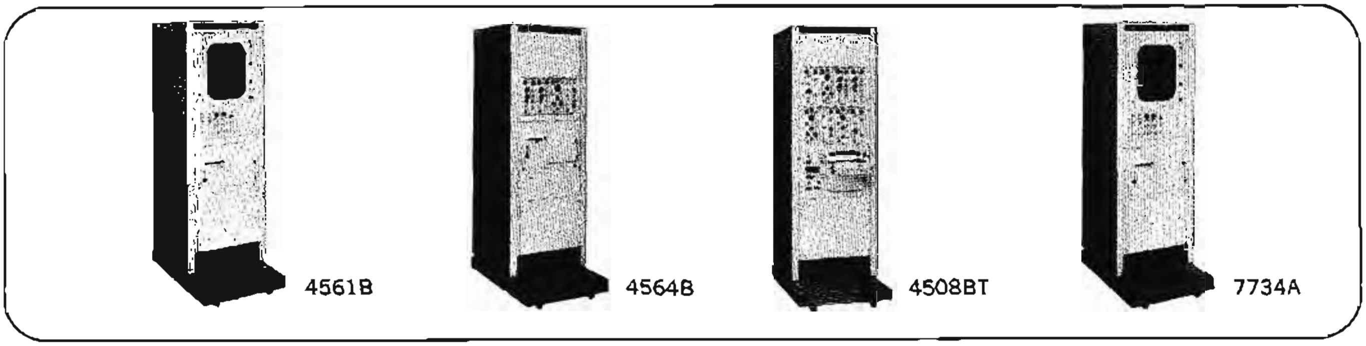
The 7722B eight-channel Thermal Recording System operates with any eight 350 Preamplifiers. The system features a horizontal chart table for easier notation on the recording. Multichannel recording furnishes a maximum amount of information on the chart for clinical or research measurements. Recording channels are 40 mm wide (50 div), with a recorded response from dc to 150 Hz unless limited by the preamplifier. Electrically selected chart speeds are 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. It also contains a 780-6A 4-channel scope; an ECG Input Panel with buffer amplifiers is optional.

Power requirements: 115 V, 60 Hz, 950 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).
Price: HP Model 7722B, less preamplifiers, $7725.

4568B photographic recording system

The 4568B Photographic Recording System features the same optical photographic recorder used in the 4561B and 4564B systems, operating with any eight of the 350 Series of Plug-in Preamplifiers to provide separate or overlapping channels of wide-range data recording. Use of all eight channels provides a thorough presentation of physiologic events and their waveforms, as they may occur in clinical investigation of a patient or in research-oriented experimentation on a subject. The wide frequency range from dc to 500 Hz (unless limited by the preamplifier) permits extensive small-animal investigation, as well as routine recording of such high frequency variables as heart sounds and electromyographic potentials. Other ranges available on order.

Power requirements: 115 V, 60 Hz, approx. 1000 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 456 lbs (216 kg), shipping 552 lbs (248 kg).
Price: HP Model 4568B, less preamplifiers, $5160.



4561B Monitor recording system

The 4561B system features a wide-range, four-channel optical recorder (Rapid Developer optional), plus a multichannel large-screen monitoring oscilloscope. The recorder, with its eight manually-selected chart speeds (2.5 to 200 mm/second; 5 to 100 mm/second with Rapid Developer), uses either 6 inch wide, 200 foot long bromide recording paper or (with Rapid Developer) a 6 inch wide, 175 foot long roll. Paper is darkroom-loaded, exposed in the recorder under normal room illumination, then developed in the darkroom or by Rapid Developer 563. Beams may be superimposed or separated into their individual portions of the chart. Amplitude and timing lines are recorded at the same time as the data, with the timing lines being controlled by an independent synchronous motor. Recorded frequency response extends from dc to 500 Hz (other ranges available) unless limited by the Preamplifier. The monitoring oscilloscope is the same as used in the 7734A, and provides the same features. The system accepts any six 760 Series Preamplifiers; the output from four appears on the oscilloscope and recorder, leaving two channels for other display devices or for mounting other plug-in units.

Power requirements: 115 V, 60 Hz, 650 watts.

Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).

Weight: net 408 lbs (184 kg), shipping 533 lbs (240 kg).

Price: HP Model 4561B, less preamplifiers, $4765.

4564B photographic recording system

The 4564B Photographic Recording System features the same optical recorder as the 4561B system, but utilizes the more versatile series of 350 Plug-in Preamplifiers which permit recording an extensive variety of physiologic phenomena, at a frequency range from dc to 500 Hz or as limited by the preamplifier (to 1 kHz with 350-1700C). Rapid Developer 563 (optional) provides the advantages of wide-range optical recording without the delay of darkroom processing before the final recording may be used.

Power requirements: 115 V, 60 Hz, approx. 770 watts.

Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).

Weight: net 458 lbs (216 kg), shipping 554 lbs (252 kg).

Price: HP Model 4564B, less preamplifiers, $3455.

7723B six-channel recording system

The 7723B six-channel Thermal Recording System operates with any six 350 Preamplifiers. The system features a horizontal chart table for easier notation on the recording. Multichannel recording furnishes maximum comparative information on its chart for clinical or research measurements. Recording channels are 50 mm wide (50 div), with a recorded response from dc to 125 Hz, unless limited by the preamplifier. Electrically selected chart speeds are 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec. It also contains a Model 780-6A four-channel scope; an ECG Input Panel with buffer amplifiers is optional.

Power requirements: 115 V, 60 Hz, 950 watts.

Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).

Weight: net 532 lbs (240 kg); shipping 628 lbs (283 kg).

Price: HP Model 7723B, less preamplifiers, $6695.

4508BT ultra-violet recording system

The 4508BT system features a special ultraviolet sensitive recording paper whose latent image may be developed simply by exposure to fluorescent illumination. The chart paper roll may be loaded under normal room lighting, and is developed by the built-in post exposure fluorescent lamp, so the multichannel data may be viewed a few seconds after it is recorded. The system uses any eight of the 350 Series Preamplifiers, for a recorded frequency response from dc to 500 Hz (to 1 kHz with 350-1700C) unless limited by the preamplifier. The recorder provides nine pushbutton selected speeds from 2.5 to 1000 mm/sec. Data channels may be separate or may overlap to the full width of the eight inch chart. Time and amplitude lines are recorded with the data for maximum accuracy.

Power requirements: 115 V, 60 Hz, approx. 1600 watts.

Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).

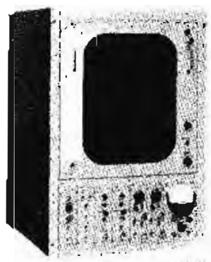
Weight: net 190 lbs (85,5 kg), shipping 250 lbs (113 kg).

Price: HP Model 4508BT, less preamplifiers, $7100.

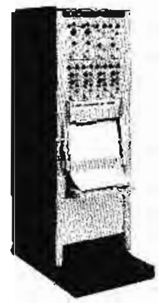
7734A Monitor recording system

The 7734A system features a complete, multichannel, 13½" x 10" (viewing area) oscilloscope for data presentation, with a four-channel data recorder having a dc to 125 Hz response (unless limited by Preamplifier). Oscilloscope sweep speeds are 3, 6 and 12 mm/second, automatic or manual, plus 30 mm/second manual, on a long persistence screen. The thermal recorder makes an instantaneous record of four 50 mm channels at a mechanically selected 0.25, 0.5, 1, 2.5, 5, 10, 20, 50 or 100 mm/second chart speed. The system uses any six 760 Series

6689AW/4688A



4689W/4684A



7868A

Preamplifiers: the output from four appears on the oscilloscope and recorder, leaving two channels for other display devices or for mounting other plug-in units.

Power requirements: 115 V, 60 Hz, 600 watts.
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: net 408 lbs (184 kg), shipping 504 lbs (223 kg).
Price: HP Model 7734A, less preamplifiers, $4980.

4689A remote monitor oscilloscope

The HP 4689A Remote Monitor Oscilloscope can accept, by option, either an 8-channel gating amplifier for 8 data channels or a 4-channel gating amplifier for 4 data channels. By displaying the data simultaneously on a 17 inch screen, the 4689A serves as a valuable visual monitoring adjunct to HP multichannel recording systems. The 4-channel monitor can be used only with systems that accept 760 Preamplifiers; the 8-channel monitor can be used with systems that accept 350 or 760 Preamplifiers and with 780 Patient Monitoring Systems. The 4689A is invaluable for large screen monitoring in OR or catheterization laboratories, for teaching purposes and for research applications.

Automatic sweep speeds for the oscilloscope are 3, 6, and 12 seconds; manually controlled speeds are 3, 6, 12 and 30 seconds. The large screen provides ample room (13½" top to bottom) for clear, well-separated presentation of multiple waveforms. A 10-division graticule facilitates amplitude measurements. A Polaroid® filter minimizes interference from room lighting. Controls on the gating amplifier permit adjustment of each signal for position at any level on the screen and for sensitivity of up to 2 inches deflection on the scope, for each centimeter on a direct writing recorder.

Power requirements: 115 V, 60 Hz, 275 watts (8 channels); 115 V, 60 Hz, 185 watts (4 channels).
Size: 29⅝" high, 21¼" wide, 21¼" deep (746 x 540 x 540 mm).
Weight: net 115 lbs (8 channels); net 112 lbs (4 channels).
Price: HP Model 4684A (4 channel gating amplifier), $325. HP Model 4688A (8 channel gating amplifier), $700. HP Model 4689A, $1675. Combine price of gating amplifier with price of 4689A to obtain total system price.

7868A ink recording system

The 7868A System is an eight-channel, modulated pressurized ink recording system designed for medical applications. It features Z-fold chart paper for instant access to any part of the recording. This feature facilitates observation of physiological variables to assess experimental trends or to decide on immediate action. The chart can be copied by any method, with the uniform trace width giving exceptional clarity even at high frequencies.

The 7868A System uses up to eight Hewlett-Packard 350 Series Preamplifiers to provide a capability to fit your special requirements from temperature to EEG applications. Any combination of preamplifiers can be used, and it is easy to change the function of an individual channel by loosening two front panel thumbscrews and replacing the preamplifier with a different model.

Because the system translates patient phenomena into visible waveforms it logically includes everything from sensing the data at the patient to providing a chart, or other output, for the observer. The applications of a 7868A System are determined mainly by its transducers and preamplifiers. Each transducer picks up a physiological variable from the patient and couples it, electrically, to a preamplifier, which conditions the signal for one channel. The preamplifier output is applied to a power amplifier that drives the recording pen for that channel. From the preamplifier output on, all eight system channels are identical.

The 7868A System, which features complete control of the variables to be recorded, also provides many new operator conveniences. Any part of the record is immediately accessible with Z-fold chart paper. The paper, numbered at intervals, provides its own reference within the recording and indicates the amount of paper remaining.

The Z-fold chart paper is perforated so that any sheet can be readily removed. Z-fold chart paper can be stored flat or filed in book form by punching and binding the sheets into such documents as medical reports, laboratory notebooks, and formal publications. Rolls or Z-fold packs can be installed without paper threading in less than one minute.

Fourteen chart speeds (including standard 25 mm and 50 mm/second speeds) permit convenient matching of the chart speed to the waveform being recorded, for easier reading. These chart speeds range from 0.025 mm to 200 mm/second.

The low pressure ink supply is modulated to match the recording pen velocity and chart speed, assuring sharp, constant-width traces over all points of the signal waveform.

The recording fluid, a permanent blue ink that dries rapidly on contact with the paper, permits high resolution copying of recorded data. The fluid comes in a disposable plug-in cartridge that supplies over 1000 miles of recorded line, and which can be replaced from the front of the system without stopping the recorder. A light indicates when the cartridge must be replaced.

Power requirements: 115 V, 60 Hz, 350 watts (less preamplifiers).
Size: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" with base (927 mm).
Weight: 550 lbs (249 kg), in cabinet with representative group of 350 Preamplifiers.
Price: 7868A system, less preamplifiers, $10,350.

MAGNETIC TAPE RECORDING

Moderate cost, system compatible

Models 3907B, 3914B, 3917B, 3924B

System performance:

HP 3900 Series magnetic tape record/reproduce systems (see page 177 for specifications) are available with 7 or 14 analog data recording channels plus: one edge track for recording voice commentary or timing information, six standard speeds from 1⅞ ips to 60 ips, and choice of plug-in circuit cards for direct, FM or pulse mode recording. Low cost electronics incorporate both record and reproduce functions on the same circuit card. Low bandwidth systems (3907B, 3914B) have a maximum frequency response in direct mode of 100 kHz; intermediate bandwidth systems (3917B, 3924B) have a response to 250 kHz. Systems are housed in mobile cabinets, as shown at right, in portable cases, or unmounted for installation in RETMA standard cabinets.

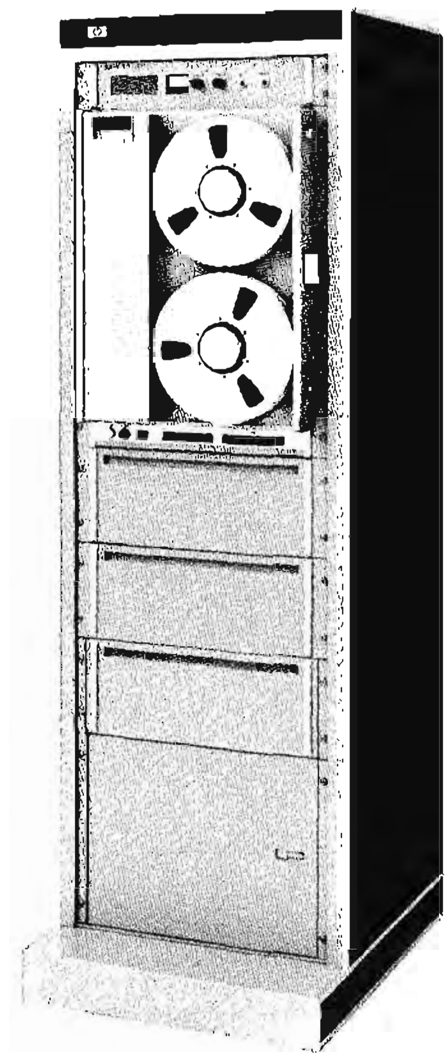
Performance of these systems is compatible with the widely accepted standards of the Inter-Range Instrumentation Group, permitting the playback of 3900 Series tapes on other compatible systems, and vice-versa. Representative specifications include: 0.2% pp flutter (dc to 200 Hz, at 30 and 60 ips); extremely low interchannel crosstalk, even when direct and FM channels are mixed on the same head stack; at least 40 dB signal-to-noise ratio; direct connection of single-ended inputs from 0.5 to 10 V rms (direct) and ±1.2 to ±3 V pp (FM), 20 K input resistance.

System features:

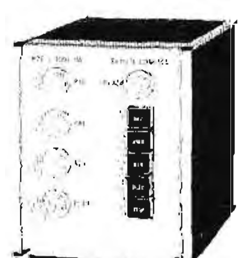
An important advantage offered by the 3900 Series tape systems is the compatibility of the tape systems to the many Hewlett-Packard medical signal conditioners and signal display instruments. Standardization of connectors and cables for Hewlett-Packard medical instrumentation has made this possible. Standard cables connect the output of such instruments as the 1508A, 1509A Multichannel ECG Amplifier or the 1510A Electromyograph to the tape system. Similarly, connecting cables are available for Hewlett-Packard multichannel ink, thermal, optical or ultraviolet medical recording systems; tape playback signals are conveniently displayed on the multichannel 5601A Numerical Display, 768S Oscilloscope or the 1309A Monitor. This compatibility is augmented by other benefits such as ease of tape reel loading, system alignment without elaborate equipment or special skills; rapid location of data by a precision tape footage counter; maintenance-free transport except for periodic cleaning of magnetic heads and tape guides; availability of optional tape speeds; and purchase of only those circuit plug-ins needed for the desired operating mode. A complete list of accessories is available for the tape systems, including the 3907-11A Remote Control Unit shown, and the 3907-04B, 3914-04B Loop Adapters for repetitive playback of up to 125′ lengths of magnetic tape.

Medical applications:

The 3900 Series magnetic tape systems are valuable tools for research, training, and diagnostic studies. Catheterization laboratories and operating room installations typically include one or more tape recorders in data acquisition systems. Complete procedures can be recorded on an unattended 3900 tape system which provides 8 hours of recording time at 1⅞ ips tape speed. Tapes can be played back up to 32 times faster than when recorded to facilitate viewing or analysis of slowly changing variables.



3900 Series Magnetic Tape System in vertical mobile cabinet



3907-11A Remote Control Unit

NUCLEAR INSTRUMENTATION

Hewlett-Packard offers research grade instruments for measurement of nuclear radiations. Important characteristics of nuclear radiations are their energy, angular distribution, and time relationships. Electronic pulse techniques are used for assessing and recording these characteristics.

Pulse spectrometers start with a radiation detector capable of producing an electrical pulse with amplitude related to the energy of the incident radiation. These detector signals are further amplified and are shaped suitably for analysis. Finally, the shaped pulses are sorted according to size or to time of arrival and are counted. A spectrum showing numbers of pulses versus energy constitutes the output information. Hewlett-Packard Nuclear offers instruments capable of serving in each one of these areas: detectors, amplifiers, scaler-timers, multichannel analyzers, automatic sample changers, and recorders.

The area of greatest interest for Hewlett-Packard's instruments lies with research physicists and chemists, with teachers, and with specialists in nuclear medicine. The Hewlett-Packard packaging format utilizing modular design and a unique systems approach brings real benefits for customers who need complex systems adaptable to a variety of measurements.

Hewlett-Packard scintillation detectors find application for measuring gamma or X-radiation from solids or liquids. The appropriate model can be selected for sample size and for either planchet or test tube counting. The NaI(Tl) crystal and a preamp-amplifier are housed in a sturdy case. Or, where a separate preamplifier is needed, Hewlett-Packard offers a versatile unit capable of serving with a variety of detectors including semiconductor, gas proportional, Geiger, and scintillation.

Hewlett-Packard scalers accept pulses from a wide variety of nuclear detectors to accumulate, display and record nuclear events.

The Hewlett-Packard Multichannel Analyzers are the fastest, most accurate, more versatile systems available for spectrum analysis.

In the AEC-NBS standard configuration, Hewlett-Packard offers the NIM Series of nuclear instrument modules: a power supply and combining case, a linear amplifier, a single channel analyzer, a scaler-timer, and timing units. Soon these will be joined by other modules presently under development.

Nuclear counting systems built around Hewlett-Packard automatic sample changers or manual changers offer capability to count α, β, and γ. Backgrounds for counting are the lowest available, up to 120 planchets can be counted in one loading, and the printed record includes complete information: count, time, and sample number.

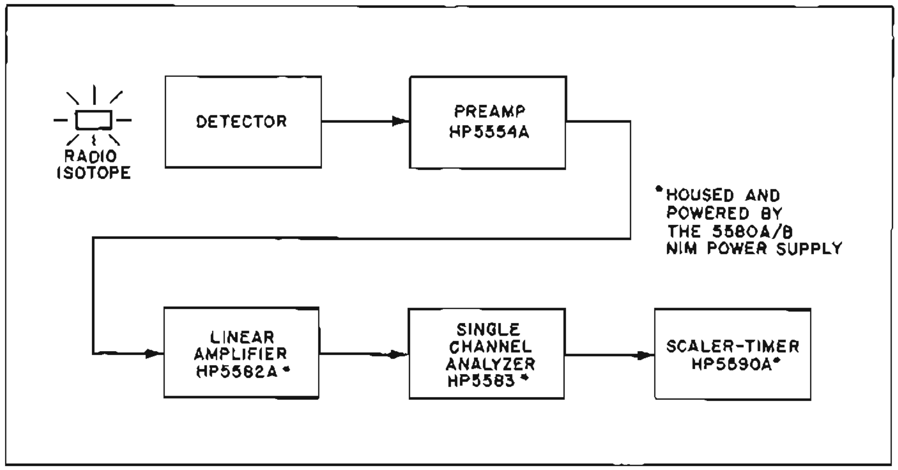


Figure 1. Nuclear system block diagram.

Systems capability

Hewlett-Packard offers a unique systems capability among nuclear instrumentation manufacturers: witness to this is the catalog you are now reading, filled with data acquisition and recording instruments and systems of every type. This in-house capability brings the customer an important benefit. His instrumentation interface problems are for the most part eliminated entirely, and those that remain can be completely solved on an engineer-to-engineer basis within Hewlett-Packard where technical details can be exchanged in full.

Spectrometer systems—single channel analyzer

The basic nuclear instrumentation system Hewlett-Packard offers for counting nuclear events with use of a single channel analyzer is shown in Figure 1. It is a complete system for detecting, counting, and displaying gamma radiation. All systems for counting nuclear events contain these basic instruments, although they may be packaged differently. The Hewlett-Packard packaging format, utilizing modular cabinets, provides for the widest possible range of applications. Instruments are grouped so that they may be used to count almost any type of nuclear event if the proper detector is used.

With the HP 5583A Single Channel Analyzer or the 5201L Scaler-Timer operated in pulse height analysis mode, that is in the "narrow window—ΔE mode," the system may be used for counting all pulses with heights falling within a window having a width calibrated between 0 and 0.5 volt. With this narrow window, the user is able to easily analyze the photo peaks of radiation samples.

NIM Series

Hewlett-Packard now has in production six instruments in the AEC-NBS standard configuration: the 5580A/B NIM Power Supply (a combining case and supply), the 5582A Linear Amplifier, the 5583A Single Channel Analyzer, the 5584A Dual Timing Pickoff, the 5585A Fast Coincidence, and the 5590A Scaler-Timer.

The AEC-NBS standard configuration is a concept aimed at reducing the experimenter's interface difficulties. A typical physics experiment requires a rather large array of equipment; interface problems often result. An AEC-NBS committee took these problems in hand and has formulated a set of standards (TID-20893) for compatibility in size and voltage requirements among instruments.

The 5580A/B NIM Power Supply promotes trouble-free operation of the modular instruments it houses and powers by providing hefty power capability, blower cooling, and protection circuits. In addition to ±24 V and ±12 V, the 5580A/B also supplies ±6 V. Many modular instruments utilize integrated circuits, and many of these require ±6 V. An efficient blower forces air through each module and also through the supply itself.

The 5582A Linear Amplifier provides maximum flexibility for nuclear pulse counting with all types of detectors and with a wide range of counting rates. RC shaping time constants, selectable by front panel switches, allow the experimenter to choose the optimum pulse shape for the detector and preamplifier he is using. In addition to RC shaping, there are two plug-in delay lines for shaping. The 5582A provides single or double differentiation and also integration, and gain is variable from 2 to 1280.

The 5583A Single Channel Analyzer has two basic modes of operation: single channel for pulse height analysis and dual integral where the discriminators operate as completely independent integral discriminators. The 5583A offers 200 nanosecond multiple pulse resolution, and strobed and/or gated operation.

With the aid of the 5584A Dual Timing Pickoff and the 5585A Fast Coincidence, the experimenter can make precise time as well as pulse height information the basis for his nuclear studies. The 5584A offers leading edge or zero crossing detection in each one of two independent channels. The 5585A accepts up to four channels of information and has meaningful resolving times down to one nanosecond.

A key unit in nuclear counting systems is the scaler-timer that totalizes the pulse count. The 5590A Scaler-Timer has a highly readable display of lighted digits and combines scaling and timing for the same measurement. Both count and time can be preset, and pulse resolution is 100 ns. Automatic or manual operation and printer output are included.

Automatic nuclear counting systems

Built around the 5560A Automatic Sample Changer, the Hewlett-Packard Nuclear Counting Systems bring ultra-low backgrounds (down to 0.1 count per minute) to meet the needs of α, β counting of low activity samples. More reliable and far faster counting of multiple samples is possible with these systems. The 5560A has a 120 sample capacity, with a manual drawer for interrupting the automatic mode at any time. This changer is ideal for use in health physics, on-site reactor environmental monitoring, bio-scientific studies and chemical investigations.

The 5560A's modular design lets the user virtually design his own counting system. He can use scintillation detectors for γ counting, or even for β,γ or γ,γ coincidence work. Modular design lets the user build up his system unit by unit, starting with a manual changer for example, yet looking toward a future system that is automatic and computer-compatible.

Applications in nuclear medicine

Hewlett-Packard offers the means to acquire and analyze a mass of measurement data—and to give the nuclear medical specialist results in a form that is directly useful.

To nuclear medicine, Hewlett-Packard brings more than 25 years of electronics experience. With a Hewlett-Packard system made up of components that are field proven and reliable, and put together by a team of experts, the nuclear specialist need not worry about such matters as time constants, frequency response, linearity, impedance matching, systems and line noise, cabling and grounding, overload recovery, count rate shift—all problems that Hewlett-Packard's nuclear instrumentation engineers can solve for him.

Multichannel analyzers

The Hewlett-Packard Multichannel Analyzers rapidly record complete energy spectra by simultaneously registering data into up to 4096 or even more memory channels. The resulting spectrum, in the form of a histogram plot with the number of events as a function of energy (pulse height, voltage, time), can be displayed "live" during accumulation, or after.

Multichannel analyzers, first developed for nuclear physics research and today widely used also for analyzing mixtures of radionuclides, have a host of potential applications in many other areas.

The Hewlett-Packard analyzers, described on the next six pages, are extremely versatile instruments. The 5401A offers three modes of operation: pulse height analysis, sampled voltage analysis, and multichannel scaling.

In Pulse Height Analysis mode, the MCA accumulates a pulse height distribution. In Sampled Voltage Analysis mode, the 5401A continually monitors an input waveform, samples it on command, and processes waveform amplitude at that instant as though it were a pulse. Result is a plot of the probability density function of the signal. In Multichannel Scaling mode, the 5401A sequentially addresses each channel and it may be incremented by an input pulse string: thus, each one serves as a scaler. This is useful for Mossbauer applications and time-rate studies.

Analyzer features

Figures 2 and 3 are oscillograms. Figure 2 shows a spectrum of selenium-75 taken with a lithium-drifted silicon detector. Figure 3 shows the probability density function for a sine wave. The 5401A's CRT is far superior to any offered as standard equipment on a multichannel analyzer. The HP H51-180AR Oscilloscope is the mainframe for the 5431A Display plug-in; all that is needed to have a 50 MHz dual channel oscilloscope is a set of two plug-ins: the HP 1801A Vertical Amplifier and the HP 1820A Time Base.

Modular design and use of plug-ins make the 5401A easy to modify and to expand. A log display unit, an 8-input router, and a multi-input multiscale unit are among the special-purpose modular units and plug-ins now offered for Hewlett-Packard Analyzers. With modular systems, the user has the assurance that tomorrow's capabilities can be added at minimum cost.

Input-output flexibility is assured by provision of an interface card cage which accepts cards to interface the 5410A to peripherals such as a teletype or digital recorder or even to a Hewlett-Packard computer.

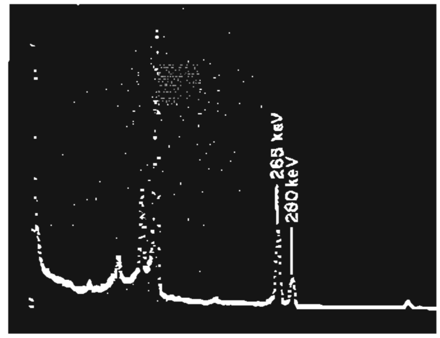


Figure 2. Spectrum of selenium-75.

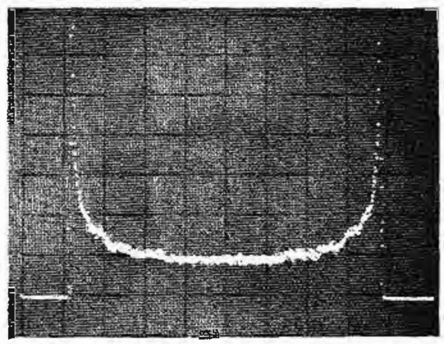


Figure 3. Probability density function for a sine wave.

Single and multi-parameter analyzers

The Hewlett-Packard single and multi-parameter analyzers combine the features of the analog-to-digital converter and display unit in the 5401A with the flexibility of a software-controlled memory.

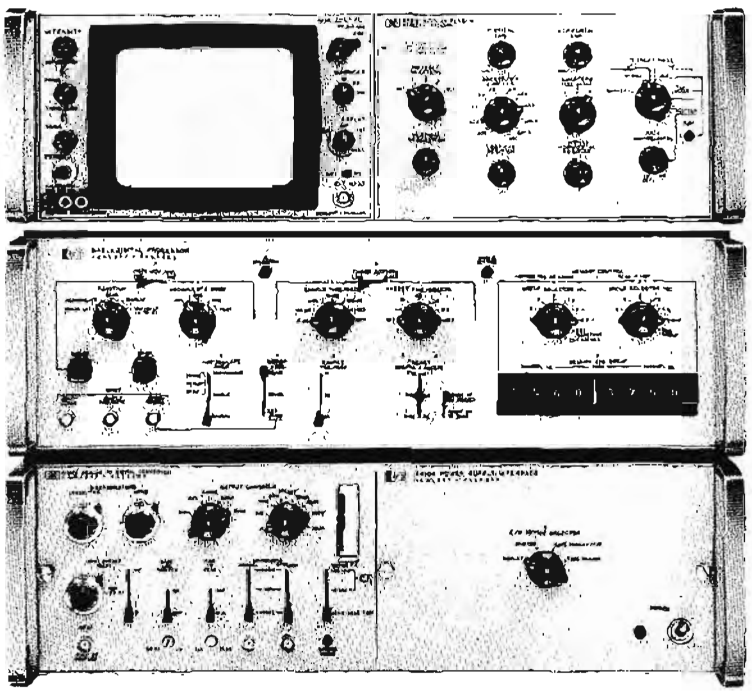
These systems add the capabilities of an instrumentation computer—monitoring and control of the experiment, calculation and manipulation of data—to those of the advanced hardware built into the 5401A ADC and display. These capabilities, plus the special software provided, bring the user analytical systems of great power.

The single parameter analyzer uses one display, one ADC, the HP 2115 Computer with a 4k memory, and a teletypewriter as its minimum configuration. Multi-parameter systems may utilize from two to four ADC's.

The dual-parameter analyzer's software package includes sub-routines for three display modes: isometric (with virtually 360° rotation to any of 20 viewing positions), contour displays, and an X and Y slice of the data, intensified.

Special software programs give these systems the ease of operation of an instrument by providing direction to the computer so that it is a silent partner. Yet, when the user so desires, he has at his command a system with all the flexibility afforded by FORTRAN programming capability.

MULTICHANNEL ANALYZER
200 MHz clock rate ADC; expandable memory
Model 5401A



H51-180A Oscilloscope with 5431B Display Plug-in

5422A Digital Processor

5416A Analog to Digital Converter in 5410A Power Supply/Interface

5401A Multichannel Analyzer

Advantages:

1024 Channels, optionally 4096 or 8192
0.05% Integral; 1% Differential linearity, worst case
100 ns multiple pulse resolution (MCS mode)

The Hewlett-Packard 5401A Multichannel Analyzer is a fast, accurate, versatile tool for spectrum analysis work. It has a pulse height analyzer (PHA) mode of operation, a sampled voltage analysis (SVA) mode of operation (for probability function analysis) and a multichannel scaling (MCS) mode of operation. It consists of a power supply/interface mainframe with plug-in analog to digital converter (ADC), a digital processor, and an oscilloscope mainframe with display plug-in. This modular separation, with the functional grouping of controls, and the annunciator function-keying system makes the front panel self explanatory.

The combination of 12-bit resolution, 0.05% integral linearity and high digitizing speed is unmatched in the industry. Low repetition rate analyses may easily be monitored by a unique display mode which combines the advantages of live and static readout.

The HP 5401A Multichannel Analyzer adapts easily and economically to input/output devices through selection of plug-in cards in the interface "card cage". Cards for a wide variety of I/O devices are available either with the initial order or at any time after receipt of this instrument.

Specifications

ACCUMULATION MODES

Pulse height analysis (PHA)

In this mode, the analyzer accumulates a pulse height distribution. Automatic termination of data accumulation may be employed. Coarse pulse amplitude discrimination is provided. Coincidence with an externally applied signal may also be a criterion for acceptance of a pulse.

Input pulse requirements:
- **Amplitude:** 10 V; positive.
- **Pulse shape:** >100 ns to peak above the baseline.
- **Input Impedance:** 1 kΩ, <60 pF shunt; dc coupled.
- **Trigger Level:** 0 to 10 V, adjustable (establishes timing).
- **Time to peak:** 1 to 15 μs adjustable, or 3 μs fixed.

ADC clock rate: 200 MHz.

Output Range: 512, 1024, 2048, or 4096 channels.

Conversion gain (channels out/volt in):
- **Range:** 4096 to 512 channels/10 volts.
- **Temperature stability:** <±0.005%/°C.
- **Time drift:** <±0.01%/24 hours.
- **Trigger distortion:** linearity perturbed within 50 mV of trigger.

Baseline (input offset)
- **Analog:** ±1 V adjustable, 0 or −5 V fixed.
  - **Count rate shift:** <10 mV to 90% dead time.
  - **Temperature stability:** <±1.0 mV/°C.
  - **Time drift:** <±1 mV/24 hours at fixed temperature.
- **Digital:** 0 to 3584 in steps of 512 channels.

Linearity
- **Integral:** <±0.05% over full range.
- **Differential:** <1±% over full range.

Except, in PHA mode offset <100 mV, see Trigger Distortion.

Pulse analysis time

Output range setting determines analysis time in either fixed or or variable (internally selected) mode:

512 channels =	9.5 μs fixed or	(2.8 + 0.005n) μs
1024	9.5	(3.1 + 0.005n)
2048	16.5	(3.8 + 0.005n)
4096	30.5	(6.0 + 0.005n)

where n = number of channel addressed

System dead time: analysis time plus time to peak.

System noise: less than 1 mV rms referred to the ADC input.

Coincidence inputs (normal and strobed)

Amplitude: 4-12 V positive.

Pulse shape: dc level or with specified timing. For Timing-Normal, input must be high for >100 ns after pulse crosses trigger level and prior to the coincidence strobe. For Timing-strobed, input must be high for a >300 ns interval which includes the coincidence strobe. Coincidence strobe is a 200 ns pulse, generated at the end of the time-to-peak setting. Strobe monitor jack provided.

Timing jitter-strobe: ±50 ns from average.

Discriminators (upper and lower level) range: 0 to +10 V. Lower level discriminator sets trigger level.

Meter: three ranges, each with ±5% accuracy, displays reading of dead time 100% full scale, or counting rate at either 100 kHz or 10 kHz full scale.

Live timer accuracy: ±0.5%.

Data control: add or subtract, switched.

Timing: count up to Preset, or down to Zero.

Preset time range: Live or Clock time, switch selectable; 0.01 min to 5000 min (decade steps x multiplier in 1, 2, 5, steps).

Memory grouping: any quarter, any half or whole memory. Pulses exceeding selected memory range are rejected. No pulses are stored in 1st channel of group selected.

External routing: external control of memory grouping.

Pulse requirements: positive 4-12 V for >100 ns.

Memory: 10^6 counts per channel; 1024 channels standard, 4096 or 8192 optional. Address is binary; 24-bit data word is BCD coded.

Multichannel scaling (MCS)

In this mode, the analyzer sequentially addresses each channel of the selected portion of memory and the contents of each address may be incremented by an input pulse string. There is provision for vertical display. The address information is converted to an analog voltage available for such applications as driving a Mössbauer apparatus.

Input pulse requirements: (AEC standard compatible).

Amplitude: 4-12 positive.

Input impedance: 1 kΩ (dc coupled).

Minimum pulse width: 25 ns; separation 65 ns.

Pulse pair resolution: 100 ns (10 MHz).

Sample time per channel: 10 μs to 5 s (decade steps x multiplier in 1, 2, 5, steps), or ext.

Preset sweeping: 1 sweep to 500,000 sweeps (decade steps x multiplied in 1, 2, 5, steps).

Sweep modes

Single: internal or external triggering.

Continuous: internal or external triggering with saw-tooth sweep drive; increasing channel number. Also, internal triggering with triangle waveform drive; increasing then decreasing channel number. (Output is available to drive Mössbauer apparatus for three sweep modes.)

Dead time between channels: 2.2 μs.

Sampled voltage analysis (SVA)

(Probability density functions.) Operation in this mode is identical to pulse height analysis except that the ADC continuously monitors a slowly changing voltage, samples it upon receipt of a pulse, and processes the sampled voltage as though it were a pulse.

Input signal requirements

Amplitude: 10 V.

Polarity: positive or bipolar.

Bandwidth: 512 Channel Range, dc to 120 kHz; 4096 Channel Range, dc to 15 kHz.

Input impedance: 1kΩ, <60 pF shunt, dc coupled.

ADC clock rate: 200 MHz.

System dead time: Analysis Time plus Time to Peak.

Elapsed time or sweeps: first channel of selected memory group records elapsed time in increments of 0.01 min (PHA & SVA) or of number of sweeps (MCS & TEST).

Digital processor operations

Transfer memory quarters: the contents of a quarter or half may be copied into any other quarter or half respectively. Receiving group contents are erased prior to copying.

Erase: the entire memory, or the contents of any selected quarter or half may be erased.

Accumulate cycle: accumulation of data may be manually controlled or may be automatically sequenced through a cycle of erase, accumulate for preset time or sweeps, and read-out into the device selected on the 5420A Interface panel. Single cycle selects one such sequence; Auto cycle selects indefinitely repeated sequences.

Read-in/Read-out Modes

CRT display (linear) modes

During PHA and SVA accumulation, each channel addressed by the ADC is displayed live for about 12 μs. Prior to Start, address is displayed at baseline. After Start, the vertical displacement of the displayed point shows channel content (see Gain below). During MCS & TEST modes the CRT is statically unblanked. During Display function the entire memory is displayed in an interlaced sequence which sweeps from first to last channel at line frequency (to eliminate flicker), and any channel is displayed at least six times per second. Accumulation during display. Read function allows selection of any contiguous sequence of channels by setting of digital switches.

200 MHz clock rate ADC; expandable memory
Model 5401A

Channel identification

Decades: intense dot for channels numbered 10n.

Sub group: ½ cm tail on data point.

Horizontal gain: x1 to x20 continuous. Expand about center screen.

Horizontal quarters full screen: 1, 2, 4 selectable.

Quarter overlap: halves or quarters may be overlapped. 2nd, 3rd, 4th quarters and 2nd half are movable vertically to fully off screen up or down.

Vertical gain: x1 through x3 continuous.

Vertical calibration: 200, 500 1k through 200k counts/cm in 1, 2, 5 sequence, selectable. In Log position (with K-20 special) 1 decade/cm. Analog output (plotter connector and BNC's for X, Y and Unblank).

Amplitude: +5 V full scale into open circuit.

Impedance: 100Ω.

Resolution: ±0.0125% of full scale.

Integral linearity: ±0.0125% of full scale.

Zero drift: ±0.01%/°C, ±0.1%/day at fixed temp.

Gain drift: ±0.05%/°C, ±0.1%/day at fixed temp, full scale.

Output rate: external timing, 600 channels per sec, max; internal, 1-20 channels per second, variable.

Digital input/output

Code: parallel, 8421 BCD.

Serial: IBM compatible or ASCII as selected by I/O cards. Levels, polarity and control logic are determined by I/O cards provided with the various I/O options.

Maximum transfer rate: 60,000 characters or channels/sec.

Format:

Parallel: 10 digits simultaneously, four address, six data.

Serial: 76 character line sequence (one address, 10 data channels) is determined by serializer cards of processor and adapted by I/O cards to match requirements of specific device.

Input/output options

Peripheral devices for readin or readout of digital data are specified by option number according to column headings A, B and C in the table below. Under column A are listed options which provide the peripheral device for service on 115 V 60 Hz plus cards and cables required for interface with the card-cage of the HP 5410A. Column B lists devices operated from 230 V 50 Hz mains. Column C lists options which provide cards and cables only. The peripheral device is not supplied. A number in parentheses indicates the time in minutes for transfer of 1024 channels of memory. Note that typewriter readout of all 8192 channels of the largest available memory would require nearly 2 hours. Computer transfer takes less than 1 sec.

Processor options

Option 20: Substitute 4096-channel memory.

Option 21: Substitute 8192-channel memory.

NOTE: The 1024, 4096 and 8192 channel memories are optionally interchangeable at any time.

Name	Capability	A 60 Hz device cards & cable	B 50 Hz device cards & cable	C Cards & cable only
		Option	Option	Option
Printer HP 5050	Parallel readout 20 chan/s (0.87)	02	52	12
Teleprinter HP 2752A	Serial readout 10 char/s (13)	03	53	11
Teleprinter HP 2752A	Serial input 10 char/s (13)	04	54	11
Tape Punch HP 2753A	Paper tape output 120 char/s (1.1)	05	55	13
Tape Reader HP 2737A	Paper tape input 300 char/s (0.4)	06	56	14
Mag Tape Kennedy 1400, etc.	Mag tape readout 200 to 800 bpi (0.3 to 1)	07	57	available
Computer HP 2114/5/6	DM interface between memories	Consult factory		08
Teleprinter HP 2752A	Serial input & output 10 char/s	10	50	11

Option 11 cards and cable provide interface for both readout and readin.

Equipment list

The standard HP 5401A Multichannel Analyzer consists of one each of the following. Total net weight is 111 lb (50 kg). Shipping weight is 148 lb (67 kg).

5410A Power Supply/Interface 45 lb (20 kg).
5416A Analog to Digital Converter (plug-in) 6 lb (2,8 kg).
5422A Digital Processor 27 lb (12 kg).
5431B Display (D to A converter plug-in) 6 lb (2,8 kg).
H51-180AR Oscilloscope 26 lb (11,5 kg).
05421-6030 Display cable (dual 36-pin).
05421-6033 Power cable (50-pin).
05421-6034 Data cable (50-pin).
05421-6035 ADC Decimal Data cable (dual 50-pin).

Rack mounting kits, power cords, extender cards and card puller are provided.

Dimensions: typical for H51-180AR, 5422A and 5410A, 16¾" wide x 5¼" high x 21⅜" deep (425 x 133 x 543 mm).

Power input for full capacity operation: 425 W, 50-60 Hz 115 or 230 V.

Price: available on request.

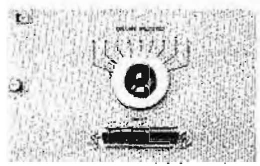
Accessories

A convenient method of preserving the visual display available on the scope is to plot the analog of memory contents on an x-y recorder. The HP 7004A provides an ideal combination of accuracy and speed and may be interfaced directly with the 5431A Display plug-in through a connector on the rear of the H51-180AR mainframe. It plots an analog record of any selected portion of the memory at the rate of 50 channels per second. Required are: HP 7004A, $1295; two 17170A DC Coupler plug-ins, $50 each; 17173A Null Detector plug-in, $200; 17012B Plotter, $95; and 10640B Cable, $50. An extended plot for good resolution of individual channels on continuous or fan-fold paper may be obtained using the HP 17005A Incremental Chart Advance, $895.

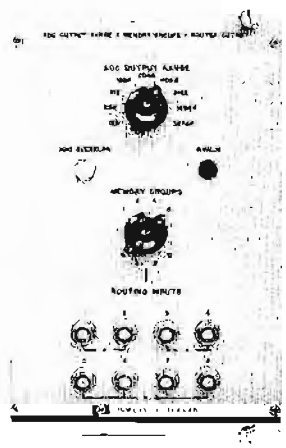
Insertion of the HP 1801A Dual Channel Amplifier, $650, and the HP 1820A Time Base, $475, in place of the 5431B Display plug-in converts the H51-180AR to a laboratory quality oscilloscope with 50 MHz bandwidth and triggering to 100 MHz for fast timing setup and checkout. A wide variety of plug-in modules is available in the HP 1800 series.

The three mainframes of the 5401A may be conveniently joined to make a single unit with the use of the Joining Bracket kit, HP 5060-0243, $30.

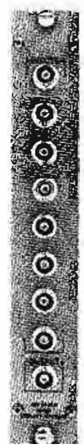
Multi-Input Multi-Scale
K05-5400A



BCD to Binary
K20-5400A



8-Input Router
K09-5400A



8-Input Mixer
K15-5400A

K05-5400A, multi-input, multi-scaling

Replaces the ADC to permit multiscaling of up to 8 independent inputs at common sample time into 1, 2, 4, or 8 equal segments of memory. Memory cycle time prevents acceptance of pulses within 3 μs following a pulse. Pulses coincident within about 150 μs are both lost. The address at which a pulse is incremented is determined as follows: The most significant 0, 1, 2, or 3 bits are determined by selection of 1, 2, 4, or 8 memory segments (Groups switch). The balance of the address (up to 15 bits) consists of the contents of the address scaler. The address scaler range is selected by the Channels/Group switch. The address scaler is incremented by the timing controls of the digital processor (5422A, 2116B, etc.) or by external input to the K05-5400A. A sweep may be initiated and stopped either manually, or by signal to the internal connector (rear) or to the front panel BNC. Continuous or single sweep mode is selectable by switch. Input requirements are $>+4$ V, >100 ns wide. Price, $1500.

K09-5400A, eight-input routing

This four-width NIM module provides the capability for accumulation of up to eight separate pulse height spectra simultaneously into 1, 2, 4, or 8 equal segments of memory. The K09-5400A is connected between the ADC and the processor (memory) so as to add 0, 1, 2, or 3 most-significant bits to the address output of the ADC according to the selection of 1, 2, 4, or 8 memory groups. (Within any given memory eighth, for example, each address has the same, unique combination of the first 3 most significant bits). The information necessary for this routing is supplied by logic inputs to the front panel BNC which corresponds to a given memory segment. A logic pulse must be generated for each analog pulse to be analyzed and must arrive at the K09-5400A input during Time-to-Peak of the ADC. The arrival of more than one logic pulse during this interval will cancel the analysis of the analog pulse. The eight (or fewer) analog pulse sources are connected to a summing network such as the K15-5400A (see below) so as to provide a single input to the ADC. The router output is an address of up to 15 bits. Combinations of ADC Output Range and Memory Group settings which would produce a router output of more than 15 bits are ambiguous and will actuate the Invalid light. Price, $1000.

K15-5400A eight-input mixer

This single-width NIM module provides passive summation of up to 8 inputs through 1 kΩ each to a common 50Ω output. It is conveniently used for combining the preamplified outputs of up to 8 nuclear detectors for input to an ADC. The NIM configuration is for convenience of mounting and connection; no power is required. Price, $150.

K10-5400A log display converter

This 3½″ high rack-width module (not illustrated) is provided with integrally attached cables to permit its insertion in place of the standard 05421-6030 Display Cable to provide the capability for logarithmic display of the HP 5422A Digital Processor memory. When the Counts/Div switch of the HP 5431B Display is set to Log position, the CRT display will be linear in address (X-axis) and logarithmic in counts (Y-axis). When the Vertical Gain control is calibrated, the vertical calibration is one decade per cm. The cable arrangement permits the module to be located either above the H51-180AR mainframe or behind the analyzer. Price, $600.

K20-5400A BCD input

When the ADC is replaced by this plug-in module, a device which provides +8421 BCD coded output (e.g. electronic counter) in up to 9 digits may be connected to the HP 5401A through the 50-pin connector mounted in the front panel. The selector switch allows any three decimal digits from the input to be converted to binary form and addressed in a manner similar to ADC operation. The resultant accumulation in PHA mode is a frequency histogram which displays the relative probability of occurrence of any selected reading between 0 and 999. Price, $750.

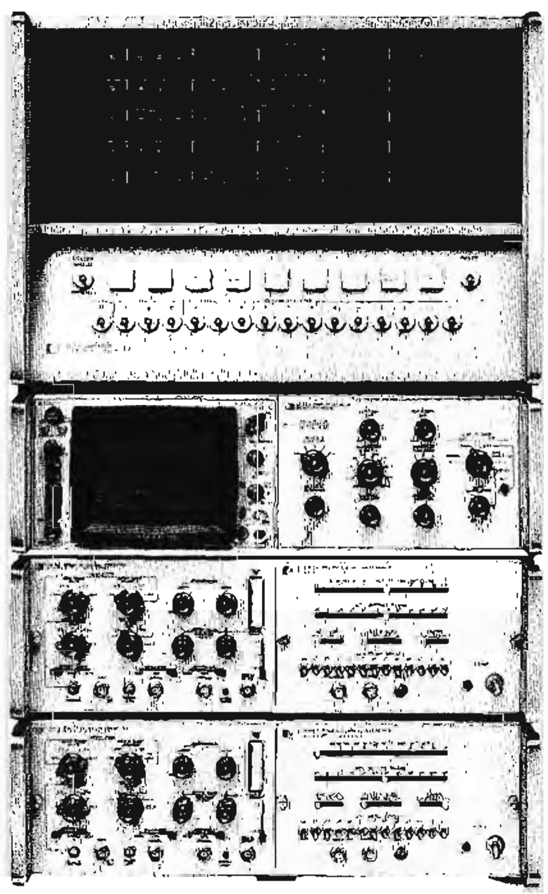
H06-5401A multichannel analyzer with signal averaging

This modification of the HP 5416A ADC and the HP 5422A Digital Processor (not illustrated) allows either one-shot digitizing of an analog input to the ADC or, with synchronized repetitive sweeping, signal averaging for enhancement of the signal-to-noise ratio. The ADC operates in the Sampled Voltage Analysis mode, sampling the input waveform so as to provide a gate time proportional to instantaneous input amplitude. The processor operates in the Multiscaling mode, accumulating at 10 MHz in a channel for the corresponding gate time. Price, add $400 to price of MCA.

ANALYZER SYSTEMS

Single parameter, multiparameter

Model 5405A (Single), Model 5406A (Multi)



5406A Multiparameter Analyzer

Advantages:

On-line computation

4096 words of data storage

Easy expandibility

Monitoring and control of experiments

Easy peripheral interfacing

General

The HP 5405A Single Parameter Analyzer system and the 5406A Multiparameter Analyzer system combine the features of the Analog-to-Digital Converter and Display Unit used in the HP 5401A Multichannel Analyzer (see page 70) with the flexibility of a software controlled memory. The 5406A system may also be used in a multiplex mode with up to 16 ADC's multiplexed into a single computer memory. The advanced hardware design of Hewlett-Packard's displays and ADC's coupled with the special software provided with these systems gives the user the most advanced and flexible analyzing/computing systems available.

Single parameter analysis

The 5405A Single Parameter Analyzer uses a single display, a single ADC, a 2115A with an 4K memory, and a teletypewriter as its *minimum configuration.* The capabilities of the 5405A system are quite similar to those of the 5401A system, but with the additional flexibility of the computer monitoring and control of the experiments plus the calculation and manipulative power available from an instrumentation computer. It can be operated in a pulse-height analysis mode for nuclear pulse-height spectrometry and in a sampled voltage analysis mode for statistical analysis of amplitude data.

Multiparameter analysis

The HP 5406A Multiparameter Analyzer system is identical in hardware configuration to the 5405A system except that it may be configured with two to four analog-to-digital converters. When using two ADC's (standard 5406A configuration) the user may accumulate data that has a coincidence requirement in addition to the normal pulse-height versus count rate data. The X dimension range is 1 to 4096 channels and the Y dimension range is 1 to 4096 channels, in increments of powers of 2.

Internal coincidence capability is in the microsecond range. With this system, coincidence circuits must be added externally to supply the coincidence input to the ADC's for resolution in the nanosecond range. External coincidence equipment such as the HP 5584A and the HP 5585A (shown on page 78) may be used for higher resolution.

Sub-routines are included in the software package to allow the user to have 3 display modes for the dual parameter data collected in the 5406A system. These are isometric with a rotational capability for 20 different viewing positions (displayed data can essentially be rotated 360° around its central axis), contour displays, and an X and Y slice of the data. Figure 1 illustrates the isometric display of a two parameter experiment.

Optionally available with the 5406A system is up to a total of 16 ADC's with a multiplex control so that the ADC's (1 through 16) may be scanned at a >0.2 MHz rate for inputting data into the computer memory.

Software

A special software program has been written to permit the user to have the ease of operation of an instrument rather than a computer. Special software package consists of an EXECUTIVE program and a PREPARE EXECUTIVE TAPE program (PET). The PET program is for configuring the EXEC program into a users' package. Also supplied in the software package are a standard Hewlett-Packard sub-routine library for such operations as Accumulate, Display, Erase, Punch, Type, Transfer, Read-in, and such computing routines as Integration, Differentiation, Background Subtraction, Spectrum Stripping, etc. Control sub-routines can also be written to control external devices through the use of an output card such as the relay register or a general purpose register. When configuring a package by the use of the PET program, the user calls up from the sub-routine library, via the teletype by a question and answer routine, those sub-routines he desires to use. It is also possible for the customer to develop his own

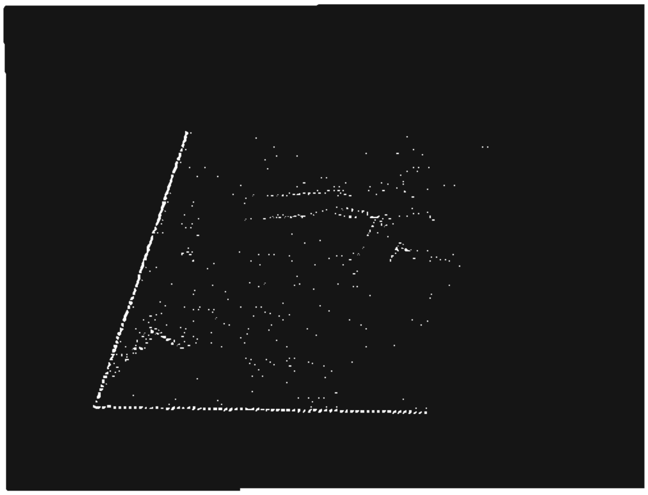


Figure 1. Isometric Display

sub-routine library in FORTRAN or modify existing sub-routines in ASSEMBLY.

Furnished with each 5405A and 5406A system will be all of the standard HP 2115A computer software. The user will be able to make general purpose measurements immediately by using the PET and EXEC program with the Hewlett-Packard sub-routine library, and can easily modify the package to suit his specific needs. The computer, with its standard software, will also allow the user the convenience and flexibility of a stand-alone instrumentation computer.

Output peripherals

By the use of the HP 2115A instrumentation computer in this system, the addition of output or input peripherals (such as the high speed digital tape transports, paper tape punches, photo-readers, etc.) is quite easy. All of these peripherals have been interfaced to the HP 2115A computer and are optionally available. Their interfacing requires only the I/O cards and the software driver routine for outputting or inputting data via these peripherals.

Additional peripheral instrumentation

For expanding the capability of either the single parameter, multiparameter, or multiplexed system, additional instrumentation may be added to the system, such as, the K05-5400A Multi-Input/Multi-Scale plug-in and the K09 8-input router (see page 83).

For additional information concerning optional configurations of these systems, or for additional applications information, please contact the factory.

Specifications

Interface

Outputs: 0-12 bit, buffer storage, impedance; "1" = saturated npn to ground, "0" = 1K to +10 V or open circuit.

Flags:

DAR = Data Ready to Computer: "1" implies Data Available, "0" implies Data Undefined.

RFD = Ready for Data from Computer: "1" implies ready to accept new data, "0" implies not ready to accept new data.

Impedance: Data Ready: same as outputs. Ready for Data: "1" same as ouputs, "0" >4 V or open circuit.

Timing: delay between availability of data and Data Ready signal >0.5 μs or >10 μs, selectable on ADC interface board.

Minimum delay from RFD to DAR: same as above.

Minimum acceptable RFD width: RFD = "0" >500 ns; RFD = "1" until DAR.

Modes: single parameter, multiparameter, multiplex.

Hardware configurations

Single parameter (SGL): single ADC; control and timing board; buffer and offset board; live time clock board panel with offset, live/clock; mode and bit programming control.

Multiparameter (MPR): 2 to 4 ADC's; control and timing boards; buffer and offset boards; live time clock multiparameter control; jumpers; and panel as in single parameter.

Multiplex (MPX): 2 to 16 ADC's; multiplex control; interface boards the same as in multiparameter.

Timer control: LIVE/CLOCK/OFF: counts stored in Channel 0, 10 per second. In LIVE mode, clock gated off by busy signal. MPX: each ADC gates clock. MPR: clock gated off when any ADC busy.

Zero offset: each ADC may be independently offset 0-4095 channels.

Bit programming: output bits from each ADC may be shifted with respect to 12 bits to computer.

ADC holdoff (output, MPR): for input to NORMAL coincidence input on ADC. Saturated transistor to ground.

Sample input: for external sampling of ADC. +4 V to +12 V, width >200 ns, >1 kΩ, <60 pF.

Delay (holdoff): 200 ns to >1 μs, variable.

Single mode: 1 ADC to 1 computer.

Multiparameter: 2-4 ADC's to 1 computer.

Single events: 1 ADC processes pulse, other ADC's output 0.

Coincidence events: all ADC's process pulses; outputs from ADC's merge into 12 bits controlled by bit programming.

Timing: at start of time to peak in the first ADC a delay timer starts. At the end of holdoff (variable from 0.2 μs to >1 μs) delay a holdoff signal is applied to the normal coincidence inputs on all ADC's. Any ADC which has not yet detected a pulse will be held off for the event being analyzed. The coincidence window is, therefore, equal to the holdoff delay.

Multiplex: 1-16 ADC's to 1 computer.

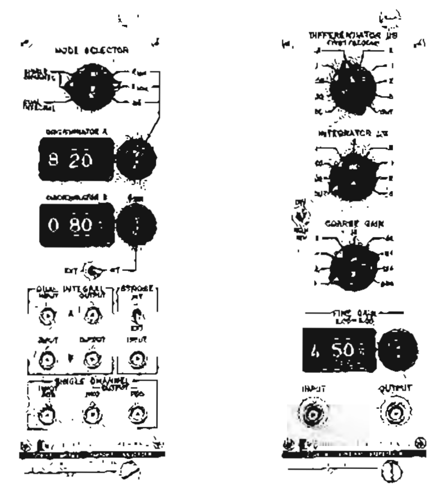
Priority: ADC's are scanned at >0.2 MHz rate until one is ready. It outputs to computer, and when RFD is received scanning resumes. Scan can resume either with next ADC or with first ADC, by programming a jumper.

Memory region: each ADC is assigned a 4 bit code (less for fewer ADC's). The code bits become the most significant bits of the output to the computer.

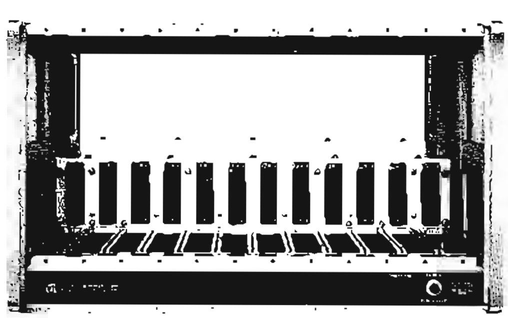
Control signals: from computer to ADC via interface. Each ADC may have the following functions controlled by a GPR card or equivalent: SVA/PHA mode; stabilizer on/off mode; sample input waveform—pulse; trigger stabilizer—pulse.

Ordering information, price: please consult the factory.

Nuclear Instrument Modules
AEC compatible series
Models 5582A, 5583A, 5580A/B



5583A 5582A



5580A/B

Advantages:

- *TID-20893 compatible*
- Easy to operate
- Versatile, research grade instruments

Model 5583A

The Hewlett-Packard Model 5583A Single Channel Analyzer is the most versatile instrument of its type ever offered. The 5583A has two basic modes of operation: single channel for pulse height analysis and dual integral where the discriminators operate as completely independent integral discriminators.

In the single channel mode, discriminator A may operate as ΔE (narrow window) to determine the window width up to 1.00 V wide. The window is tied to discriminator B (E_{min}) which determines the window's position relative to zero volts. Discriminator A may also operate as E_{max}; the two discriminators may then be varied independently over their range.

In the single channel mode there are outputs triggered from both the leading edge and trailing edge of the input signal. The trailing edge outputs, fast negative and slow positive, are generated for input signals with amplitudes within the window limits. For single channel analysis work, this instrument may be strobed, either internally or externally.

A gate input allows the application of a +3 V signal to inhibit the output of the single channel analyzer.

The discriminators have a highly readable and in-line display of voltage 0.05-10.05 V, set by 10-turn pots.

Model 5582A

The Hewlett-Packard Model 5582A Linear Amplifier is an original HP design which provides maximum flexibility for nuclear pulse counting with all types of detectors and with a wide range of counting rates.

Front panel switches give the user his choice of pulse shaping for optimum response: integration and single or double RC differentiation, or single or double delay line shaping. Eight RC time constants from 20 ns to 5 μs are provided.

The delay lines are plug-ins, making a change easy if different time constants are needed. Shaping times from 1 μs to 100 ns are available. The standard 5582A is supplied with 1 μs delay lines and these are temperature compensated for stability.

The fine gain control is variable from 2.00 to 5.00 by means of a 3-turn pot with horizontal in-line gain markings which eliminate ambiguity in reading.

Model 5580A/B

The Hewlett-Packard 5580A/B NIM Power Supply provides output voltages required by AEC-NBS standards (TID-20893), houses any combination of modular instruments (NIM) in a sturdy bin, and promotes trouble-free operation by oversized power capability, blower cooling, and special protection circuits.

Total power output capability is 120 watts and current ratings allow heavy drain without overload: ±24 V at 2A, ±12 V at 4A, and ±6 V at 5A. Direct wiring between each connector and the six supplies improves regulation. The 6 V supplies are particularly useful with integrated circuits.

The 5580A/B incorporates a number of features that protect the nuclear instrument modules to which it is supplying power. A warning light advises the operator when operation could be marginal and protection circuits act automatically to prevent costly damage due to shorts and overloads.

The 5580A and the 5580B are electrically identical. Both are rack mount or bench top convertible, all hardware included. The 5580A provides space for 11 single widths in the NIM configuration and is packaged to be compatible with the standard Hewlett-Packard modular enclosure system. The 5580B has space for 12 single widths and because of this has its side frames ½ in. wider than the standard HP enclosure.

Specifications

5582A Linear Amplifier

Input
Polarity: positive or negative.
Impedance: 1.5 kΩ, dc coupled.
Maximum voltage: 15 V peak, 15 V dc.

Gain
Range: 2 to 1280.
Resettability: one minor division (0.2% of full range at constant temperature).
Control: coarse, switch from 1 to 256 in binary steps. Fine, continuously variable from 2.00 to 5.00.

Pulse shaping
RC mode: integration, first and second differentiation: Time constants for each, 0.02, 0.05 and 0.1 to 5 μs in 1, 2, 5 sequence.
Delay line mode: single or double; 1 μs delay lines (plug-ins) are standard; others are available.

Amplifier
Rise time: <40 ns, typically 25 ns.
Bandpass: 2 kHz to 6 MHz, typical.
Stability: gain shift <0.05%/°C, typically 0.02%/°C.

Output
Amplitude: ±10 V except ±5 V at 0.02 and 0.05 μs differentiation time constants.
Impedance: <5Ω; minimum load 90Ω.
Polarity: positive and negative.
Delay: 65 ns, relative to input, typical.

Linearity: integral, <0.3%; differential, <1%, 0.3% below 8 volts (typical).

Noise: <15 μV RMS referred to input at maximum gain.

Crossover walk: < ±0.5 ns.

Count rate shift: <0.05% with inputs to 10^5 cps, typical.

Overload recovery: from a 200x overload to 2% of baseline in less than 3 non-overload pulse widths.

Gain control input: for external fine gain control; BNC.

Power required: +24 V, 260 mA; −24 V, 325 mA.

Preamp power out: +24 V (TNC connector).

Price: $550.

Option 01: 5582A without delay lines, $500. With special delay lines installed, add $75. Plug-in delay line kits (each has two delay lines), $75.

Time Constant, ns	Delay Line Kits	5582A with Special Delay Lines Installed
100	K01-5582A	H01-5582A
200	K02-5582A	H02-5582A
300	K03-5582A	H03-5582A
400	K04-5582A	H04-5582A
500	K05-5582A	H05-5582A
600	K06-5582A	H06-5582A
700	K07-5582A	H07-5582A
800	K08-5582A	H08-5582A
900	K09-5582A	H09-5582A

5583A Single Channel Analyzer

Modes of operation
Single channel—ΔE: pulses between E_{min} and E_{min} + ΔE.
Single channel—E_{max}: pulses between E_{min} and E_{max}.
Dual integral: pulses greater than E_{min}, two channels.

Multiple pulse resolution: 200 ns.

Input circuit: ac coupled, 1 ms time constant. Impedance is 500Ω, single channel; 1 kΩ, dual integral.

Input signal: 50 mV to 10 V. Unipolar positive or bipolar with positive portion leading (negative on special order). Discriminator sensitivity to a 30 ns wide pulse drops to 90% of nominal. Nominal is defined as NaI-shaped pulse with rise time constant 0.25 μs and decay time constant 1 μs.

Discriminator Ranges
E_{min} and E_{max}: adjustable from 0.05 V to 10.05 V.
ΔE: adjustable from 0.005 V to 1.005 V.

E_{min} bias input: allows external control of lower level discriminator, 5 V to scan complete range.

Integral linearity: ±0.25% of full scale.

Temperature stability: <0.01%/°C, E_{max} and E_{min}; <0.1%/°C, ΔE; change over 0-55°C with dc voltage tolerance per TID-20893.

Spurious output pulses ("leak through"): none for input pulses outside window (as measured with Co-57).

Strobe input: 0.6 V negative and 15 ns wide (min.), ac coupled.

Gate input: >+3 V inhibits single channel outputs (dc coupled).

Outputs: available in all three modes; dc coupled, conform to AEC preferred practice logic.

Output	Pulse		Triggered From
	Amplitude	Width	
Dual Integral A and B	+5 V into 100Ω	100 ns	Leading edge of input pulse.
Single Channel Positive	+6 V open circuit		Trailing edge of input pulse or from strobe input.
Negative	−0.8 V into 50Ω	20 ns (5 ns rise time)	

Power required: +24 V, 225 mA; −24 V, 190 mA; +12 V, 10 mA.

Price: 5583A, $550.

5580A/B NIM Power Supply

Outputs, dc: ±24 V at 0 to 2A; ±12 V at 0 to 4A; ±6 V at 0 to 5A. Maximum output power, 120 W.

Outputs, ac: 115 V at line frequency.

Regulation: line, less than 0.05% for a 10% change. Load, output impedance <0.040Ω dc; <0.3Ω at 100 kHz.

Temperature coefficient: 0.02%/°C.

Ambient operating temperature: 0 to 55°C.

Noise and ripple: peak to peak 3 mV.

Recovery time: returns to within 0.1% of specified output within 50 μs for a 1A load current change.

Input line voltage: 105 to 125 V or 210 to 250 V, 50 to 60 Hz.

Price: 5580A (11 modular widths), $775. 5580B (12 widths), $825.

Options: for applications not requiring the full set of output voltages.

Option	Power Supplies Included	5580A	5580B
01	±24 V, ±12 V	$725	$775
02	±6 V, ±24 V	$725	$775
03	±6 V, ±12 V	$725	$775
04	±6 V	$675	$725
05	±12 V	$675	$725
06	±24 V	$675	$725

Options 01-06 can later be expanded to full capability by the addition of plug-in regulator board(s): the circuit is tuned to produce ±24, ±12 or ±6 volts. Model 05580-6004, $75.

Common Specifications

Operating temperature: 0 to 55°C.

Connector block, power: AMP 202515-5.

Connectors, signal, inputs and outputs: BNC.

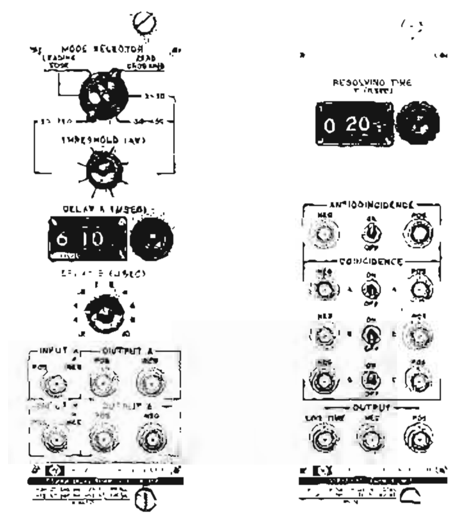
Dimensions: standard double-width module (5582A and 5583A) 2.703 in. wide by 8.709 in. high by 10.487 in. deep (68.6 x 221 x 266,0 mm).

NIM power supply 5580A/B: mechanical tolerances provide for use of the 5580A/B with standard AEC modular instrumentation (TID-20893). 5580A (holds 11 modular widths): 10-15/32 in. high by 16¾ in. wide by 19⅝ in. deep (266 x 425 x 472 mm). 5580B (holds 12 modular widths): 10-15/32 in. high by 17¼ in. wide by 19⅝ in. deep (266 x 438 x 472 mm).

Weight: double width module (5582A, 5583A) net 3.6 lbs (1.6 kg); shipping 5 lbs (2.3 kg). 5580A/B, net 35 lbs (15.9 kg); shipping 40 lbs (18.2 kg).

Cables, terminations, and accessories: HP 10519A 50-ohm 6 ft. long, BNC connectors, $7. HP 10517A cable 6 ft. long, TNC connectors, $8. NIM Power Supply Extender Cable 10521A for ease of servicing modules, $35. HP 10510A 50-ohm BNC termination, $5. HP 10100A 50-ohm feedthrough termination, $15. HP 10100B 100-ohm feedthrough termination, $18.

Nuclear Instrument Modules
AEC Compatible Series
Models 5584A, 5585A



5584A 5585A

Advantages:

TID-20893 compatible
Outstanding performance

Models 5584A, 5585A

The HP 5584A Dual Timing Pickoff determines the times of occurrence of pulses from up to two independent channels, each of which can receive pulses from an amplifier such as the HP 5554A Preamplifier or the HP 5582A Linear Amplifier and can detect either the leading edge or zero crossing. Output pulses follow by delays independently set and can be used to gate other instruments such as the HP 5585A Fast Coincidence and the HP Multichannel Analyzers. A special feature is an external delay sweep capability for Channel A.

The HP 5585A Fast Coincidence accepts input pulses from up to four channels from such instruments as a strobed single channel analyzer or a dual timing pickoff and examines them over a time period as short as one nanosecond. Pulses which meet your selection of coincidence/anticoincidence criteria trigger an output pulse to drive a scale-timer, to gate or direct routing in a multi-channel analyzer, or to activate further pulse selection circuitry. Outstanding performance: resolving time jitter (chance counting to full) is less than 0.5 ns, typically 0.2 ns, makes possible meaningful resolving times of down to 1 ns.

These double-width NIM instruments accept power from an AEC-type supply such as the 5580 A/B NIM Power Supply. Outputs are AEC preferred practice slow and fast logic.

Specifications

5584A Dual Timing Pickoff

Zero crossing detection: two independent channels; each generates a pulse with an adjustable delay following the zero crossing.

Leading edge detection: two independent channels; each generates a pulse with an adjustable delay following the input LE.

Zero crossing and leading edge: one channel responds as above to each.

Multiple pulse resolution: 100 ns + delay time.

Crossover walk (ZC mode): 5 ns over range 50 mV to 10 V; 2 ns over 100 mV to 2.5 V.

Temp stability: resolving time, <0.2 ns/°C over nanosecond delay ranges.

Threshold: for each channel, adjusts over range set by mode selector switch.

Delay A: switch selects delay range for Channel A, 0.1-1.1 μs or 1-11 μs. Front-panel 10-turn pot. adjusts delay continuously. Sweep input can also control delay.

Delay B: 10-position switch adjusts Channel B delay from 200 ns to 1 μs in 200 ns steps and from 2 μs to 10 μs in 2 μs steps.

Input A and Input B: switches select polarity for inputs in LE mode.

Indicators: lamps indicate proper polarity for inputs; Decimal point, Delay A display.

Inputs, Channels A and B: accept pulses between threshold and 10 V; 1 kΩ. For LE mode, either polarity, ac coupled, 100 ns time constant; for ZC, pos. bipolar, dc coupled.

Input, sweep: 0 to 5 V sweeps "A" delay from setting to setting plus 100 ns (low range), plus 1 μs (high range); 4.75 kΩ, dc coupled.

Outputs, Channels A and B: output pulses are triggered by the terminations of the delay periods.

Positive: nominally +5 V into 100Ω, 100 ns width, dc coupled.

Negative: nominally −0.8 V into 50 Ω, 15 ns width, 5 ns rise time, dc coupled.

5585A Fast Coincidence

Multiple pulse resolution: for coincidence measurement, <200 ns (typ. 150 ns) plus resolving time, τ.

Asymmetry: for τ >2 ns, within 0.75 ns +1% of dial reading (negative inputs). For coincidence-anticoincidence work, multiple pulse resolution time (see tech. data sheet).

Chance counting to full: short term variation in τ is <0.5 ns (type 0.2 ns).

Temp stability: resolving time, <0.2 ns/°C over range.

Inputs: coincidence, 3 switchable pairs, separate pos. and neg.; anticoincidence neg. accepts 0.6 to 10 V pulse >15 ns; pos., 2 to 12 V. When off, pulse has no effect.

Outputs: positive, negative, live time. Positive is +5 V into 100 Ω, width factory set to 100 ns (80 ns to 500 ns); negative is −0.8 V into 50 Ω, 20 ns width, 5 ns rise. All dc coupled.

Resolving time control: 10-turn pot, in-line display, 1 ns to 100 ns continuous.

Common Specifications

Temperature range: 0° to +55°C.

Power required: 5584A, +24 V, 350 mA; −24 V, 170 mA; +12 V, 280 mA; −12 V, 300 mA. 5585A, +24 V, 60 mA; −24 V, 50 mA; ±12 V, 400 mA. Can be supplied by 5580A/B NIM Power Supply.

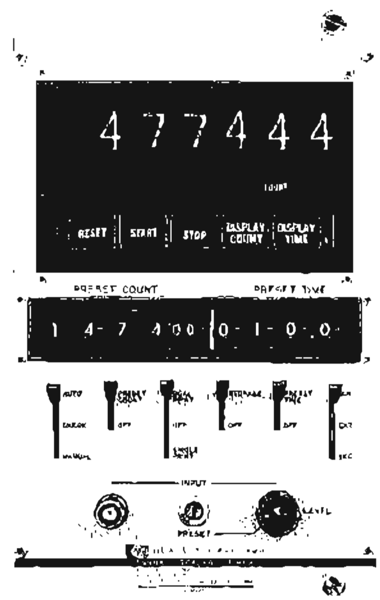
Dimensions: standard double-width module.

Weight: 5584A, net, 4 lb, 2 oz (1,9 kg); shipping, 5 lb (2,3 kg).
5585A, net, 3 lb, 10 oz (1,6 kg); shipping, 5 lb (2,3 kg).

Price: 5584A, $900. 5585A, $900.

NUCLEAR INSTRUMENT MODULES
AEC compatible series
Model 5590A

NUCLEAR



5590A

Advantages:

Scaler *and* Timer
In-line lighted display
Dual (count and time) printout
100 ns pulse resolution

Model 5590A

In one compact package, the HP 5590A Scaler-Timer combines scaling *and* timing (two separate registers), dual preset of count and time, integral discrimination, in-line display, and 8421 BCD printer output including format and printer-paper advance information. Both count and time can be separately preset for the same measurement with the interval terminated by the one that first limits.

Readout is a row of 6 (optionally 7) digital display tubes easily read. Lighted indicators tell at a glance whether the display shows Count or Time, and also status. Display storage holds each measurement in readout until the next one is complete.

The 5590A is easy to use: pushbuttons command it, lever switches program it, and thumbwheels set the exact preset numbers you want (no confusing scale factors required).

Pulse resolution is better than 100 ns, and a crystal time-base provides accurate timing intervals.

The 5590A is a 4-width module in Hewlett-Packard's NIM series compatible with standard AEC modular instrumentation (TID-20893). It is a key unit for building nuclear measurement systems with maximum capability.

Specifications
5590A Scaler-Timer
Performance

Resolving time, signal input: 100 ns.
Resolving time, ext clock input: 100 ns; 0.5 μs with lever switch at Preset Time.
Count input sensitivity: 100 mV peak 20 ns width at half max. Max input rise time limited by 1 ms input TC.
Accuracy: ±1 count, ± time base accuracy.
Crystal time base accuracy: $< \pm 5$ parts in 10^6 with temp stability better than ±5 parts in 10^5 over range.
Temperature range: 0°C to 55°C.

Controls

Pushbuttons: RESET, START, STOP DISPLAY COUNT, and DISPLAY TIME
Preset thumbwheel switches:
Preset count: range (1 to 1999) x (10, 100, or 1000).
Preset time: range 0.1 to 999.9 s or min or 1 to 9999 external units.
Lever switches: Function, Preset-Count, Print, Storage, Preset Time, Time Unit.
Discriminator level potentiometer with preset detent: adjusts discrimination level from 0.1 V to 10 V or sets it at the PRESET value.
Preset screw adjust: factory set to 100 mV. Adjustable from −1 V to +10 V.

Indicators

Digital display tubes: 6 decades.
Illuminated decimal point: Defines 0.1 time units.
Condition indicator: OVERFLOW, ARMED, GATE ON, COUNT, and TIME.

Inputs

Count: between discriminator and +20 V when LEVEL/PRESET is pos. (disc. and −20 V when LEVEL/PRESET neg.) BNC, 1 kΩ, ac coupled.
External clock: standard AEC pulse +4 to +12 V, >30 ns. Absolute maximum +25 V. BNC, 3 kΩ, dc coupled.
Accessories input (24 pin):
Start, stop: +4 V pulse, +25 V max, >200 ns (3 kΩ, dc coupled).
Reset: +4 V pulse, +15 V max, >200 ns (510 Ω, dc coupled).
Recycle inhibit: +4 V dc min, +25 V max (3 kΩ).

Outputs

Gate: open, +5 V (120 Ω source); Closed, 0 V (2.2 kΩ source).
Printer (50 pin):
Data: 4-line 8421 BCD "1" state positive; "1" state level, 5 V (2.7 kΩ source); "0" state level, <+0.4 V.
Reference levels: +4.5 V (120 Ω source) and 0 V (Ground).
Print command: +12 V pulse, 200 ns wide (120 Ω source).
Paper advance: +8 V pulse (1 kΩ source).
Inhibit: hold-off, +4 V dc min, +25 V max (3 kΩ).
Accessories (24 pin):
Gate output: same as gate output above.
Reset output: +5 V pulse, >200 ns wide (120 Ω source).
Line power detector output: +5 dc (5 kΩ source).
24 V dc Supply.
+24 V dc (TNC connector): to power scintillation detectors and amplifiers.

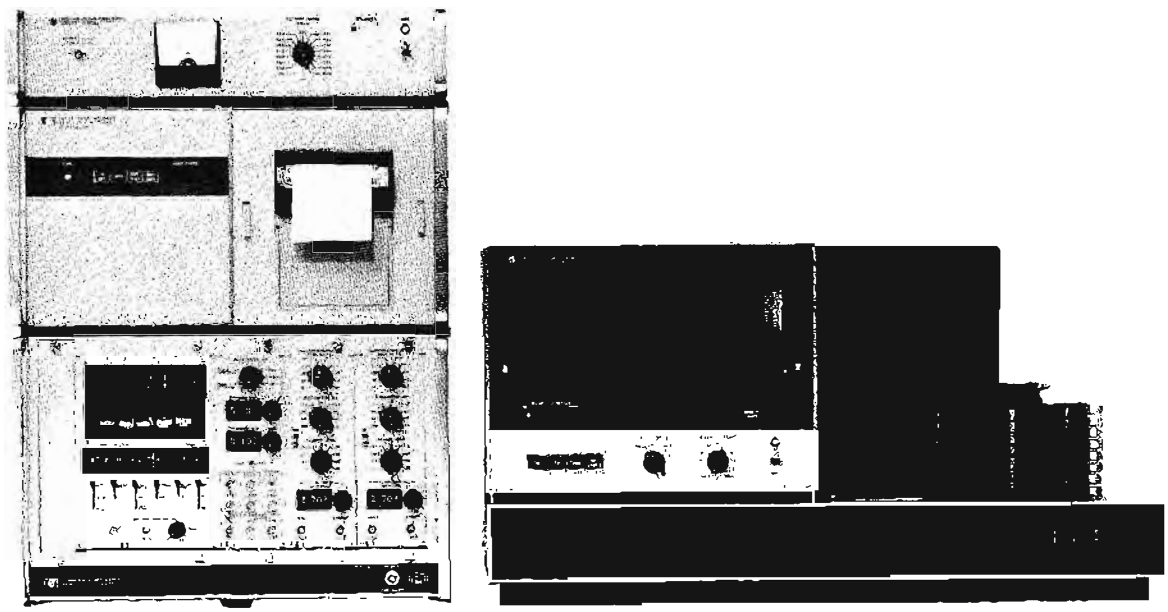
General

Power requirements: 117 V ac, 35 mA; +24 V, 45 mA; −24 V, 30 mA; +12 V, 150 mA; +6 V, 1.4 A.
Dimensions: standard NIM four-width module, 5.407" wide x 8.709" high (137,3 x 221,2 mm) per TID-20893 (Rev. 2).
Weight: net, 6 lb (2,7 kg); shipping, 8 lb, 7 oz (3,8 kg).
Price: $1,675.00.
Options:
Option 01: 60 Hz line-frequency time base; less $75.00.
Option 02: 7 digital display tubes in readout; add $50.00.
Accessories furnished: HP 10519A 50 Ω cable, 6 ft, BNC connectors. Circuit board extender.

NUCLEAR COUNTING SYSTEMS

With automatic sample changer

Systems 5561A-5565A with 5560A



Advantages:

Detectors for α, β, γ counting
Lowest backgrounds available
Automatic and manual modes

Systems 5561A-5565A

Hewlett-Packard Nuclear Counting Systems are built around the 5560A Automatic Sample Changer. These systems offer a selection of detectors including gas-flow detectors with ultra-low background down to 0.1 count per minute. Sample holder capacity is 120 planchets of popular sizes. Printout includes sample number, count, and time. Outstanding performance, versatility, and flexibility aptly describe these systems, which can serve analytical and experimental needs in physics, chemistry, health physics, nuclear medicine, environmental monitoring, meteorology, the biosciences, and other areas where multiple sample counting is required.

The Hewlett-Packard Nuclear Counting Systems are high-performance, rugged systems planned for daily use. These systems are very easy to operate and are ideal for routine use in assessing massive numbers of samples.

An important benefit for the experimenter comes because these systems are combinations of individual state-of-the-art nuclear instruments that can easily be withdrawn for nuclear experiments when the changer is not required. This versatility is economic justification for purchase of a changer system for casual use. Also, these systems are easy to modify or expand. For example, it is easy to add the HP 5400A Multichannel Analyzer or adapt for computer-controlled operation and data analysis via interface to the Hewlett-Packard computer systems.

Each system includes a sample changer with both an automatic changing mechanism and a manual drawer, and a detector, preamplifier, scaler-timer, printer, high-voltage power supply, and NIM bin to hold and power the modular instruments. In addition, systems employing a guard detector include an anticoincidence unit, and proportional systems for use at high count rates have a linear amplifier for the same detector. The scintillation system has, in addition, a single channel analyzer.

Systems 5561A and 5562A

These gas-flow counting systems offer the lowest backgrounds available for α and β counting. With a background as low as 0.1 cpm, it is possible to measure low-level environmental contaminants not previously open to analysis with good statistical accuracy.

Both systems include a 120-holder-capacity automatic sample changer with manual drawer; 4 in., 4π lead shielding; guard detector; choice of three sizes of detector windows; thin or microthin windows; proportional or Geiger modes; dual preset count/time; and printout of sample number, count, and time. If count rate is expected to routinely exceed about 50,000 counts per minute, choose system 5562A; this system includes the 5582A Linear Amplifier for pulse shaping. A summary of important specifications follows:

5561A Gas-Flow Counting Systems With Ultra-Low Background

Background cpm	Window, Sensitive Dia.	Dynamic Range for <1% Loss, cpm	Detector Mode	System Numbers
<0.1 typ. 0.08	0.5 in.	2×10^4 cpm, Geiger; 5×10^4 cpm, Propor.	Geiger	5561A
			Propor.	5561A, Op. 05
<0.5 typ. 0.38	1.2 in.		Geiger	5561A, Op. 06
			Propor.	5561A, Op. 07
<1.3 typ. 1.2	2.2 in.		Geiger	5561A, Op. 08
			Propor.	5561A, Op. 09

5562A Gas-Flow Counting Systems Ultra-Low Background for High Count Rates

Background cpm	Window, Sensitive Dia.	Dynamic Range for <1% Loss, cpm	Detector Mode	System Numbers
<0.1 typ. 0.08	0.5 in.	10^6	Propor.	5562A, Op. 05
<0.5 typ. 0.38	1.2 in.			5562A, Op. 07
<1.3 typ. 1.2	2.2 in.			5562A, Op. 09

The multiple anode design of the detectors imparts a high uniformity of efficiency: within ±5% over the area viewed. This excellent uniformity allows meaningful, repeatable measurements of non-uniform samples (radio-active deposits are notorious for non-uniformity).

Systems 5563A and 5564A

These systems offer low backgrounds for a wide range of counting needs not requiring the ultimate in background reduction. System 5564A is for high count rates.

Both systems include a 120-holder-capacity automatic sample changer with manual drawer; 2 in., 4π lead shield; choice for detector of window sizes, thicknesses; operating modes; dual preset count/time, and printout of sample number, count, and time.

System 5565A

In this system, the gas-flow detector is replaced with a scintillation detector, and a single channel analyzer is added to make it possible to count a selected range of gamma-ray or x-ray energies.

A 2 x 2 in. NaI(Tl) crystal is standard, packaged with its photomultiplier and its preamp-amplifier. On special order, a 3 x 3 in. crystal is available.

For coincidence work, a second detector can be positioned beneath the sample cavity. For X-ray work, a special detector offering excellent sensitivity and low gamma-ray background is available; consult the Factory.

All systems include a 120-holder-capacity automatic sample changer with a 4 in. lead shield; a single channel analyzer, dual count/time preset; printout of sample number, count, and time. A valuable accessory is the 5582A Linear Amplifier for pulse shaping.

Semiconductor detector

The versatile 5560A can be supplied on special order for use with the customer's selection of compatible semiconductor detectors.

Specifications

Brief specifications for the 5560A Automatic Sample Changer and for Systems are presented here. See nearby catalog pages in the nuclear section for specifications relating to other system components, or refer to the 5560A Systems brochure available upon request from the Factory.

Automatic sample changer (HP 5560A)

Planchet-holder capacity: 120 drum, 1 manual drawer.

Method of loading: magazines of 10 holders each, random access and 1 holder by manual drawer.

Planchet sizes: standard holder is recessed to accept the common planchet sizes from ½″ to 2″. Holders to accept sizes up to 2″ dia, x ¾″ deep are available on request.

Holder and magazine color: blue gray.

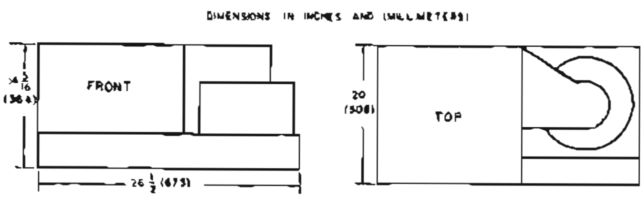
Transport system: motor-driven chain in horizontal guided channel and manual drawer.

Controls:

Pushbuttons: START, STOP, STORE, NEXT SAMPLE
CYCLE MODE switch: SINGLE and CONT.
MULIPLE COUNT switch: 1 through 10 and CONT.
Gas-Flow Valve: 0.01 to 0.08 SCFH.

Indicators: Sample Number, SAMPLE POSITION-CAVITY, SAMPLE POSITION TRANSIT, MANUAL MODE, ON/OFF, and CAUTION (when off, indicates drum is released for manual positioning.)

Dimensions:



Detectors, shielding, and guard

Gas flow detectors: Geiger or Proportional.

Sensitive window diameters: 2.2″, 1.2″, or 0.5″.

Window density: 585 $\mu g/cm^2$ standard. $<100\ \mu g/cm^2$, optional.

Detector efficiency for $C^{14}\beta$: $>24\%$ (std window), $>32\%$ (μthin windows).

Detector efficiency for $Sr^{90}\beta$: $>45\%$ (std and μthin windows).

Detector efficiency for $Pu^{239}\alpha$: $>25\%$ (std window), $>32\%$ (μthin window).

Uniformity of efficiency: $<\pm5\%$ over central 90% window area.

Operating voltages: typically 850 ±50 V (Geiger), 1050 ±50 V (α prop), 1450 ±50 V (β prop).

Scintillation detectors:

Crystal: 2″ dia x 2″ d, NaI(Tl), 3″ dia x 3″ d on special order.

Crystal window: 0.015″ Al

Resolution: $<8\%$ FWHM (Cs^{137} photopeak).

Shielding: 4″ or 2″, 4π, low-background lead in gas-flow systems. 4″ low-background lead in scintillation systems. ¼″ OFHC copper on bottom of cavity. ⅛″ OFHC copper between guard and sample detectors.

Guard detector: gas-flow detector, ultra-low background systems only. Operating voltages, 850 ±50 V (Geiger), 1450 ±50 V (prop). γ-anticoincidence loss nominally 0.01%.

Background: ultra-low background gas-flow systems, <0.1 cpm (0.5″ window), <0.5 cpm (1.2″ window), <1.5 cpm (2.2″ window). Standard-background gas-flow systems, <3 cpm (0.5″ window), <9 cpm (1.2″ window), <24 cpm (2.2″ window).

Maximum count rate for 1% counting loss. 2×10^4 cpm (Geiger), 5×10^4 cpm (prop), 10^6 cpm, systems for high count rates.

Outputs: gross detector counts, gross guard counts, and net counts are available from front panel connectors.

General

Operating voltage: 115 V or 230 V, 60 Hz, 50 Hz optionally available. (Specify 5551A High-Voltage Supply, Option 01.)

Gas required: 99.05% He, 0.95% isobutane for Geiger detector; 90% Ar, 10% methane for proportional detector. Pressure 5 PSIG recommended, 10 PSIG maximum.

Gas input connector: accepts ¼″ copper tubing; adapter supplied for 0.094″ I.D. plastic gas tubing.

Gas consumption: 0.07 SCFH (33 cc/min). A 200 ft^3 gas tank will last about 4 months with continuous flow.

Nuclear counting systems

The table which follows indicates which instruments make up each system.

System components

System Components \ Systems	Gas-Flow Ultra-Low Background 5561A	5562A	Gas-Flow Standard Background 5563A	5564A	Scintillation 5565A
5560A Automatic sample changer	●	●	●	●	●
5580A Nim power supply	●	●	●	●	●
5551A High-voltage power supply	●	●	●	●	●
H042-5050A Digital recorder	●	●	●	●	●
5554A Preamplifier (In 5560A)	●●	●●	●	●	*
5582A Linear amplifier		●		●	†
5583A Single-channel analyzer	●	●			●
5590A Scaler-timer	●	●	●	●	●
Gas-flow detector (Size, mode depends on system)††	●	●	●	●	
Guard detector	●	●			
10601A Scintillation detector					●

*NaI(Tl) 2 x 2 in., preamplifier included.
†5582A a recommended accessory.
††Geiger 0.5″ dia furnished unless option is ordered.

The following table shows options which are available to help you tailor your nuclear counting system to your exact needs.

Options

Option 01	Remove manual drawer
Option 02	Add a second 2 x 2-in. NaI (Tl) detector below cavity**
Option 03	Add deep planchet holder; remove shallow holder
Option 04	Remove sample number readout
Option 05	Proportional, 0.5 in. dia†
Option 06	Geiger, 1.2 in. dia†
Option 07	Proportional, 1.2 in. dia†
Option 08	Geiger, 2.2 in. dia†
Option 09	Proportional, 2.2 in. dia†
Option 10	Geiger, 0.5 in. dia††
Option 11	Proportional, 0.5 in. dia††
Option 12	Geiger, 1.2 in. dia††
Option 13	Proportional, 1.2 in. dia††
Option 14	Geiger, 2.2 in. dia††
Option 15	Proportional, 2.2 in. dia††
Option 16	Substitute microthin window, 0.5 in. detector
Option 17	Substitute microthin window, 1.2 in. detector
Option 18	Substitute microthin window, 2.2 in. detector
Option 19	Modify for scintillation detector

**Second 5551A High-Voltage Power Supply required; not furnished.
†For 5561A, 5562A.
††For 5563A, 5564A.

Power requirements and weights

	Power, Watts	Shipping Wt., Instruments	Shipping Wt., Lead	Shipping Wt., Total
5560A Sample changer	90	85	—	85
5561A system	380	216	692	908
5562A	425	226	692	918
5563A	360	208	270	478
5564A system	380	213	270	483
5565A system	400	221	692	913

Price: depends upon system components selected. A typical ultra-low background system is $10,555.

SCALER-TIMERS

Gross counting and pulse height analysis

Models 5201L, 5202L, 5203L

Advantages:

- Preset time or count
- Output for HP printers
- 6-digit in-line readout
- 200 ns pulse resolution
- Output for ratemeter
- Highly stable

The Hewlett-Packard scaler-timers allow wide flexibility in nuclear counting applications. The HP 5201L Scaler-Timer has a single-channel pulse height analyzer that allows manual or automatic spectrometry. In manual operation, the two integral discriminators have a digital (voltage) readout, and the discriminator levels are stable to 0.01% per °C full scale. In automatic operation, the lower level discriminator may be scanned by application of an external voltage.

The HP 5201L and 5202L differ in that the pulse height analyzer in the 5201L is replaced by a simple integral discriminator in the 5202L. Both may be used to totalize counts, count for a preset time or register time for a preset number of counts to occur. They have selectable preset count times in integral multiples of 0.1 second or 0.1 minute and utilize the power line frequency as the time base. Sampling mode may be either automatic or manual. The HP 5203L Scaler may be either manually operated or externally gated. It may be slaved to a 5201L or a 5202L.

All of the scalers and the scaler-timers have the same input counting capability with multiple pulse resolution of 200 ns. A binary-coded-decimal (BCD) output for driving HP digital recorders or other devices is provided in these instruments as a standard feature.

The compact modular cabinet design gives high portability, maximum utilization of space, plus the ability to convert quickly from bench to 19 in. rack mounting configuration (all conversion hardware included at no extra cost).

Specifications, 5201L

General

Resolving time: preset time mode, 200 ns, preset count mode 10 μs.

Maximum periodic count rate: preset time mode, 5×10^6 counts/s; preset count mode, 1×10^5 counts/s.

Preset count times: 0.1 s to 9,999.9 s in 0.1 s steps; 0.1 min to 9,999.9 min in 0.1 min steps.

Sampling modes: "AUTO" position allows repeat of count at sampling rate. Sample time is 200 ms plus count time. "MANUAL" position requires that "START" button be depressed to start sample.

Accuracy: ±1 count ± time base accuracy.

Time base: power line frequency (typically ±0.1% or better). 100 kHz crystal time base optional).

Gate In: gate opens with external dc level > +5 V and < +20 V. Gate closes with dc level < +2 V.

Gate out: > +15 V when gate open, < +2 V when gate closed.

Reset: front panel pushbutton.

Power: 115 V or 230 V ±10%, 60 Hz, 60 W (50 Hz version optional).

Temperature range: —0°C to +55°C.

+20 V power supply: output through rear TNC.

Pulse height analyzer

Modes of operation: (a) integral; (b) differential with narrow window; and (c) differential with wide window.

Input circuit: ac coupled. Impedance 500 ohms. Maximum input pulse rise time is determined by 1 ms input time constant.

Polarity: positive or negative (selectable).

Output: nominal 0.5 V pulse into 50 ohms for ratemeter input.

NaI (Tl) scintillation counting performance

Discriminator ranges: E_{min} and E_{max} are adjustable from 0.05 V to 5.0 V.*

ΔE range: adjustable up to 0.5 V.*

Discriminator stability: ±0.01%/°C full scale (±0.5 mV/°C) change in E_{min} and E_{max}; and less than ±0.1%/°C of full scale (±0.5 mV/°C) change in ΔE over 0 to +55°C and with ±10% line voltage variations.

Integral linearity: ±0.25% of full scale.

5 MHz scaler performance (integral mode only)

Multiple pulse resolution: 200 ns.

Minimum pulse requirements: 40 ns minimum pulse width, 0.1 V peak.

Functions

Preset time: displays number of counts during preset time interval of 0.1 s or 0.1 min, x preset number N.

Preset count: displays number of 0.1 sec or 0.1 min intervals required for N counts to occur.

Preset range: "N" number selectable 1 to 99,999 on thumbwheel switches.

Manual: counts from discriminator are totalized for (a) time between pushbutton START-STOP; or for (b) time duration of a dc level applied at rear connector. (See Gate In, above.)

Specifications, 5202L

(same as 5201L except as follows)

Pulse Height Analyzer:

Lower level only.

Input pulse range: 0.1 to 5.0 V (max peak pulse amplitude).

Level adjustment: variable over small range around 80 mV (factory setting).

Input circuit: ac coupled. Impedance 1000 ohms. Maximum input pulse rise time is determined by 1 ms input time constant.

Minimum pulse requirements: 40 ns minimum pulse width.

Multiple pulse resolution: 200 ns.

Specifications, 5203L

General

Resolving time: 200 ns.

Maximum periodic count rate: 5×10^6 counts/s.

Gate In: gate opens with external dc level > +5 V and < +20 V. Gate closes with dc level < +2 V.

Gate out: > 15 V when gate is open, < +2 when gate is closed.

Reset: (a) front-panel pushbutton or (b) automatic internal reset.

*ΔE is differential between E_{min} and E_{max}
E_{min} is level set by Lower Level Discriminator (LLD)
E_{max} is level set by Upper Level Discriminator (ULD)

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 45 W.

+20 V power supply: output at rear TNC.

Discriminators: same as 5202L.

Functions

Check: totalize internal source of approx. 80 kHz when START button is depressed.

Specifications, all models

Printer output

Output: 4-line BCD (1-2-4-8) code, "1" state negative standard; (1-2-4-8 code, "1" state positive or 1-2-2-4 code, "1" state positive optional).

Impedance: 100 k ohms each line.

Positive state level: + 18 V.

Negative state level: —8 V.

Reference levels: +17.6 V, 350-ohms source impedance. —6.9 V, 1000-ohm source impedance.

Print command: +28 V step, from 2700 ohms in series with 470 pF.

Hold-off requirements: externally applied +5 V to —6 V.

Printer output connector: 50-pin Amphenol 57-30500, rear.

Physical

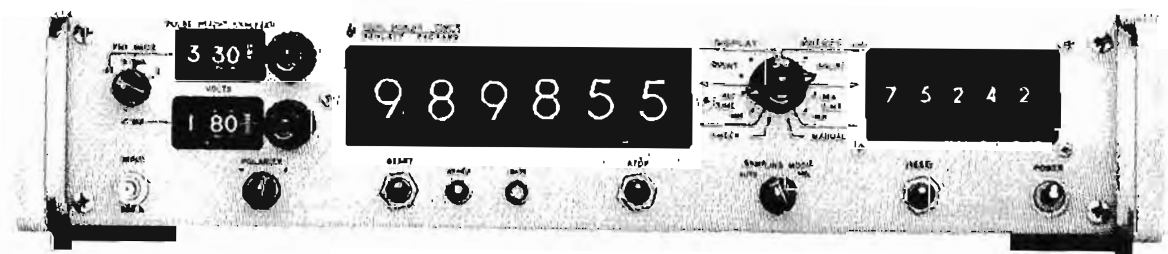
Registration: 6 long-life rectangular digital display tubes with display storage.

Dimensions: 16¾" wide, 3-15/32" high, 11¼" deep (426 x 88,2 x 286 mm).

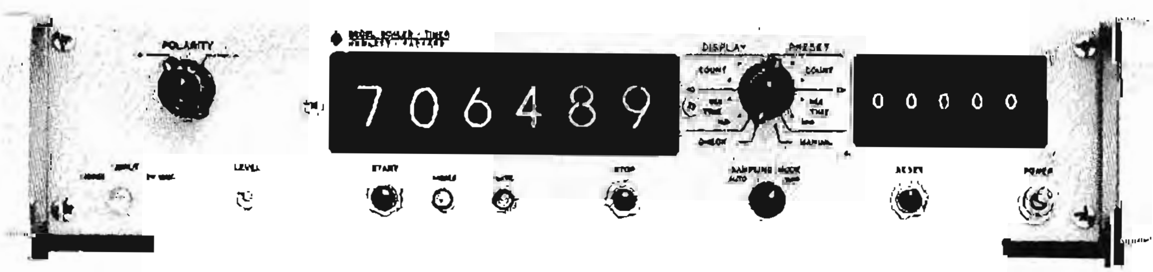
Weight: 18 lbs (8,2 kg) net; 23 lbs (10,4 kg) shipping.

Accessories furnished (5201L, 5202L and 5203L): two HP 10519A Cables, 6' long, BNC connectors; circuit board extenders; detachable power cord.

Prices: 5201L, $1950; 5202L, $1400; 5203L, $950.



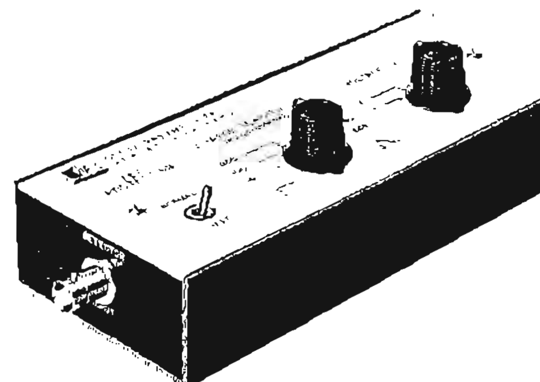
5201L



5202L

5203L

PREAMPLIFIER
General Purpose
Model 5554A



5554A

Advantages:

FET Protection
Quick-change Bias Resistor
Switch-selected charge sensitivity, voltage gains
Can be used as combination preamp amplifier

Model 5554A

The HP 5554A ends the experimenter's need for a multitude of special-purpose preamplifiers by providing a single unit that can serve with a variety of detectors, including semiconductor, gas proportional, Geiger, and scintillation. This versatile charge-sensitive preamplifier can be set up for a different detector as fast as the user can reset the charge sensitivity and gain switches, and can slip a replacement bias resistor between the quick-connect clips. No soldering of components is needed.

The 5554A accepts a burst of charge (current pulse) from a nuclear detector and produces an output pulse of voltage proportional to the amount of charge in the burst. This, in turn, is proportional to the energy of the incident nuclear particle or gamma ray photon.

The circuit comprises a charge-sensitive stage coupled to a voltage amplification stage either of two ways, switch-selected: via a pole-zero cancellation network that eliminates undershoot and gives an output pulse ideal for input to a linear amplifier; or, via a shaping network that differentiates and integrates the output for direct input to pulse analyzing equipment.

The input device is a field-effect transistor (FET) for low-noise performance. The FET is diode-protected against damage from high voltage transients, or protection can be switched out for lowest noise performance.

Noise performance is excellent; at zero external input capacitance, FWHM (Ge) is 2.2 keV (typ).

The 5554A is ideal for use with the HP nuclear instrument modules (NIM) in the AEC-compatible configuration.

Specifications
5554A Preamplifier

Charge sensitive preamplifier
- **Signal input polarity:** either.
- **High voltage:** 2.5 kV max, either + or − as required for detector.
- **HV decoupling:** 3 stages, R = 1 M, C = 0.0047 μF, τ = 4.7 ms.
- **Detector bias resistor:** inserts between spring-loaded clips. 1000 M, 100 M, 4.7 M provided; others may be used.
- **Charge sensitivity (conversion gain):**
  - **With non-shaped output pulse:** 10, 100, or 1000 mV/pC (millivolts per picocoulomb) nominal.
  - **With shaped output pulse:** 3, 30, 300 mV/pC nominal.

Voltage amplifier
- **Gain:** with R_L = 50 Ω: 1,2,4,or 8; With R_L ≥ 500 Ω: 2,4,8,or 16.
  - **Loss as a function of input capacitance:** <3% at 100 pF for conversion gain 300 or 1000; otherwise much less. Gain overall is conversion gain x voltage gain.

Output
- **Polarity:** inverted from input.
- **Postive output:** into a 50 Ω load, dynamic range is 5 V; into ≥500 Ω, 10 V (with voltage gain X2,X4, or X8).
- **Negative output:** into a 50 Ω load, dynamic range is 3.5 V; into ≥500 Ω, 7 V (with voltage gain X2,X4, or X8).
- **Impedance:** 50 Ω.
- **Note:** outputs measured with power input at +24 V.
- **Tail pulse:**
  - **Rise time:** 50 ns at zero external capacitance.
  - **Tail time constant:** 100 μs.
  - Pole-zero cancellation.
- **Shaped pulse:**
  - **RC differentiation, integration time constants:** both 1 μs.

Noise

External Input Capacitance, pF	rms ion pairs		FWHM, keV (Ge, 2.98 eV/ion pair	
	Typical	Max.	Typical	Max.
0	310	360	2.2	2.5
10	360	410	2.5	2.9
100	780	900	5.4	6.3

- **Noise slope:** 0.038 keV/pF max; typ. 0.035 keV/pF.

Stability, linearity
- **Temperature stability:** 0.01%/°C (nonshaped pulse).
- **Integral nonlinearity:** 0.05%.

Power required: +20 to +24 V dc, 80 mA max.

Physical
- **Connectors:**
  - **Detector input:** BNC, female, high voltage type.
  - **Output:** BNC, female.
  - **Test input:** BNC, female, 50 Ω termination. Capacitor, 1 pF ±0.25 pF.
  - **Low voltage:** TNC, female, +20 to +24 V dc.
  - **HV:** BNC, female, high voltage type.
- **FET protection switch:** diode network, normal or out.
- **Dimensions:** 3" wide, 2¼" high, 8¼" long (76 x 57 x 210 mm).
- **Weight:** net, 1.11 lb (0,506 kg); shipping, 2 lb (1 kg).
- **Accessories furnished:**
  - Power input cable, TNC connectors, 6 ft. long (HP 10517A).
  - Bias resistor kit: 4.7 M, 100 M, 1000 M.
- **Accessories available:**
  - High voltage cable, 6 ft. long, HV-type BNC connectors, (HP 10516A, $10.00).
- **Price:** 5554A, $300.00.

SCINTILLATION DETECTORS

Premium resolution, stability with low drift

10600A Series

Advantages:

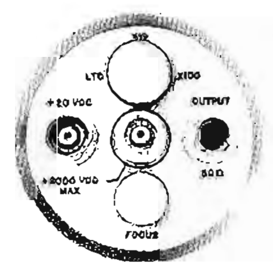
Low drift characteristics

Premium resolution and stability

Hewlett-Packard scintillation detectors utilize selected sodium iodide (thallium activated) crystals and photomultiplier tubes as integral assemblies. These assemblies combine efficient scintillators for gamma ray detection with photomultipliers having the best light collection characteristics. A preamp-amplifier with three levels of gain completes the scintillation detector and is capable of driving Hewlett-Packard pulse height analyzers directly. The LTC (long-time constant) position on the gain switch gives a low gain output for use into an external amplifier such as the HP 5582A Linear Amplifier.

The HP scintillation detectors are available in both solid and well configurations, with 2 x 2 and 3 x 3 NaI (TI) crystals. A magnetic shield utilized in all detectors maximizes protection from external ac and dc magnetic fields. The entire assembly is sealed against moisture in a stainless steel case. A TNC connector is used for the low-voltage power supply input, a high-voltage BNC connector is used for the high-voltage power supply input, and a BNC connector for the signal output. A focus control and three-position selector switch (for selecting: long time constant; short time constant, X1 gain; short time constant, X10 gain) are accessible on the detector assembly for optimizing measurements.

10602A 10612A 10611A



Typical Detectors and view of switches, terminals

Specifications

All Models

Crystal: NaI (TI).

Typical output:

Long Time Constant (LTC) 0.30 V/MeV.
Short Time Constant, Gain 10: 1.8 V/MeV.
Short Time Constant, Gain 100: 18 V/MeV.
(Detector at 25°C, High Voltage 1000 V.)

Magnetic field effects:

AC: < ±0.5% change in pulse height (2 gauss rms).
< ±0.1% change in resolution (2 gauss rms) 60 Hz.
DC: < ±0.5% change in pulse height (±2 gauss field).

Amplifier

High voltage input: 2000 V (max.), 7.35 MΩ (approx.).

Low voltage input: +20 V at 21 mA (+ 25 V max. input).

Typical output pulse shape @ 25°C:

LTC: 0.25 μs rise time-constant, 12.5 μs fall time-constant, 30 μs fall time, peak to 0 volts.

Gain: X10 0.25 μs rise time-constant, 1 μs fall time-constant, 3 μs fall time, peak to 0 volts.

Gain: X100 0.25 μs rise time-constant, 1 μs fall time-constant, 3 μs fall time, peak to 0 volts.

Maximum no load output:

LTC +4 V
X10 +10 V
X100 +10 V

Output impedance: 50Ω nominal.

Physical

Focus control: to adjust photomultiplier tube for optimum gain and resolution.

Connectors:

Low voltage: TNC connector (female).
High voltage: high voltage BNC connector (female).
Signal output: BNC connector (female).

Gain switch: 3-Position Slide Switch:

LTC: Long Time Constant.
X10: Short Time Constant, Gain 10.
X100: Short Time Constant, Gain 100.

Magnetic shield: internal between integral assembly and case.

Case: stainless steel, moisture proof.

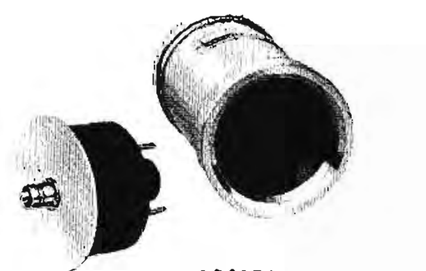
Accessories furnished: one HP 10517A cable 6' long, TNC connectors.

Specifications
Individual

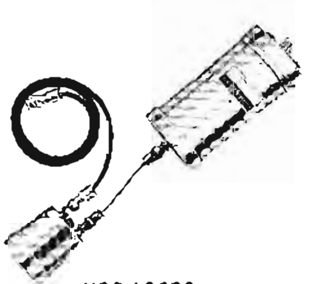
Model Type	10601A	10602A	10611A	10612A	10613A	10614A
Crystal Type	Solid		Well Type			
Crystal Dimensions	2″ dia x 2″ long	3″ dia x 3″ long	2″ dia x 2″ long	3″ dia x 3″ long	2″ dia x 2″ long	3″ dia x 3″ long
Well Dimensions			1″ dia x 1-35/64″ deep (25,4 x 39,3 mm)	21/32″ dia x 2″ deep (16,7 x 50,8 mm)	21/32″ dia x 1-35/64″ deep (16,7 x 39,3 mm)	1.024″ dia x 2-3/64″ deep (26 x 51 mm)
Resolution	<8% FWHM*		<10% FWHM*			
Drift	<±2%**	<±1%**	<±2%**	<±1%**	<±2%**	<±1%**
Stability	<±2%***	<±1%***	<±2%***	<±1%***	<±2%***	<±1%***
Overall Dimensions	2¾″ dia x 12¼″ long (70 x 312 mm)	3½″ dia x 13¾″ long (82 x 350 mm)	2¾″ dia x 12¾″ long (70 x 324 mm)	3½″ dia x 13¾″ long (82 x 350 mm)	2¾″ dia x 12¾″ long (70 x 324 mm)	3½″ dia x 13¾″ long (82 x 350 mm)
Crystal Window	0.015″ Aluminum	0.019″ Aluminum	0.010″ Aluminum			
Weight: Net / Shipping	5 lbs (2,3 kg) / 12 lbs (5,4 kg)	8 lbs (3,6 kg) / 15 lbs (6,8 kg)	5 lbs (2,3 kg) / 12 lbs (5,4 kg)	8 lbs (3,6 kg) / 15 lbs (6,8 kg)	5 lbs (2,3 kg) / 12 lbs (5,4 kg)	8 lbs (3,6 kg) / 15 lbs (6,8 kg)
Price	$835	$1475	$885	$1565	$885	$1565

*FWHM = Full width at half maximum of Cs-137 photo peak.
**Pulse Height change at 25°C over 24 hours at 1000 cps.
***Rate shift change from 1000 cps to 10,000 cps (integral count rate Cs-137).

PREAMP-AMPLIFIER
Three levels of gain, pulse shaping
Model 10615A



10615A



K02-10600

K03-10600A

The Hewlett-Packard Model 10615A Preamp-Amplifier accepts input from a scintillation detector or other nuclear detector and provides output pulses suitable for driving a scaler or other follow-on instrumentation. The 10615A is the same excellent preamp-amplifier used in the HP Scintillation Detectors, Series 10600A. With the 10615A, special-purpose, high-performance detector assemblies can be quickly and easily made. A standard 10-stage photomultiplier tube plugs directly into the 10615A's recessed socket; a BNC adapter (included) provides for easy connection of units that cannot be plugged in directly. The 10615A is housed in a sturdy metal case that provides excellent RFI and noise shielding. This case also permits convenient decontamination, should that become necessary.

The unit is compatible with HP Scalers and High Voltage Supplies. Dimensions: 2.95 in. (75 mm) diameter, 6.25 in. (158 mm) long. Price, $295.

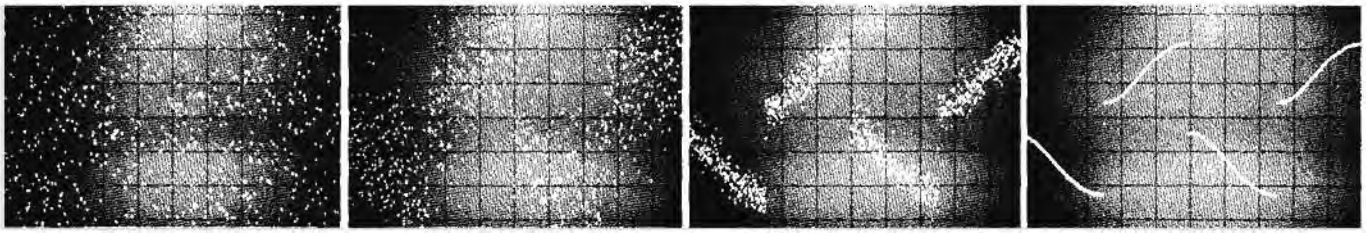
X-Ray Detector

A low-noise, low-background x-ray detection system is easily arranged with use of the 10615A, as shown. The 10615A connects to an x-ray detector assembly comprising a voltage divider adapter and a NaI(Tl) crystal. The adapter has two BNC connectors, one for the signal and the other for the high voltage. (Note that no high voltage connection need be made to the 10615A's high voltage terminal when an adapter is used.)

K02-10600A X-ray detector, NaI(Tl) crystal, Price, $425.

K03-10600A Plug-in voltage divider. Price, $100.

SIGNAL AVERAGING



A new method of signal averaging gives a continuously calibrated display.

Conventional method

For more than a decade man has been able to make use of signals previously too obscured by noise to be usable. The process used has been a form of averaging.

If the signal was repetitive, successive repetitions could be sampled and added to the sum of previous repetitions. That part of the signal that repeated exactly each time reinforced the sum while random positive and negative components of noise eventually cancelled themselves out. To obtain a value for the amplitude of the waveform involved dividing by the number of sweeps.

This process is called "summation" averaging and is shown in block form in Figure 1. The sync signal marks the beginning of each repetition and puts the sampling circuit into operation. The sample values are converted to digital form, stored in successive locations of memory and when the last location of memory is filled, the process stops until another sync pulse arrives. At that time the process starts over again, adding the new sample values to what is already in memory. The information in memory is converted to analog and in some units displayed on a built-in CRT. The resulting display is the waveform growing out of the noise. As the waveform grows, it must be scaled down to keep it on the CRT.

Problems involved

There are three major drawbacks encountered in using the conventional "summation" averaging to reduce noise.

First, the waveform is never calibrated. During the experiment the waveform is continually growing on the CRT, so the operator must wait until the experiment is over, and then manually (sliderule or otherwise) divide the amplitude by the number of sweeps. Thus no information other than waveshape is available until the end of the experiment.

Second, it is difficult, if not impossible to perform experiments involving slowly changing, but noisy signals. Or alternately, if the researcher wants to vary any experimental parameters and observe the results, he must perform a new experiment for each change.

Third, if the waveform is a very low frequency, the sweep speed is so slow that the resulting display is a spot jumping from point to point where the waveform should be. Even if the sweep speed is fast enough to give the appearance of a complete waveform, if the repetition rate is low, the display will be a flash of the waveform once each repetition. Thus there can be no visible display of the waveform until the experiment is over.

Even with these drawbacks, "summation" averaging has been the best method available up until the introduction of the HP 5480A Signal Analyzer.

The new method

With the 5480A, not only is the display of your waveform always calibrated (in volts/cm) and always visible, but if the waveform changes, the display can follow.

These exclusive features are made possible through an analog-digital feedback technique to calculate a new average each time a data point is handled. This new average is derived by use of the old average, the new input value and the number of sweeps which have been taken. Because the 5480A stores the average value rather than the sum in memory, it always has a calibrated display.

A more detailed explanation of calibrated averaging techniques can be found in the April, 1968 HP Journal.

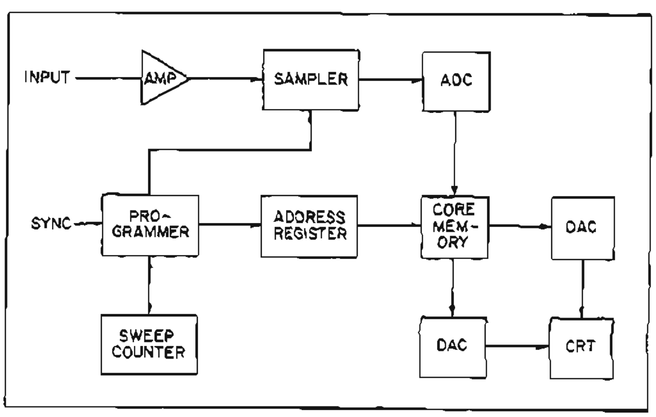


Figure 1. Conventional method of "summation" averaging.

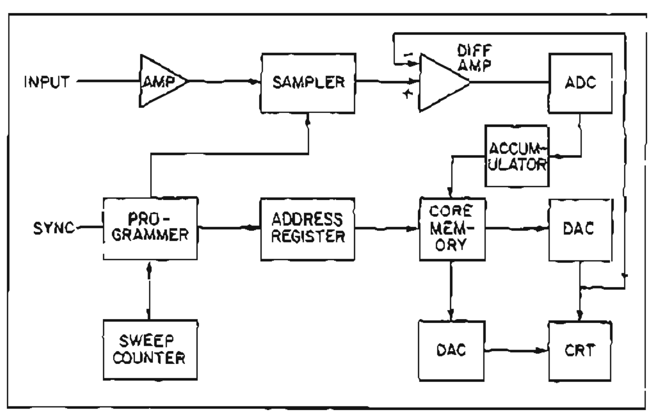
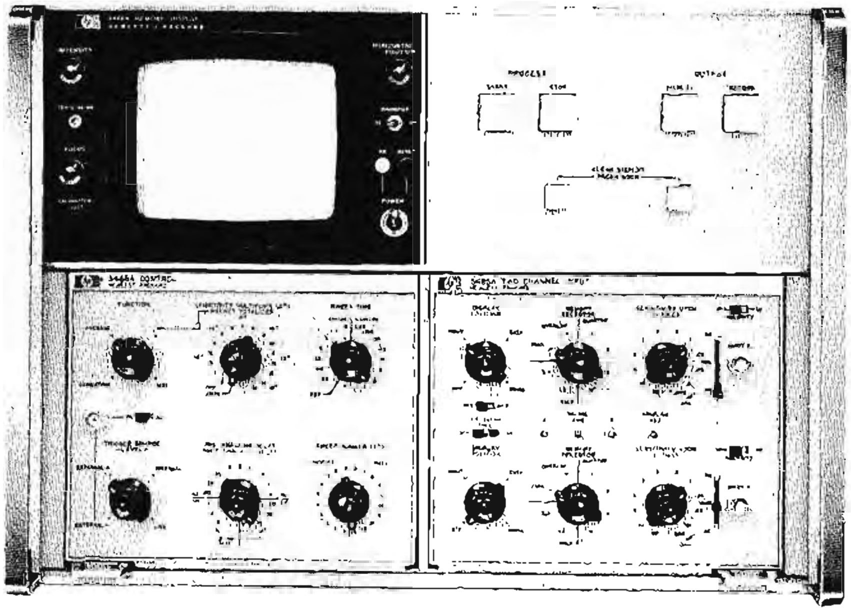


Figure 2. HP method of true "calibrated" averaging.

SIGNAL ANALYZER
For averaging, histograms, and MCS
Model 5480A



5480A

Signal Analyzer

Advantages:

Calibrated averaging gives continuously calibrated display.

Display is always visible—regardless of sweep time or repetition rate.

Weighted averaging allows averaging of slowly changing waveforms.

The Hewlett-Packard 5480A Signal Analyzer marks a new level of achievement in extracting usable signals from a noisy background. Now, for the first time, you can view a continuously calibrated display of your waveform as it is averaged. As a result of the newly developed algorithm used to produce the average, the only change in the display is a rapid transformation from noise into a distinct waveform.

Also for the first time, you can average a waveform that is changing. Logic circuitry follows slow changes by placing more emphasis on new data. This means you can watch the effects as you vary parameters.

A common problem encountered with conventional signal averaging techniques is that at slow sweep speeds or repetition rates, the operator cannot see the waveform as it is processed. Hewlett-Packard has solved this problem, however, by using a separate and independent address register for display. The result is a display which is always visible and never flickering—even between sweeps.

The plug-in design of the HP 5480A Signal Analyzer not only guards against obsolescence, but also allows for a far more versatile instrument. The mainframe contains the core memory, with related circuitry, digital to analog converters, and CRT display, while the two plug-ins chosen depend upon the specific application.

The two standard plug-ins (the HP 5485A Two Channel Input plug-in and the HP 5486A Control plug-in) provide not only complete averaging capability, but also histograms and multichannel scaling (MCS). Frequency histograms from dc to 1 MHz and time interval histograms from 10 μsec to 500 sec can be performed. Multichannel scaling to 1 MHz with dwell times from 10 μsec to 0.5 sec are also standard.

Input/output flexibility is another convenience of the HP 5480A Signal Analyzer. Over 200 input and output connectors solve virtually any digital or analog interfacing problem. Through direct interface with a card and cable assembly, the HP 5480A becomes an input/output device for any HP computer. By interfacing through the Hewlett-Packard 5495A Input/Output Coupler, the Signal Analyzer will communicate with a wide variety of computers, as well as with punched tape readers, tape punches, teleprinters, and printers.

Specifications

Calibrated averaging mode

In this mode, the averager performs a true calibrated average. Waveform amplitudes are read directly from the CRT in volts/cm without normalizing.

Input characteristics: (for 5485A Two Channel Input plug-in)
Bandwidth: dc (2 Hz ac coupled) to 50 kHz.
Sensitivity: 5 mV/cm to 20 V/cm in 1, 2, 5 steps.
Input impedance: 1 MΩ shunted by 25 pf.
Polarity inversion: +up or −up selectable.
A+B: adds channel B input to channel A input and sum is fed through channel A. Polarity of either channel may be inverted to give difference.
ALT: Processes and displays both channels simultaneously.

Resolution: 1000 points (or 500 or 250 by front panel selector).

Sampling rate: 2 samples/sec through 100,000 samples/sec in 1, 2, 5 steps.

ADC clock rate: 20 MHz.

ADC resolution: 9 bits from 50 sec/cm through 5 msec/cm. 7 bits at 2 msec/cm, 5 bits at 1 msec/cm.

Triggering:
External:
Slope: + or − selectable.
Amplitude: >100 mV, <10 μsec rise time.
Trigger: level is adjustable.
Input impedance: 1 MΩ shunted by 30 pf.
Internal: sweep is triggered by internally generated pulse occurring at end of each sweep. This free-running mode is used to control the experiment.
Line: sweep is triggered by line frequency.
Pre analysis delay: 20 μsec through 0.5 sec in 1, 2, 5 steps.
Post analysis delay: continuously variable from 0.01 to 10 sec.

Sweep time: 1 msec/cm through 50 sec/cm in 1, 2, 5 steps

External time base: up to 20 kHz allows sweep times from 5 msec/cm to ∞.

Horizontal magnifier: expands horizontal axis by factor of 5.

Sweep number: number of sweeps to be averaged may be preselected from 1 through 2^{19} (524,288) in powers of 2.

dB improvement: dB of signal-noise ratio improvement from 0 dB to 57 dB in 3 dB increments can be selected.

Memory selection: operator may select any quarter, either half, or full memory (1000 points) for each channel independently.

Overlap display: two waveforms may be stored, while two more are processed; then all four displayed simultaneously for comparison.

Display: operator may select CRT display of waveform as it is averaged, noise portion only, or input signal after sampling.

Weighted averaging

In this mode the averager is able to follow a slowly changing waveform. This is accomplished by placing more emphasis on new data. The averager essentially "forgets" old data in favor of the new.

All specs are identical with Calibrated Averaging.

Summation mode

In this mode the averager merely adds successive repetitions of the noisy waveform, resulting in an uncalibrated display which is proportional to the averaged signal.

Sensitivity multiplier: manual adjustment allows scaling of vertical up or down in power-of-two increments up to 64 counts/cm.

Automatic scaling: provides automatic scaling down of vertical in power-of-two increments to keep display on screen.

Stable baseline: baseline always represents zero volts.

All other specs are identical with Calibrated Averaging, except Weighted Averaging is not possible.

Histogram mode

In this mode the averager displays a probability versus frequency (or time interval) plot. The number of incoming pulses in a set gate time determines the memory location into which a count is placed. After several gate times, a distribution results.

Input characteristics:
Bandwidth: dc to 1 MHz.
Sensitivity: 100 mV.
Input impedance: 1 MΩ shunted by 30 pf.

Frequency ranges: 200 Hz/cm through 10 MHz/cm in 1, 2, 5 steps.

Time interval ranges: 50 sec/cm through 1 msec/cm in 1, 2, 5 steps.

Preset totalizer: if desired, operator may preset number of values to be histogrammed from 10^3 through 10^7 in powers of 10.

Sensitivity multiplier: expands vertical to 64 counts/cm in power-of-two increments.

Multichannel scaling (MCS) mode

In this mode the averager displays a plot of frequency versus time. The averager sweeps through memory remaining at each location for the set gate time. The number of counts placed in each location is determined by the number of incoming pulses occurring during the gate time.

Pulse requirements:
Amplitude: >2 V (20 V max).
Maximum repetition rate: 1 MHz.
Minimum pulse width: 500 ns.
Pulse pair resolution: 500 ns.

Input impedance: 3 kΩ minimum.

Dwell time per channel: 10 μsec through 0.5 sec in 1, 2, 5 steps (external time base: 50 μsec to ∞).

Sweep modes: sawtooth or triangular sweep. External time base input allows any desired sweep shape.

Triggering: external triggering is possible on sawtooth sweep.

Outputs

Analog:
X-Y Recorder:
X: 0 to +10 V sweep ramp; 0.2% linearity.
Y: −4 to +4 V; output is proportional to CRT display (0.5 V output per cm deflection); 0.2% linearity.
NOTE: These X and Y signals will drive other devices such as scopes, or NMR systems.
Pen lift signal: +5 V = pen up; 0 V = pen down.
Z-axis: +5 volt blanking pulses for external scope display.
Point plotter: (typically Moseley 7004A).
Seek: +10 V, >50 μsec pulse to tell point plotter to seek a null.
Plot: >+2 V, 200 nsec pulse accepted from point plotter indicating plot is complete.
X-Y signals are same as above.
Sweep voltage: 0 to +1 V sweep ramp; conveniently adjusted by changing resistors to give output ramp going from 0 V to any value between 0 to +10 V.
Sync: "Pos" provides +12 V, >0.5 μsec pulse at start of each sweep (before pre-analysis delay); "Neg" provides same except −12 V.
Sampling pulses: pulses go from +5 volts to ground and return to +5 V once each time the input is sampled.
Pulse width: 100 ns.
Noise: train of voltage pulses whose amplitude equals difference between input and average; amplitude is proportional to CRT display of noise (½ V per cm deflection). (This signal can be gated with Z-axis output).

Digital: four 50-pin connectors interface the averager, through the 5495A I/O Coupler, to computers, teleprinters, tape punches, tape readers, and printers. (See 5495A I/O Coupler on next page). A direct interface to all HP computers is also available.

General

Power: 115 or 230 volts ±10%, 50-400 Hz, 175 watts.

Dimensions: 16¾" wide, 12½" high, 24⅜" deep overall (425 x 311 x 593 mm).

Weight: 76 lb (34,5 kg) net.

Price: 5480A with 5485A and 5486A plug-ins, $9950.00.

I/O COUPLER

Complete digital interfacing for the HP 5480A

Model 5495A

Advantages:

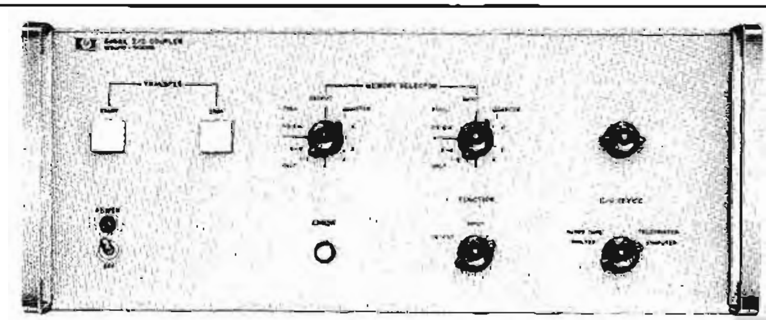
- Interfaces printers, tape readers, tape punches, teleprinters, and computers.
- Card-cable assemblies allow plugging in additional digital peripherals at any time.
- Capability to add, subtract, or move any quarter or half of memory to another.

The HP 5495 I/O Coupler serves with the HP 5480A Signal Analyzer (see preceding page). The I/O Coupler has two main functions: complete digital input and output interfacing for the HP 5480A and some processing of wave-forms stored in the 5480A memory.

Using only a printed circuit card and cable, you can add digital peripherals to your averaging system as needed by merely plugging the card and cable into the back of the coupler. Because of the versatile parallel-serial input/output format used, it is possible to interface with many different computers.

The HP 5495A will add or subtract two waveforms stored in memory, then place the result back into memory.

Color coding of front panel controls makes operation almost self explanatory. Output controls are in blue, input in red and processing controls in white. To further simplify operation, an error light warns of either an illegal control setting or an improper format from an input device.



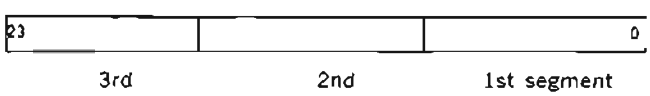
5495A

Specifications

Computer

Direct Interface to: HP 2114A, HP 2115A, HP 2116A Computers
Data flow: input and output
Operating mode: asynchronous
Data transfer mode: parallel-serial; the 24 bit binary words of the 5480A Signal Analyzer are transmitted in 3 segments, 8 bits at a time.
Format:

HP 5480A 24-bit Word



Order of transmission

This versatile format makes possible interfacing with a wide variety of computers.
Data code: binary
Data transfer rate: 20,000 words/sec.

Teleprinter

Direct Interface to: HP 2752A Teleprinter
Data flow: input and output
Operating mode: synchronous
Data transfer mode: bit serial
Format:
2 lines of data, five words each (words are 7 decimal digits plus sign); then a blank line and 2 more lines of data. This pattern repeats for 10 lines of data (50 words); then 2 blank lines, after which the whole pattern repeats. Symbol # indicates start of data; symbol S indicates end of data
Data code: Standard ASCII
Data transfer rate: 10 characters/sec.

Paper tape output

Direct Interface to: HP 2753A High Speed Tape Punch
Data flow: output
Operating mode: asynchronous
Data transfer mode: character serial
Format: same as teleprinter
Data code: Standard ASCII
Data transfer rate: 120 characters/sec.

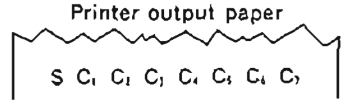
Paper tape input

Direct interface to: HP 2737A High Speed Tape Reader
Data flow: input
Operating mode: asynchronous
Data transfer mode: character serial
Format: same as teleprinter
Data code: Standard ASCII
Data transfer rate: 300 characters/sec.

Printer

Direct Interface to: HP 5050 Digital Recorder
Data flow: output
Operating mode: asynchronous
Data transfer mode: word parallel
Format:

Printer output paper



S is sign of data ("-" or blank)
C_1-C_7 are decimal digits ("0" thru "9")
Data code: BCD, 1-2-4-8 positive true
Data transfer rate: up to 20 lines/sec.

General

Power: 115 or 230 volts ±10%, 50-60 Hz, 100 watts.
Dimensions: 16¾" wide, 7-9/32" high, 18⅜" deep overall (425 x 185 x 467 mm).
Weight: 32 lb (14,5 kg) net.
Price: on request.

ACOUSTIC INSTRUMENTATION

Unfortunately for those trying to measure and evaluate sound objectively in terms of the sensation experienced by humans, this sensation seems to involve complicated physiological and psychological mechanisms. Indeed, loudness evaluation is several orders of magnitude more complex than measuring the purely physical quantities of sound pressure and sound pressure level.

Since loudness is a subjective quantity the primary instrument for measuring it can only be a human observer.

To determine whether one sound is louder, equally loud, or less loud than another, we would have to let a statistically significant number of people compare the sounds and then average their opinions. Similarly, to determine how loud a sound is, we should have to choose a standard sound and have a significant number of people compare the unknown with the standard.

In acoustics the accepted standard is a pure 1 kHz tone or narrow-band noise centered at 1 kHz. The loudness level of any sound is defined as the sound pressure level of a standard sound which appears to a significant number of observers to be as loud as the unknown. Loudness level is measured in phons, the loudness level of any sound in phons being equal to the sound pressure level in dB of an equally loud standard sound. Thus a sound which is judged to be as loud as a 40 dB 1 kHz tone has a loudness level $L = 40$ phons.

Although the logarithmic phon scale covers the large dynamic range of the ear (120 dB) conveniently, it does not fit a linear loudness scale. A factor of two in loudness does not correspond to double the number of phons.

It is also difficult to add loudnesses in phons. If, for instance, we produce one tone at 200 Hz with a loudness level of 70 phons, and another at 1 kHz with the same loudness level, it would be convenient if both tones together would yield a loudness level of 140 phons. Unfortunately, this doesn't happen. The two tones actually are perceived as a loudness level of 80 phons.

In an effort to obtain a quantity proportional to the intensity of the loud-sensation, a loudness scale was defined in which the unit of loudness is called a sone. One sone corresponds to a loudness level of 40 phons. For loudness levels of 40 phons or greater, the relationship between the numerical values of loudness level L (in phons) and loudness S (in sones) is given by

Loudness Level (phons)		Loudness (sones)
140	Threshold of pain	1024
120	Jet aircraft	256
100	Truck	64
80	Orator	16
60	Low conversation	4
40	Quiet room	1
20	Rustling of leaves	
3	Hearing threshold	

Table 1

$$S = 2^{(L - 40)/10}$$

(ISO Recommendation R 131). Table 1 compares loudnesses (sones) and loudness levels (phons) of several common sounds.

The loudness level of a 1 kHz tone is the same as its sound pressure level. This would also be true of pure tones of other frequencies if perception were constant with frequency. However, it is not. The loudness level of any other sound (in phons) is not, in general, equal to its sound pressure level (in dB).

Equal loudness contours were first published in 1933 by Fletcher and Munson. Slightly modified curves are now universally accepted as reference data (ISO Recommendation 226). These curves are for pure tones in a frontal sound field (sound traveling in only one direction and approaching the observer from the front).

To human ears, broadband sounds, like those of jet aircraft, seem much louder than pure tones or narrow-band noise having the same sound pressure level. Figure 1 shows what increasing bandwidth does to the loudness of noise having a center frequency of 1 kHz and a constant sound pressure level of 60 dB. Up to a critical bandwidth of 160 Hz, the loudness is constant. Beyond that point, however, there is a marked increase in loudness. At a bandwidth of 2 kHz the loudness level L has increased from 60

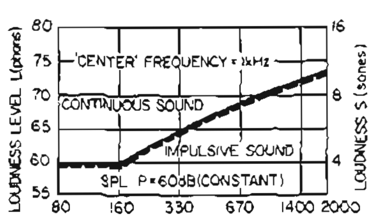


Figure 1. Effect of bandwidth on loudness.

phons to 74 phons. Loudness S has increased by a factor of 2.5. Similar investigations using different center frequencies yield different critical bandwidths. At a center frequency of 200 Hz the critical bandwidth is approximately 100 Hz; at 5 kHz, about 1 kHz.

The human ear's critical bands seem to be related to another property of the ear: subjective pitch. Subjective pitch tells us how our ears compare the frequencies of different sounds. Needless to say, subjective pitch is not linear, i.e. a unit interval is not the same at 100 Hz and 5 kHz. The unit of subjective pitch is the mel. Remarkable enough, an interval of 100 mel approximates the width of a critical band at any point in the audio range. However, the mel is not used. Instead, the width of a critical band is defined as one Bark. Accordingly, the audio range comprises 24 Barks.

Two sounds presented to the ear simultaneously produce a sensation of loudness which is larger than that produced by either of them alone. However, a simple summation of partial loudnesses can only be carried out if the individual sounds are separated widely in frequency. The closer they are in frequency the more they influence each other, and total loudness may not be quite so large as the sum of the partial loudnesses. This effect is called partial masking. In the extreme case, it becomes total masking, wherein a strong sound renders a lower-level sound completely inaudible. When total masking occurs, low-level sound components cannot be heard at all and do not contribute to loudness.

The sounds heard in everyday life are not all uniform. Many, like bangs and rattling sounds, change rapidly with time. Loudness is independent of duration for large pulse widths. Only when the pulse width drops below about 100 ms does the level of a pulse have to be increased to yield the same loudness. The test method has some effect on the results; however, regardless of the method the time constant of the ear appears to be between 35 and 100 ms. It also turns out that the laws describing loudness in terms of critical bands are valid for impulsive sound as well as continuous sound. In practical terms this means that sound should be measured with rms detectors with a time constant between 35 and 100 ms. While this seems to be a loose tolerance in light of the achievable accuracies in purely electronic measurements, we must remember that we are dealing with a subjective field in which there is yet much work to be done. Even so, the outputs of detectors with 35- and 100-ms time constants differ by only 4 dB in response to a single 5-ms tone burst, and the outputs of both are predictable and thus can be compared.

Acoustic measurements start with the transducer (microphone) which converts audio sound pressure into an electrical signal. The choice of a microphone is based on many parameters such as size, frequency response, sensitivity, and directional characteristics. Fortunately, the quality of present-day microphones simplifies the selection. The HP 15119A ½-in. Microphone (page 100) is particularly well suited for measurements in both diffuse and free (unidirectional) fields. Its size insures a minimum disturbance of the sound field, it covers a wide frequency and pressure range, it has an essentially flat frequency response, and it is omnidirectional. Where sensitivity is the prime parameter, the HP 15109B, a full 10 dB more sensitive, should be the choice.

Good measurement practice dictates the removal of the observer and other interfering objects, including the indicating instrument, from the sound field. To this end, HP microphones are equipped with 10-ft cables. Longer cables can be used, especially with the HP 15127A Cable Amplifier (page 101).

With the sound signal in electrical form, we need to process and display it in a meaningful way. The simplest and most widely used device is the sound level meter, basically an audio rms voltmeter. The frequency response of the sound level meter is shaped to account, in a first-order approximation, for the frequency response of the ear. Three response curves, A, B, and C, (Figure 2) have been standardized, e.g. in IEC Publications 123 and 179 and USA Standard S1.4-1961. (The recently proposed D curve is primarily for the measurement of jet aircraft noise.)

None of the three standards specifies detector time constant directly; instead, they specify overall response to a single 200-ms tone burst. This response, designated Fast, implies a nominal detector time constant of 127 ms (a Slow mode with a 1-s time constant is also allowed). Unfortunately, this does not enable us to predict response to shorter bursts (which are commonly found in practice). A German standard, DIN 45 633, Part 2, specifies an Impulse response in which the corresponding detector time constant is 35 ms, permitting predictable results for tone bursts as short as 5 ms. HP 8052A and 8062A Impulse Sound Level Meters (page 98) incorporate all three response modes.

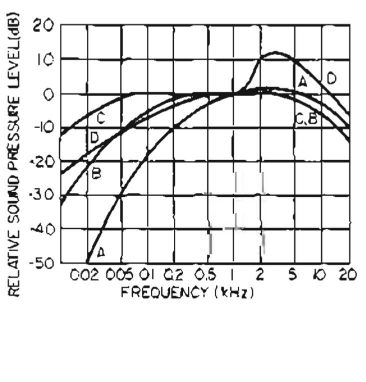


Figure 2. Frequency response curves.

The biggest problem in overall instrument response, even for a 200-ms tone burst, is the mechanical inertia of the meter. Per DIN 45 633, the 8052A/8062A include a peak detector and stretching circuit between the rms detector and the meter. The rise time of the peak detector is short compared to the 35-ms time constant of the rms detector; the discharge time, long compared to the response time of the meter. Thus the meter or an external dc level recorder has ample time to indicate the maximum rms value of impulsive sounds.

With the sound level meter, then, we measure the frequency- and time-weighted rms value of sound pressure. The frequency weighting (A, B, or C) cannot account for masking, and it's impossible to select the right weighting for all spectral components at once. Thus the sound level meter by itself can only be used to compare sounds from similar sources. We cannot, however, use it to compare autos and typewriters.

For sounds having no significant time structure, selection of time weighting is immaterial; all three give the same reading. In all other cases—and they are the rule rather than the exception—the Impulse mode is mandatory. This is the only one which provides an accurate measurement of sound level maxima and physiologically significant results.

For all its faults, the sound level meter is an extremely useful tool. It is inexpensive, easy to use, and highly portable. Properly used, it can indeed give meaningful data.

Including filters in the measurement system enables us to analyze the individual spectral components of a sound. A simple octave-band analysis system includes the 8052A or 8062A and 8055A Filter Set (page 98). Such a system is well suited for a variety of measurements including the determination of noise rating numbers. For greater resolution of spectral components the 8055A Filter Set can be equipped with third-octave filters (page 98). (HP octave and third-octave filters meet the requirements of US Standard S1.11-1966 for Class II and Class III respectively as well as IEC Recommendation 225).

For many applications, faster processing of data is necessary or at least desirable. The HP 8051A Loudness Analyzer (page 96) and 8054A Real Time Audio Spectrum Analyzer (page 93) provide rapid, completely automatic analysis. The 8051A determines loudness in objective terms according to the Zwicker method (ISO Recommendation 532, Method B). Comprising two octave filters, one 2/3-octave filter, and 17 third-octave filters, each approximating a critical bandwidth, the 8051A displays a new loudness spectrum on a crt (Figure 3) every 25 ms. The analyzer accounts for masking (the curved slopes in the figure) and the frequency response of the ear. In addition, the 8051A computes the area under the spectrum and displays it as total loudness in sones$_G$ on a front-panel meter. The crt display can be frozen for recording on a X-Y recorder, and preprinted paper permits Zwicker diagrams to be recorded directly. These diagrams can be used for detailed analysis or filed for reference purposes.

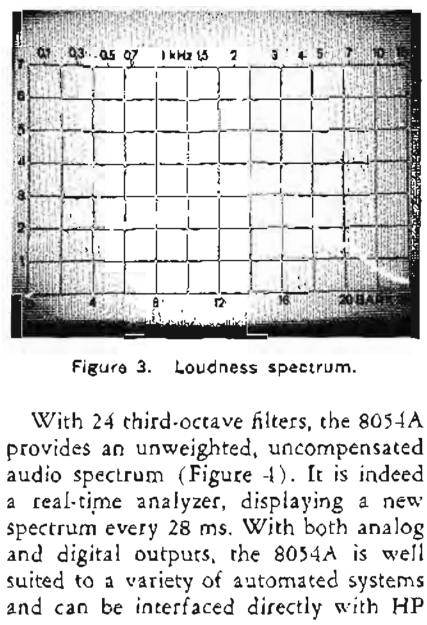


Figure 3. Loudness spectrum.

With 24 third-octave filters, the 8054A provides an unweighted, uncompensated audio spectrum (Figure 4). It is indeed a real-time analyzer, displaying a new spectrum every 28 ms. With both analog and digital outputs, the 8054A is well suited to a variety of automated systems and can be interfaced directly with HP computers.

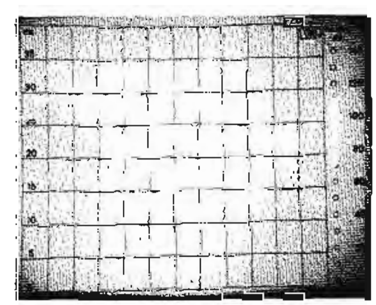


Figure 4. Third-octave spectrum.

Acoustic measurements and instrumentation are discussed in detail in Application Note 100. This Note is available from your local HP Field Office.

REAL-TIME AUDIO ANALYZER

Spectrum analysis in real time

Models 8054A, 8060A

In a real-time measurement, data must be presented in usable form at essentially the same time the event occurs, and the delay in presenting the data must be small enough to allow a corrective action to be taken if required. An advantage of measuring in real time is that the effects of external adjustments or changes in measurement parameter can be seen immediately and acted upon if necessary.

Measurements that previously took many hours to complete can now be performed in a few seconds with the Hewlett-Packard 8054A Real-Time Audio Spectrum Analyzer. Unlike other spectrum analyzers, which measure signal frequency components one at a time, the 8054A looks at twenty-four ⅓-octave frequency bands simultaneously, evaluates them in parallel, and displays the spectrum on a crt in less than 30 milliseconds, doing so at rates up to 42 spectra per second. The ⅓-octave bands have center frequencies from 50 Hz to 10 kHz in the standard instrument, other ranges are optional. The spectrum can be stored for detailed analysis, and a digital logarithmic voltmeter displays the signal levels in each channel. In addition to the visual displays, the 8054A can be connected to either analog or digital data processing instruments, giving it an unprecedented flexibility and speed in the processing of data.

The overall capability of the instrument permits measurements of signals as low as 1 μV and as high as 10 volts, an amplitude measurement range of 140 dB. The crt itself has a 40-dB display range which can be shifted in 10-dB steps to display any portion of the 140-dB amplitude range. The readout is in dB above one microvolt or in dB of sound pressure level when the input transducer is a condenser microphone with a sensitivity of 5 mV/μbar (HP 15109B). The parallel filters, with a ⅓-octave bandwidth relative to their center frequency, have an attenuation at the center frequency of the adjacent filter of typically 20 dB and at twice and half the center frequency of typically 50 dB. All filters meet the requirements of international standards (IEC 225). One-third octave filters ranging from 2 Hz to 25 kHz are available.

The display modes are selected by the front-panel push buttons designated FAST, SLOW, PEAK, and HOLD. In the FAST position an integrating time constant of about 0.1 s is used in the rms detector for rapid measurement of fast changing signals. The SLOW position provides a 1-second time constant for more random signals which require a longer integrating time. These time constants are chosen in accordance with IEC Rec. 179. Other rms time constants between 100 ms and 100 seconds can be provided on special order. The rms detectors are accurate, fast-responding devices for continuous input signals with crest factors up to 5. The PEAK mode indicates and stores the maximum peak amplitude of the spectrum over a selected period. The HOLD mode can be used in the RMS FAST, RMS SLOW, or PEAK position. The spectrum display can be retained at any instant for more extensive analysis when the HOLD push button is pressed. *A maximum RMS mode instead of true PEAK is available* as a no-cost option.

The crt controls are conveniently located in the center of the front panel. A hinged door conceals these controls during operation to prevent any accidental misadjustments.

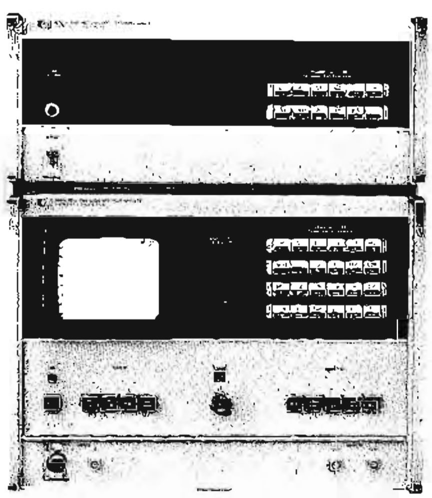
8054A

Spectrum analysis in real time
Models 8054A, 8060A

These controls adjust the horizontal and vertical position of the crt display as well as intensity, focus, and horizontal gain. No other calibration or adjustments are required.

Several scanning modes are possible to provide maximum versatility. In the MANUAL/REMOTE position any channel can be selected manually by front-panel push button or remotely by contact closure to ground. The DVM indicates the level of the signal in dB above 1 μV for the selected channel. The X-Y RECORDER scanning mode is used in conjunction with the HOLD display mode to record the displayed spectrum on an X-Y recorder; the channels are scanned at a rate of 1 s/channel. The channel being scanned is always indicated by a brightened portion of the trace on the crt and by an illuminated push button corresponding to that channel. In the PRINT 1 CYCLE mode a digital recorder can be used to scan and print out just one spectrum. For continuous recording the EXTERNAL INHIBIT mode allows the digital recording device to operate up to a speed of 1 channel/msec. If the recorder or data processing device must accept data at a rate of less than 1 channel/msec, an inhibit signal from the recorder to the 8054A prevents new data from being taken during the recording cycle. For instance, with a 5050A Digital Recorder (Page 133) the maximum rate of recording is 20 lines or 20 channels per second, whereas the 8054A can provide data at a rate of 1000 channels per second.

The Hewlett-Packard 8060A Real-Time Analyzer Module provides a twelve-channel extension for the 8054A Real-Time Audio Spectrum Analyzer. The unit is self-contained and extends the frequency range by twelve additional ⅓-octave filters, giving the 8054A a thirty-six-channel display covering all frequencies within 12 octaves. Price on request.



8060A

Applications

The 8054A can analyze any phenomena occurring in the audio spectrum and will find uses in a number of scientific disciplines. It is especially well suited for analyzing airborne or solid-borne sound, vibration, and noise.

For measurements of airborne sound the 8054A has a microphone input which is calibrated for condenser microphones such as the HP 15109B 1″ Microphone Assembly (Page 100) having a sensitivity of 5 mV/μbar. The 8054A supplies a 200 V polarization voltage to the condenser microphone, and microphone correction factors from −1 to +4.5 dB can be compensated in 0.5 dB steps by a rear panel switch. The HP 15119A ½″ Microphone Assembly can also be used with the 8054A if the operator makes a 10 dB correction to all readings to compensate for the 1.58 mV/μbar sensitivity of the ½″ microphone. The HP 15127A Cable Amplifier can be used with the HP 15119A Microphone Assembly to provide the 10 dB gain.

Using a vibration pick-up or accelerometer as the input transducer the 8054A becomes a real-time vibration analyzer for shock and vibration testing. The operational condition of machinery can be determined through such a vibration analysis. The 8054A can be a most useful quality control measurement tool to anyone who manufactures or maintains anything with moving parts. Thus, the 8054A finds many applications in the manufacture of automobiles, office equipment, industrial machines, and aircraft.

Since vibration causes the sensation of sound, the acoustical applications of the 8054A are often closely related to those applications in vibration analysis. Among the acoustical applications are aircraft noise analysis for determination of Effective Perceived Noise Level (EPNL), reverberation time measurements, frequency response testing of sound systems, determination of airborne and impact sound protection in architectural acoustics, and analysis of noise generated by industrial machines, automobiles, and jet engines. Underwater acoustical applications include studies of marine sounds and propagation. The 8054A is also a useful tool in speech analysis and in the manufacture of loudspeaker and Hi-Fi equipment. Waveform analysis and the characterization of earth tremors are other possible applications.

The major functions of the 8054A including display mode, range, scanning mode, and channel selection, can be selected remotely by contact closure or saturated npn transistor to ground. Thus the 8054A can be used in closed-loop data processing systems when used with HP Computers 2114A, 2115A, or 2116A (Page 104). The 8054A easily fits into virtually any automated system whose input signal is in the audio range.

With the advent of the small digital computer (Page 104) is it now possible to carry both the Analyzer and a computer to the measurement site to obtain processed results as the measurements are made. The flat response of the 8054A makes it possible for the computer to apply a desired weighting factor to the data. The computer can also subtract background noise, make adjustments that account for barometric pressure or relative humidity, and perform other manupulations to give the data in the desired form within an instant of the experiment.

Specifications

Frequency range: twenty-four 1/3-octave filters with center frequencies from 50 Hz to 10 kHz. Other 1/3-octave filters with center frequencies from 2 Hz to 16 kHz are available on special order.

Filter characteristics: attenuation outside the passband

at 0.79 f_o and 1.26 f_o+ : typically 20 dB
at 0.5 f_o and 2 f_o : typically 50 dB
at 0.25 f_o and 4 f_o : typically 70 dB

All filters meet the requirements of international standards (IEC 225).

+f_o is the center frequency of the passband. 0.79 f_o and 126 f_o correspond to the center frequencies of the adjacent 1/3-octave filters.

Readout

CRT display: 40 dB display range, calibrated in dB (5 dB/div) with internal graticule. Range indicated. Two channels per horizontal division.

Digital display: four-digit DVM readout of selected passband level in dB above 1 μV. Resolution of 0.1 dB.

Amplitude range: 0 to 140 dB above 1 μV (1 μV to 10 V). The 40 dB dynamic range displayed on the crt can be shifted in 10 dB steps over the entire amplitude range.

Display modes

RMS slow and RMS fast: dynamic characteristics of rms modes as specified in IEC 179. Other combinations of rms time constants between 100 ms and 100 s are available on special order.

Peak: rise time of the peak detector is less than 4 ms.

Hold: storage of the instantaneous crt display can be accomplished in any of the above modes by pressing the HOLD push button.

Accuracy

RMS mode:

Digital display: for steady sine wave signal at filter center frequency: ±1 dB in upper 30 dB of display, ±1.5 dB in lower 10 dB of display. For tone burst signals with crest factors less than or equal to 3: ±1 dB in respect to sine wave accuracy. For signals with crest factors between three and five: ±1.5 dB in respect to sine wave accuracy, for random noise ±0.2 dB in respect to steady sine wave signals.

CRT display: ±1 dB in respect to digital display accuracy.

Peak mode: ±1 dB in upper 30 dB of crt display in respect to steady sine wave rms accuracy. ±1.5 dB in lower 10 dB of crt display in respect to steady sine wave rms accuracy.

Hold mode: crt display changes less than ±1 dB/hr. at full scale, less than ±1 dB/min at full crt display —40 dB.

Scanning

Manual remote: any channel can be selected manually by front-panel push button or remotely by contact closure to ground. The digital display indicates the band level, and the channel is identified by illuminating the relevant channel button and brightening the respective zone on the crt display.

X - Y recorder: automatic sequential scanning at a rate of 1 s/channel of all 24 channels provides analog outputs suitable for processing by standard X-Y recorders. Scanning can be repeated by remote control.

Ext. inhibit: the rate of scanning is controlled by the hold-off signal (voltage greater than 10 V) from the digital recorder or computer which is processing the BCD output. The scanning is sequential and continuous. A maximum scanning rate of 1 channel/ms can be achieved with a relatively fast computer.

Print 1 cycle: this mode is similar to EXT. INHIBIT, but only one sequential scanning of the twenty-four channels is completed. Scanning can be repeated by remote control.

Reset: X - Axis and Y - Axis outputs are grounded; digital outputs produce blanking signals.

Inputs

Input A: directly calibrated in dB of sound pressure level for microphones with a nominal sensitivity of 5 mV/μbar. Microphone correction factors from —1 dB to +4.5 dB can be compensated for in 0.5 dB ±0.25 dB steps by a rear-panel switch. A built-in power supply provides a 200 V ±4 V polarization voltage for condenser microphones and operating voltage for preamplifiers. Up to 12.5 mA can be supplied for the preamplifier and additional cable amplifiers. The input connector is a three-pin Cannon type XLR-3-31 audio connector. Input impedance is >100 kΩ.

Input B: directly calibrated in dB above 1 μV. BNC input connector. Input impedance is >100 kΩ. The input amplifier has an overload capability of approximately 30 dB.

Max. input: 150 V dc, 50 V peak ac.

Outputs (all outputs—capacitive loading, ≤1 nF, resistive, ≥10 kΩ)

Analog X - Y recorder:

X - Axis: 200 mV ±40 mV/channel.
Output impedance: <20Ω. BNC connector.

Y - Axis: 0 to 8 V full scale, calibrated in dB. (200 mV/dB).
Output impedance: <20Ω. BNC connector.

Pen lift: contact closure to operate "Pen." Telephone jack.

Ext. oscilloscope:

X: Linear ramp approx. 0 to 8 V.
Output impedance: <20Ω. BNC connector.

Y: Pos. "Log" 200 mV/dB. Pos. "Lin" 8 V full scale.
Output impedance: <20Ω. BNC connector.

Z: Provides blanking pulse of approx. +6 V open circuit dc-coupled.
Output impedance: <15 kΩ. BNC connector.

Auxiliary output: output of Input Amplifier.

Gain range: —40 to +60 dB in 10 dB ±0.2 dB steps.

Maximum output swing: approx. 10 V pp.

Output impedance: <20Ω. BNC connector.

Digital outputs:

Connector type: Amphenol 57-40500 (50-pin).

Mating connector: Amphenol 57-30500.

Code: 1-2-4-8 BCD "1" state positive. "0" level: 0 V nominal; "1" level: +5 V open circuit, nominal; source impedance: 7.5 kΩ max. each line.

Reference levels: ground; approx. +5 V, low impedance.

Print command: step from approx. 0 V to +6 V, dc-coupled, 20 μs minimum duration, 5 V/μs minimum rise rate, source impedance: 100Ω maximum.

Hold-off requirement: voltage must be more than +10 V. Input impedance: 62 kΩ.

Accuracy of digital outputs and Y-axis outputs: same as digital display.

Remote control: selection of range, channel, and display mode made by contact closure or saturated NPN transistor to ground.

Environment: ambient temperature 0°C to 50°C and relative humidity to 95% at 40°C.

Power requirements: 110 or 220 V —10%, +15%, 50 Hz to 400 Hz, approximately 100 W.

Dimensions: 16¾" wide (425 mm), 12" high (306 mm) (without feet) 24⅜" deep overall (708 mm).

Accessories furnished: 200 sheets of Diagram paper (08054-90100), 10 sheets of Diagram Paper (08054-90101), 1 15-pin Extender Board, 1 18-pin Extender Board, 1 Rack Mounting Kit, 1 Connector Amphenol 57-30500, 1 BNC Male to Binding Post Adaptor, 2 Pen-lift Connectors (Telephone jacks), 2 BNC Banana Cables.

Price: Model 8054A, $8950 ($8000 at factory in West Germany).

Option 01: A MAXIMUM RMS Display Mode replaces the normal PEAK Mode. No charge.

Option 02: A to D converter and digital display not included.
Price: less $600.

ACOUSTICS

LOUDNESS ANALYZER

A powerful new tool for sound analysis

Model 8051A

8051A

Until recently, much too little was known about how the ear translates sound pressure into loudness. Early sound level meters attempted to measure loudness by measuring the level of a frequency-weighted sound pressure. They gave good results for continuous narrow-band sounds but were often in error by up to 20 dB for wide-band or impulsive sounds. Recent research has given us a much better understanding of how the human ear works. One result of this research is an instrument that responds to the loudness of sounds in very much the same way that the ear does.

The Hewlett-Packard 8051A Loudness Analyzer gives data which correspond closely to the subjective sensation of loudness. It does this by simulating the known characteristics of the human ear according to Zwicker's method, which is described in ISO Recommendation 532, Method B. The 8051A divides the audio range into approximately critical bands by use of filters with bandwidths of one-third octave or multiples thereof. The range between 45 Hz and 14 kHz is covered by 20 such filters, according to ISO Recommendation 532. The Analyzer works for wide-band or narrow-band, continuous or impulsive sounds. It can even handle single-shot sounds.

The Analyzer takes inputs from a microphone or a tape recorder and makes a continuous analysis of them. It displays the resulting Zwicker diagram (a plot of loudness density versus subjective pitch) on a crt showing how the loudness components in each of 20 frequency bands contribute to the total loudness. A new plot is made every 25 ms so that even transient sounds can be analyzed conveniently. Total loudness of a sound, that is, the integral of the Zwicker diagram, is also computed by the Analyzer and displayed on a meter.

The 8051A has four measurements ranges which accommodate sounds with loudnesses of 1 to 400 sones$_G$, equivalent to the loudness level of 40 to 127 phons$_G$. (The subscript G indicates that his loudness is calculated in terms of critical bands, not subjectively measured). This range includes sounds like those present in a 'quiet room' as well as very large sounds which can cause ear damage. Corrections for frontal or diffuse sound fields are made automatically by the Analyzer according to the settings of front-panel buttons.

How to measure short, impulsive sounds—like the sound of a stamping machine or a single typewriter stroke—has always been one of the most vexing problems in loudness measurement. Previously, the only way to analyze a single-shot phenomenon was to capture it on magnetic tape, make a tape loop and try to analyze the sound by playing it back over and over. With the new loudness analyzer, impulsive sounds are no longer a serious problem. The Analyzer has electronic storage circuits which can be called on to 'remember' the peak loudness of sounds occurring during any desired interval. If, as is usually the case, the single-shot sound is much louder than the background noise in the area, the loudness analysis stored by the Analyzer will be that of the short sound.

The 8051A can also be instructed to hold its most recent loudness analysis for several minutes. This allows the analysis of a changing sound to be frozen at any desired time and held long enough for it to be recorded or photographed. Both the hold and peak modes can be remotely controlled. Using the hold feature together with a built-in display scanner, the 8051A can make Zwicker plots automatically on an X-Y recorder. Sound pressure levels in each channel can be read from the special Zwicker recorder paper. An additional recorder output is provided for recording total loudness versus time.

Specifications

Loudness range: 1 $sone_G$ - 400 $sones_G$ (*corresponding to* 40 $phons_G$ - 127 $phons_G$) in 4 ranges. Full-scale meter deflections: 12, 40, 120, and 400 $sones_G$. Corresponding sensitivity ranges of loudness density display: 0.12, 0.4, 1.2, and 4 ($sones_G$/Bark)/division.

Accuracy: deviation less than ±5% of full scale from the results obtained by Method B for Calculation of Loudness Level according to ISO Recommendation 532 (DIN 45631; BS4 198, 1967).

Noise: less than 0.3 $sone_G$ in the most sensitive range for source resistances of 600 Ω or less.

Sound pressure level ranges: representative values of SPL for loudness and loudness density readings at 1 kHz (frontal field).

Range $sones_G$	SPL dB	Loudness Density divisions	Loudness $sones_G$
400	110	5.5 ±0.3	128 ± 20
120	90	5.7 ±0.3	32 ± 6
40	70	5.35 ±0.3	8 ± 2
12	50	5.25 ±0.3	2 ±0.6

The maximum measureable SPL at 1 kHz is 114 dB. 0 dB = 2 × 10^{-4} μBar.

Microphone input: suitable for condenser microphones with a nominal sensitivity factor of 5 mV/μBar. Microphone correction factors from −1 to +4.5 dB can be compensated in 0.5 dB steps by rear panel switch. A 200 V ±2.5% is provided as polarization voltage and to supply the microphone preamplifier and/or additional cable amplifiers.

Maximum current: 12 mA.
Input impedance: 100 kΩ.
Connector: Cannon XLR-3-3.

Direct input: accepts signals with 1 mV corresponding to a sound pressure level of 60 dB.
Input impedance: 100 kΩ.
Connector: BNC.

Filter specifications:

Channel	Relative Bandwidth	Center Frequency
1	octave	63 Hz
2	octave	125 Hz
3	two-third octave	224 Hz
4 . . . 20	one-third octave	315 Hz . . . 12.5 kHz

The ⅓ octave filters have an attenuation of about 20 dB in the center of the next pass band and about 60 dB at twice the center frequency. Roll-off of the octave filters is approximately 40 dB/octave. The filters exceed the requirements laid down in IEC Recommendation 225.

Diffuse field network: response as per ISO Recommendation 454.
Accuracy: 45 Hz - 4 kHz: ±0.5 dB
5 kHz - 12.5 kHz: ±1 dB.

Environment: ambient temperature from 32°F to 122°F (0°C to 50°C) and relative humidity to 95% at 104°F (40°C).

Outputs:

Meter: positive 4 V for full-scale deflection of the meter. Load resistance 1 kΩ or more.

X-axis: positive 10 V for full horizontal deflection of the sampling point on the crt.
Load resistance 1 kΩ or more.

Y-axis: positive 7 V for full vertical deflection of the sampling point on the crt.
Load resistance 1 kΩ.

Crt. sync: positive pulse to trigger external equipment coincident with the start of the internal sweep, about +6 V.

Crt. vertical: output waveform of vertical amplifier to drive external oscilloscopes or fast recorders. Positive 1 V/div. of the vertical deflection on the crt. Load resistance 1 kΩ or more.

Auxiliary output: output of preamplifier. The gain of the preamplifier depends on the range setting, for DIRECT input and FRONTAL sound field as follows:

Range - sones	Amplifier - Gain
400	−20 dB ±0.5 dB
120	0 dB ±0.5 dB
40	+20 dB ±0.5 dB
12	+40 dB ±0.5 dB

Display:

Instant: display of the instantaneous loudness spectrum on the crt and indication of the total loudness on the meter.

Peak: display of the maximum total loudness on the meter with the crt displaying the corresponding spectrum. Remote operation by contact closure.

Hold: storage of display on the crt and loudness reading on the meter. Less than 0.3 div. change of the crt display for up to 2 minutes of storage. Remote operation by contact closure.

Check: internal noise generator checks overall operation of the instrument.

Scanning: manual or automatic. Scanning time for the whole spectrum in the automatic mode is 90 seconds ±30 seconds.

Overload: overload lamp glows if the crest factor of the signal in any channel exceeds 7 at full scale, or if any of the circuits are overdriven.

Power requirements: line voltage 110 V or 220 V, −10%, +15%, 50 Hz - 400 Hz.

Power consumption: approximately 80 W.

Dimensions: 16¾″ wide (425 mm), 12″ high (306 mm) (without feet), 24⅞″ deep overall (708 mm).

Weight: 64 lbs (29 kg).

Accessories supplied: detachable power cord with Schuko or NEMA plug.
200 sheets of Loudness Analysis Diagram (ISO Recommendation 532) covering each range in the frontal and diffuse sound field.

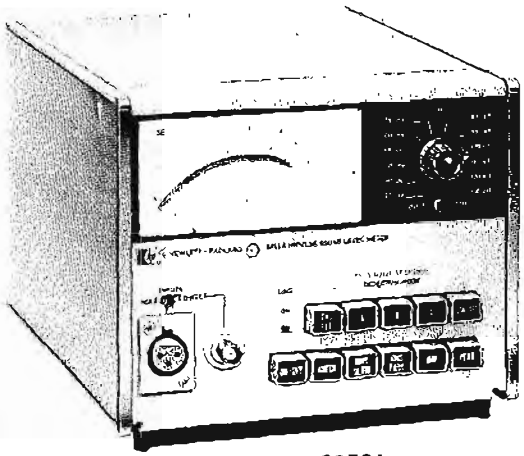
12 sones free field	P/No. 08051-90100
40 sones free field	P/No. 08051-90101
120 sones free field	P/No. 08051-90102
400 sones free field	P/No. 08051-90103
12 sones diffuse field	P/No. 08051-90104
40 sones diffuse field	P/No. 08051-90105
120 sones diffuse field	P/No. 08051-90106
400 sones diffuse field	P/No. 08051-90107
Rack mounting	5060-0779
15-pin extender board	5060-1744

Price: Model 8051A, \$5500 (\$5000 at factory in West Germany).

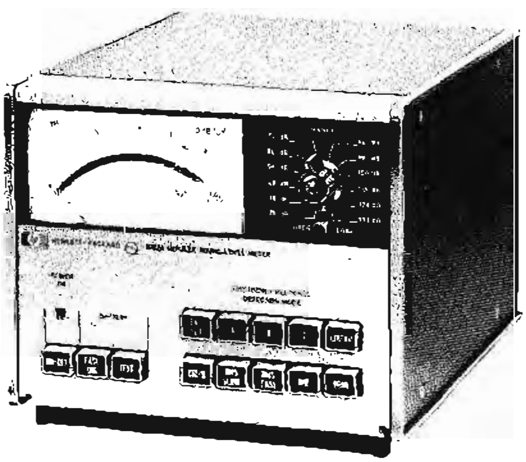
IMPULSE SOUND LEVEL METERS

Precision impulse measurements

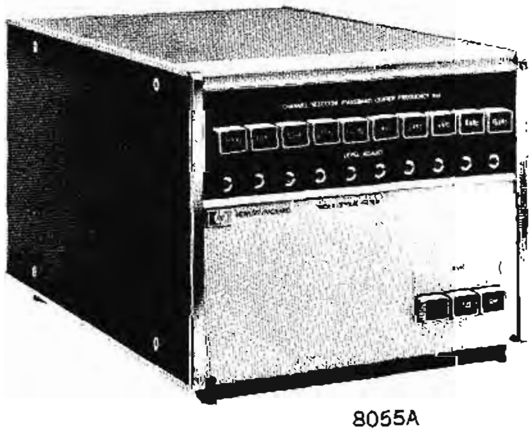
Models 8052A, 8062A, 8055A



8052A



8062A



8055A

The Hewlett-Packard Models 8052A and 8062A Impulse Sound Level Meters can make virtually the complete range of sound level measurements. Basically audio voltmeters, they have selectable weighting factors, detection modes, and rms time constants, plus appropriate meter scales. Controls are clearly marked, and push buttons simplify selection of operating modes. Both sound level meters are identical in operation. The 8052A is powered from standard power lines while the 8062A can be powered from internal rechargeable batteries as well.

Both rms and peak values can be measured. Different time constants (about 1 second "slow" and 100 ms "fast") can be selected for rms measurements of signals with crest factors up to five. These slow and fast modes can measure accurately only continuous and quasi-continuous sounds. But the new impulse mode (35 millisecond integrating time constant) allows accurate measurements of impulsive sounds as well as continuous sounds. The impulse mode ideally permits measurements of impulsive sounds like the stroke of a typewriter key or the blow of a punch press machine. In the peak mode, peak values of single impulses as short as 100 microseconds can be measured accurately.

The frequency response of these instruments is also selectable. In addition to a linear response mode, in which the response is flat from 5 Hz to 20 kHz, three weighted responses (A, B, C) are available. The response curves of these weighted modes meet the requirements specified in the IEC Recommendation 179 for precision sound level meters. The new D-weighting network for monitoring aircraft noise is also available as an option in lieu of the B-network.

The 8052A and 8062A can also be used as audio voltmeters when the linear frequency response mode is selected. As with sound measurements, both peak and rms levels can be measured and crest factors determined easily. Full-scale sensitivity ranges from 30 microvolts to 10 volts. A linear analog output proportional to the meter deflection (5 V at full scale) is available in all modes of operation.

As a companion unit for the 8052A or 8062A, the Hewlett-Packard Model 8055A Filter Set enables octave band measurements to be made quickly and easily. The 8055A is furnished with eight octave filters with center frequencies from 63 Hz to 8 kHz. Each filter satisfies the requirements of the IEC Recommendation 225, American Standard (S1. 11-1966) Octave Band Filter, Class II, and German Standard DIN 45651. The attenuation outside the band pass of one octave from the center frequency is approximately 23 dB, for two octaves and three octaves approximately 47 dB and 65 dB respectively. The signal-to-noise ratio is greater than 70 dB referred to 3 V rms output. Options are available to include additional filters to extend the center frequency range. Option 01 furnishes two additional octave filters with center frequencies of 31.5 Hz and 16 kHz, extending the frequency range from 22 Hz to 22 kHz. Option 02 adds an additional octave filter with a 31.5 Hz center frequency and one broad-band filter with a D-weighted frequency response according to the draft secretariat revision (Nov. 67) of ISO Recommendation 507 with a tolerance of ±1 dB. The same 31.5 Hz center frequency, octave filter is added for option 03 with one amplifier section for summing up the outputs of all nine octave filters. Selection of filter is done by push button, as is filter gain. Three choices of gain are available: 0 dB, 20 dB, and variable. In the variable mode the gain of each filter can be set independently between −20 dB and +20 dB. Thus any weighting curve can be preset for a specific measurement, yet easily can make general measurements without upsetting the special calibration.

Price: Model 8055A, $520 ($475 at factory in West Germany). Options 01, 02 and 03, add $100.

For greater versatility the 8055A Filter Set can be equipped with one-third octave filters covering a variety of frequency ranges. Information and prices on request.

Specifications

Frequency range: 5 Hz to 20 kHz.

Amplitude range:

Using direct input or HP preamplifier: 30 μV to 10 V full scale.

Using HP 15109B 1-in. condenser microphone:

Sound pressure level: 35 to 140 dB (0 dB = 2 x 10^{-4} μbar).

Sound level (A-weighted): 22 to 140 dB.

Octave level: 22 to 140 dB.

One-third octave level: 15 to 140 dB.

Using HP 15119A ½-in. condenser microphone:

Sound pressure level: 55 to 150 dB.

Sound level (A-weighted): 40 to 150 dB.

Octave level: 40 to 150 dB.

One-third octave level: 30 to 150 dB.

Overall accuracy:*

2 Hz – 6 Hz	6 Hz – 20 kHz	20 kHz – 40 kHz
±1 dB	±0.5 dB	+0.5 −1.0 dB

Weighting networks: three weighting networks modify frequency response in accordance with A, B, or C, specified in IEC Recommendation 179 for precision sound level meters (Also see Option 01).

Detection mode:

Rms slow and rms fast: indication proportional to rms value of applied signal. Signals with crest factors up to 5 affect accuracy less than ±0.5 dB (±0.75 dB above 40°C, for crest factors above 3). Dynamic characteristics per IEC Recommendation 179.

Impulse: indication proportional to the maximum rms value of applied signals, weighted with a 35 ms time constant per the proposed standard for impulse sound level meters.

Peak: indication proportional to the absolute peak value of applied signal with an accuracy of ±1 dB; rise time <100 μs, discharging rate <0.1 dB/s.

Noise: approximately 5 μV referred to the input with the input terminated in 600 Ω.**

Absolute maximum input: ac, 50 V peak; dc, 200 V.

Overload recovery time: <5 s for 80 dB overload in FAST meter response.

Overload indicator: front panel indicator lights when input signal crest factor exceeds five at full scale, or when the input signal is excessive.

Self check: internal signal permits verification of over-all operation.

Input impedance: 100 kΩ shunted by approximately 100 pF; about 1000 MΩ shunted by approximately 5 pF when an HP Microphone Preamplifier such as 15108B with BNC adapter is used.

Microphone input: accepts input signals from one of the HP Condenser Microphones or Preamplifiers and supplies +200 V ±2% as polarization voltage for the microphone cartridge and operating voltage for the microphone preamplifier.***

Microphone sensitivity: range switch calibrated in dB SPL for microphones with a nominal sensitivity factor of 5 mV/μbar (See Option 02); deviation up to +1 and −4.5 dB can be compensated for in 0.5 dB steps.

External filter: external filters can be used to limit the frequency range of the 8052A and 8062A. These filters are electrically inserted into the 8052A and 8062A circuits using the appropriate connectors on the rear panel of the 8052A and 8062A.

External filter input: provides output signal to filter; 100 mV peak or rms for full scale meter indication with 0 dB gain through the filter. Output impedance <20 Ω, BNC female connector.

Maximum output: 9 V pp.

Load resistance: ≥600 Ω, 1 nF.

External filter output: receives output signal from filter. Input Impedance >100 kΩ shunted by approximately 100 pF, BNC female connector.

Meter: taut-band meter movement with scales individually calibrated to the movement; three meter scales, −10 to +10 dB, 0.1 to 1, and 0.3 to 3 V.

Recorder output: 0 to +5 V proportional to meter deflection. Output impedance <20 Ω, BNC female connector. Load resistance ≥600 Ω, 1 nF.

Operating environment:

8052A: 14° to 122°F (−10° to 50°C), relative humidity up to 95% at 104°F (40°C).

8062A: 14° to 113°F (−10° to +45°C), relative humidity up to 95% at 104°F (40°C).

Power requirements:

8052A: 110 or 220 V, −10%, +15%, 50 to 400 Hz, approximately 5 W.

8062A: two internal rechargeable batteries or external 110 or 220 V, −10%, +15%, 50 to 400 Hz, approximately 5 W. Battery operating time 8 hrs. Batteries are trickle-charged when instrument is operated from external power line; fast charge can be selected, but instrument cannot be operated in this mode. Battery condition can be read on the meter.

Weight:

8052A: net 9 lb (4 kg); shipping 11 lb (5 kg).

8062A: net 12 lb (5,5 kg); shipping 14 lb (6,3 kg).

Accessories furnished: two 15-pin extender boards, one cable ac power, one adapter BNC to binding post.

Dimensions: 6-3/32" high, 7-25/32" wide, 11" deep (155 x 190 x 279 mm).

Options:

01: A, D, and C weighting networks in lieu of A, B, and C networks. The D-weighted network meets the requirements of the draft secretariat revision (Nov. 67) of ISO Recommendation 507 with a tolerance of ±1 dB. Price: Add $25.00.

02: range switch calibrated in dB SPL for microphones with a nominal sensitivity factor of 1.58 mV/μbar. No additional charge.

Price: Model 8052A, $670 ($600 at factory in West Germany).
Model 8062A, $720 ($650 at factory in West Germany).

*The overall accuracy is the sum of the errors introduced by a change of range (±0.1 dB), the deviation from linearity of the rms detector with meter reading in the upper 10 dB of the scale (±0.2 dB), and the deviation from LINEAR frequency response in the RMS SLOW detection mode referred to a steady sine wave of 1 kHz. Deviation from linearity in the lower 10 dB of the scale which overlaps the adjacent range setting is 0.5 dB. These specifications are valid for the whole operating environment range.

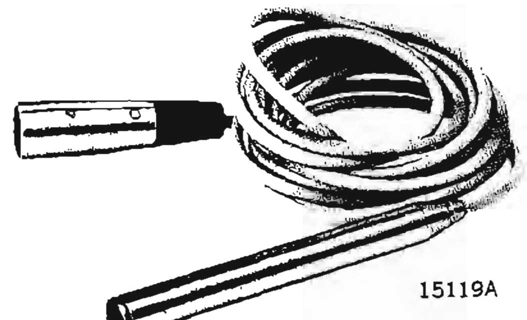
**Noise adds to the signal approximately by the relation: Reading = $\sqrt{(\text{signal})^2 + (\text{noise})^2}$.

***The combination of HP 8052A or 8062A and one of the HP Condenser Microphones fulfills the requirements of IEC Recommendation 179 and the German Standard DIN 45633 for precision sound level meters and impulse sound level meters.

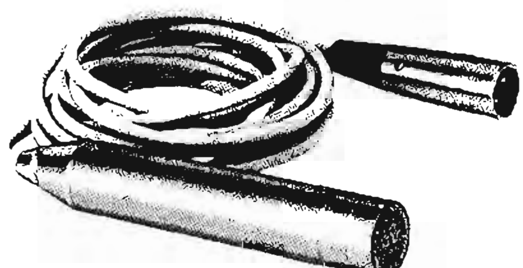
MICROPHONES, ACCESSORIES

Flat frequency response for greater accuracy

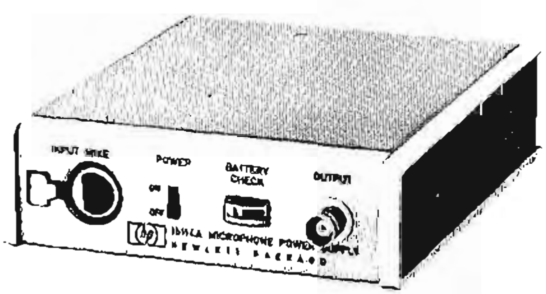
Models 15109B, 15119A, 15127A, 15114A



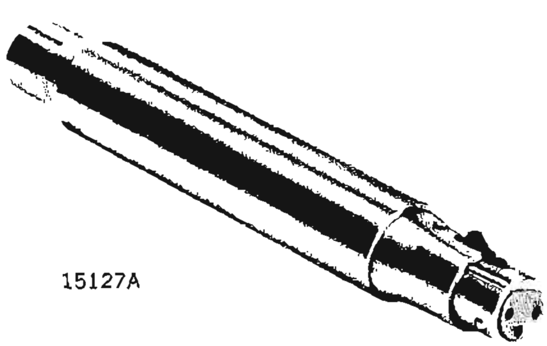
15119A



15109B



15114A



15127A

The Hewlett-Packard 15119A ½-in. Condenser Microphone Assembly is a precision tool for making critical acoustic measurements. Frequency response for a plane frontal sound field is ±1 dB over the entire audio range, 20 Hz to 20 kHz. Because it is omni-directional, the 15119A can be used to measure diffuse as well as directional sound fields. Its ½-in. configuration ensures a virtually negligible disturbance of the sound field by the microphone itself, a prerequisite for accuracy at high frequencies. Thus, full advantage can be taken of the flat frequency response.

Hewlett-Packard also offers a 1-in. Condenser Microphone Assembly, Model 15109B, for measuring extremely low level sounds. A full 10 dB more sensitive than the 15119A, the 15109B otherwise has similar characteristics. Both Microphone Assemblies include a microphone cartridge and preamplifier with a 10-foot cable.

Both preamplifiers are available separately under model numbers 15108B in the 1-in., 15118A in the ½-in. configuration. These preamplifiers are all solid state with field effect transistors (FET) in the input stage. Input impedance is greater than 1000 MΩ shunted by less than 2 pF. In addition, the preamplifiers have extremely flat frequency response (±0.25 dB from 5 Hz to 200 kHz) and low noise and are free from microphonics. With essentially unity gain, these preamplifiers make excellent broadband audio impedance converters and isolators. They are extremely well suited as preamplifiers for vibration pickups such as accelerometers. Furnished BNC adapters provide convenient input connectors and increase input capacitance to only 4 pF. Operating voltage for the preamplifiers is obtained from the same power supply which provides the polarization voltage (+200 V) required by the microphone cartridges. Being solid state, the preamplifiers are only a nominal drain on this supply.

The Microphone Assemblies and Preamplifiers make ideal input devices for HP acoustic instrumentation such as the 8051A Loudness Analyzer, 8052A and 8062A Impulse Sound Level Meters, and the 8054A Real-Time Audio Spectrum Analyzer. All these instruments have microphone inputs (three-conductor audio connectors with which the microphone cable connectors mate directly) and built-in power supplies to provide the +200 V.

15114A microphone power supply

The 15114A Microphone Power Supply permits the use of the Microphone Assemblies and Preamplifiers with instruments which do not provide the necessary voltage or do not have the appropriate input connectors. The microphone preamplifier cable connects directly to the supply, and the audio output signal is available from a BNC connector on the supply for convenient connection to the associated equipment.

The 15114A is a truly portable unit, operating for at least eight hours from four standard 1.5 volt batteries. Rechargeable batteries can also be used, and the compact 15144A Charging Unit recharges even fully discharged batteries overnight (about 14 hours). The Charging Unit also permits the 15114A to be operated from standard ac line voltages.

Price: Model 15114A, $140 ($130 at factory in West Germany).
Model 15144A, Price on request.

15127A cable amplifier

The 15127A Cable Amplifier permits HP Microphone Assemblies and Preamplifiers to be operated at considerable distances from associated equipment. A single 15127A can drive up to 100 meters (330 feet) of cable, even longer if a reduction in upper frequency limit and/or maximum output voltage is permissible. Operating power is obtained from the microphone voltage, so the number of Cable Amplifiers which can be used is limited only by the ability of the power supply to furnish the required current. Standard Cable Amplifiers provide 0 dB gain option 01 units, 10 dB gain. If desired, the gain can be changed in the field with a simple wiring change.

The 15127A is particularly useful with less portable measuring instrumentation such as the HP 8051A Loudness Analyzer and 8054A Real-Time Audio Spectrum Analyzer. These instruments can supply enough current from their microphone power supplies to support a Cable Amplifier in addition to a Microphone Assembly. Also, the 10 dB gain of the option 01 Cable Amplifier provides direct calibration of the display of these instruments when used with the ½-in. Microphone Assemblies.

Price: Model 15127A, $90 ($90 at factory in West Germany).

Specifications — 15119A/15109B

Sensitivity (nominal): individual calibration supplied
15119A: 1.58 mV/μbar (—56 dB re 1 V/μbar).
15109B: 5 mV/μbar (—46 dB re 1 V/μbar).

Frequency response: free field (frontal incident)
15119A: ±1 dB from 20 Hz to 25 kHz.
15109B: ±1.5 dB from 20 Hz to 16 kHz.
+0, —3 dB from 16 kHz to 18 kHz.

Maximum deviation from free field for diffuse field:
15119A: —1 dB up to 3 kHz
—2 dB up to 5 kHz
—4 dB up to 10 kHz
—6 dB up to 20 kHz
15109B: —1 dB up to 1.5 kHz
—2 dB up to 3 kHz
—4 dB up to 6 kHz
—6 dB up to 9 kHz

Dynamic range (from equivalent A-weighted noise level to 3% harmonic distortion):
15119A: 30 to 150 dB above 2 x 10^{-4} μbar
15109B: 17 to 140 dB above 2 x 10^{-4} μbar.

Temperature coefficient: ≤0.01 dB/°C (0.006 db/°F) change in sensitivity, —10 to +50°C (14° to 122°F).

Effect of atmospheric pressure: for 10% change in ambient pressure from 1 atm.
15119A: ±0.1 dB
15109B: <±0.2 dB.

Power requirements: +200 V ±5 V, <5 mV ripple, 2.5 mA maximum.

Dimensions (not including 10 ft (3 m) cable):
15119A: 0.50" (12.7 mm) diameter, approximately 5⅛" (130 mm) long.
15109B: 0.97" (23.8 mm) diameter, approximately 5¼" (135 mm) long.

Weight:
15119A: net 1 lb (0,45 kg). Shipping 3 lb (1,4 kg).
15109B: net 1½ lb (0,65 kg). Shipping 4 lb (1,8 kg).

Environment: —10 to +50°C (14 to 122°F), relative humidity up to 95% at +40°C (104°F).

Accessories furnished: 1000 pF Input Adapter, Tripod Mounting Adapter.

Accessories available:
HP 15124A for 1": Insert voltage adapter.
HP 15125A for ½": Insert voltage adapter permit determination of microphone cartridge open circuit voltage for calibration purposes. $50.00.
HP 15142A for 1": Matching capacitors.
HP 15134A for ½": Matching capacitors. Capacitive load for measuring noise under operating conditions. $12.50.
HP 1000-0501 Tripod, permits support of the microphone away from bulky objects such as measuring instrumentation, which would interfere with the sound field. $35.00.

Price: Model 15119A, $275 ($250 at factory in West Germany).
Model 15109B, $270 ($250 at factory in West Germany).

15108B and 15118A preamplifiers

Gain (at 1 kHz with Input Adapter attached): 0 dB +0, —0.25 dB.

Frequency response (with Input Adapter attached):
With Nominal Load and 1 V rms Maximum Output: ±0.25 dB from 5 Hz to 200 kHz.
With Nominal Load and 10 V rms Maximum Output: ±0.25 dB from 5 Hz to 20 kHz.

Maximum input: 10 V rms (sine wave).

Dynamic range (from equivalent A-weighted noise level to 1% distortion):
15108B: 17 - 140 dB above 1 μV.
15118A: 20 - 140 db above 1 μV.

Noise (A-weighted):
15108B: <7 μV rms with 68 pF across input.
15118A: <10 μV rms with 27 pF across input.

Input impedance: >1000 MΩ shunted by <2 pF without input adapter, <4 pF with.

Output impedance (at 1 kHz): <100 Ω.

Nominal load: 100 kΩ shunted by 500 pF.

Maximal output current: 0.6 mA.

Power requirements: +200 ±5 V, <5 mV ripple, 2.5 mA maximum.

Environment: —10 to +50°C (14 to 122°F), relative humidity up to 95% at +40°C (104°F).

Dimensions:
15108B: 0.936" (23.78 mm) diameter, 4¾" (120 mm) long not including 10 ft (3 m) cable.
15118A: 0.50" (12.7 mm) diameter, 4¾" (120 mm) long not including 10 ft (3 m) cable.

Weight:
15108B: net 1½ lb (0,65 kg). Shipping 4 lb (1,8 kg).
15118A: net 1 lb (0,45 kg). Shipping 3 lb (1,4 kg).

Price:
Model 15108B. $140 ($130 at factory in West Germany).
Model 15118A: $145 ($130 at factory in West Germany).

PRECISION NOISE GENERATOR
Pseudo-random pink and white noise
Model 8057A

8057A

The Hewlett-Packard 8057A Precision Noise Generator is an audio frequency noise generator producing pseudo-random signals, available at binary and Gaussian distribution outputs. These signals are repeated noise patterns of known content and duration. Both white and pink noise with an equal rms value can be selected by push buttons. By producing a defined rms value, the high stability of the output level allows the use of a directly calibrated attenuator with 0.1 dB resolution. This makes the 8057A a highly accurate noise source.

The basis of the 8057A is a clock-controlled binary waveform generator arranged so that the transitions between output levels can occur only on "beats" of an internal clock. Alternately, the waveform generator can be timed by an external clock of frequency up to 1 MHz. Hence, the bandwidth can be varied externally. A predictable noise pattern can be produced by applying a trigger to the gate input.

A shift register and a digital-to-analog converter together form a low-pass digital filter. This filtering mechanism converts the family of two-level outputs from the shift register into a multi-level signal having a Gaussian probability density function and a nearly rectangular power spectrum. Crest factors up to 3.5 give a remarkably close fit to the Gaussian distribution. The unique feature of the digital filter produces a bandwidth which is directly proportional to the clock frequency.

Outputs from the 8057A are available at a fixed amplitude of 10 volts (binary) and 3.126 volts rms (Gaussian). A precision step attenuator provides control of the Gaussian output in 0.1, 1, and 10 dB steps from 129.9 down to 20 dB above 1 μV rms. Push buttons allow an output impedance selection of 50 or 600 Ω. A positive 2 μs trigger pulse available from a rear-panel connector indicates the period of the noise pattern. Hewlett-Packard also manufactures Model 3722A Noise Generator (Page 363).

Specifications

Gaussian output

White noise

Frequency spectrum: dc to 26 kHz (−3 dB point) (with external clock, upper frequency limit is equal to 1/20th of external clock frequency). Effective bandwidth: 27 kHz. Spectrum is flat within ±0.3 dB up to 15 kHz and more than 25 dB down at 52 kHz.

Power density: 362 x 10^{-6} V^2/Hz.

Crest factor: 3.5.

Probability density: near Gaussian.

Pink noise

Frequency spectrum: 3 dB/octave decreasing from 2 Hz to 20 kHz. Accuracy: ±0.5 dB up to 15 kHz; +0 dB, −1 dB at 20 kHz.

Crosspoint from white and pink noise frequency spectrum: 2.5 kHz.

Period of noise pattern: approx. 2 sec. (for external clock: 1 048 575 x clock period)

Amplitude (open circuit): 3.126 V rms or 129.9 dB above 1 μV.

Amplitude attenuator: 0.1; 1 and 10 dB steps from 129.9 to 20 dB above 1 μV. Overall attenuator accuracy: ±0.5 dB.

Output impedance: 50Ω or 600Ω ±3%.

Zero drift: <±30 mV from 32° to 122°F (0° to 50°C).

Binary output

Output signal: pseudo-random binary sequence. Clock rate: 520 kHz (or external clock) Sequence length: 1 048 575 Bit.

Amplitude (open circuit): 10 V ±10%.

Output impedance: approx. 600Ω.

Rise, fall time: <50 nsec.

Trigger output (Positive trigger pulse indicates period of the noise pattern).

Trigger pulse amplitude: approx. 10 V.

Output impedance: approx. 1 kΩ.

Trigger pulse width: 2 μsec (or equal to clock period of external clock frequency).

External clock input: only for white noise output. (Pink noise should not be used with external clock. Overloading amplifiers distorts output).

Postive clock pulses: min. +2 V; max. + 20 V amplitude. Sine wave at least 4 V peak to peak.

Maximum clock rate: 1 MHz.

Minimum pulse width: 15 nsec.

Input impedance: approx. 1 kΩ.

Gate input: −1 V to +2.8 V or connected to ground disables Noise Output. (Gate input connected to ground: Output current approx. 2.5 mA). +4.5 V to 12 V or not connected enables Noise Output.

General:

Power: 115 V or 230 V +10%, −15%, 50 Hz to 400 Hz, 14 VA.

Dimensions: standard HP ½ module; 6" high, 7¾" wide, 11" deep (155 x 190 x 27 mm).

Weight: net 6½ lb (3,25 kg), shipping 8 lb (4 kg).

Price: 8057A, $775 ($675 at factory on West Germany).

Option 01: without attenuator, subtract $100.

GENERAL PURPOSE DIGITAL COMPUTERS

Computers may be divided into two main classes, "digital" and "analog". A digital computer is one that obtains the solution to a problem by operating on information in the form of coded numbers, while the information processed by an analog machine is in the form of physical analogs, such as voltages or shaft positions, that represent numbers. Principal advantages of the digital computer are its ability to store vast amounts of data and to perform calculations to any required degree of precision, while the analog computer lends itself to direct solution of complicated equations (such as differential equations) through simulation of many variable parameters. In recent years, "hybrid" computers have been developed which combine digital computer memory, logic and accuracy with the dynamic simulation and differential equation solving capability of the analog computer. The hybrid computer is capable of solving problems which lie in both the digital and analog domains, but is necessarily more difficult to use, and more expensive, than a straightforward digital or analog machine.

Digital computers, in turn, may be divided into two classes, general purpose and special purpose. Special-purpose computers are designed to solve only a specific class of problem. One example is a differential data analyzer, a digital computer tailored to the solution of problems that can be reduced to a set of differential equations. Machine tool controllers represent another type of special purpose computer.

General-purpose computers, on the other hand, are not oriented toward specific tasks, but may be programmed to compute and manipulate information for many different purposes. However, certain broad areas of application are better serviced by computers emphasizing particular hardware characteristics. Thus, the general field of general-purpose digital computers breaks down into business data processors, which emphasize large internal memory and external data storage capacity to perform relatively simple calculations on very large amounts of data, and scientific computers, which stress computational capability to solve complex problems, and input/output flexibility for ease of interface with instruments.

The Hewlett-Packard family of computers (models 2116B, 2115A and 2114A) are general-purpose digital computers for scientific and industrial applications. They may be used (with appropriate data input and output devices) as laboratory tools for solving scientific research and engineering design problems, and can be incorporated into instrumentation systems to compute data and perform control functions while experiments are in progress.

The computer system

A computer system is composed of two parts: hardware and software. The hardware comprises the computing machine or 'central processor' and peripheral equipment such as paper tape readers, typewriters and tape punches. Software consists of the programs or lists of instructions that control operation of the computer; these programs are commonly recorded on punched cards, punched tape or magnetic tape, and are then read into the computer through one of its input devices.

The computer itself is made up of five elements: input section, output section, arithmetic unit, memory, and control.

Input: The input section, in conjunction with appropriate external devices, receives data and instructions from various storage media (e.g. punched tape or magnetic tape) or via a manual-entry keyboard. The incoming information is stored by the computer in its memory.

The basic function of the input section is to translate the external data into a form in which it can be stored in the computer memory (e.g. 16-bit binary words). Input devices used with the Hewlett-Packard computers include punched tape readers, keyboards, magnetic tape and magnetic disc units, card readers, and also digital voltmeters, counters, and other measuring instruments.

Output: The output section of the computer transmits data to output devices such as typewriters, tape punches, magnetic tape and magnetic disc units, and printers, performing code translation and formulating as appropriate. The output section also transmits signals for controlling external devices; for example, function commands for instruments such as digital voltmeters and scanners. Some peripheral units can function both as input and output devices. For example, the computer can both read from and record on magnetic tape and magnetic disc units.

Arithmetic: The arithmetic unit performs calculations (using basic arithmetic operations) and manipulates data. Multiplication and division are accomplished either by successive additions and subtractions initiated by software, or with additional hardware, usually offered as an option (e.g. Hewlett-Packard Extended Arithmetic Unit). An example of data manipulation is the rearrangement of a string of characters so that they may be recorded by the computer in a desired format.

The arithmetic unit consists of one or more registers or 'accumulators', and associated logic circuitry. The accumulators hold the results of arithmetic and logical operations performed by instructions, while the logic enables data in the accumulators to be combined with information transferred from memory. The Hewlett-Packard computers have two accumulators, usable independently for computational flexibility.

Memory: This section is the heart of the computer; all information processed by the computer passes through the memory. Most small computers use a 'core' memory, consisting of an intricate matrix of ferromagnetic cores, each capable of storing one bit of information. The basic memory of the HP 2115A and 2114A Computers can hold 4096 (4K) words, each consisting of 16 bits of information. This can be expanded to 8K words. Basic memory of the HP 2116B is 8K, expandable to 32K words.

Besides word capacity, the speed with which information can be stored or read from memory is one of the principal characteristics defining the performance of the computer. In the HP 2116B the memory cycle time is 1.6 microseconds, which means that information can be written into or read from memory at a rate of 625,000 words per second. This allows, for example, 312,500 additions to be performed in one second.

Control: This section controls and coordinates the whole operation of the computer. It directs the transfer of data between the computer registers and controls the operations performed. It also interprets the instructions read from memory and sets up the gating functions to carry out their execution.

Software

Even the simplest tasks involve intricate movements of numerous binary bits of information within the computer, such that exhaustively explicit instructions must be given to the computer to perform each task. Therefore, while it is possible to write programs for the computer which are coded in the binary form the computer uses, called "machine language", it is too time-consuming and susceptible to errors to be practical. Various aids have therefore been devised to make programming a computer easier, and consequently more effective.

Software is the general term given to the programs which, when loaded into the computer, utilize the computer itself to perform all the detail work, leaving the programmer free to concentrate on designing a program to solve the problem at hand. The function of software is therefore to make the computer usable. It is usually (but not necessarily) designed by the computer manufacturer and furnished along with the hardware, in a form ready for reading into the computer—punched tape, magnetic tape or punched cards.

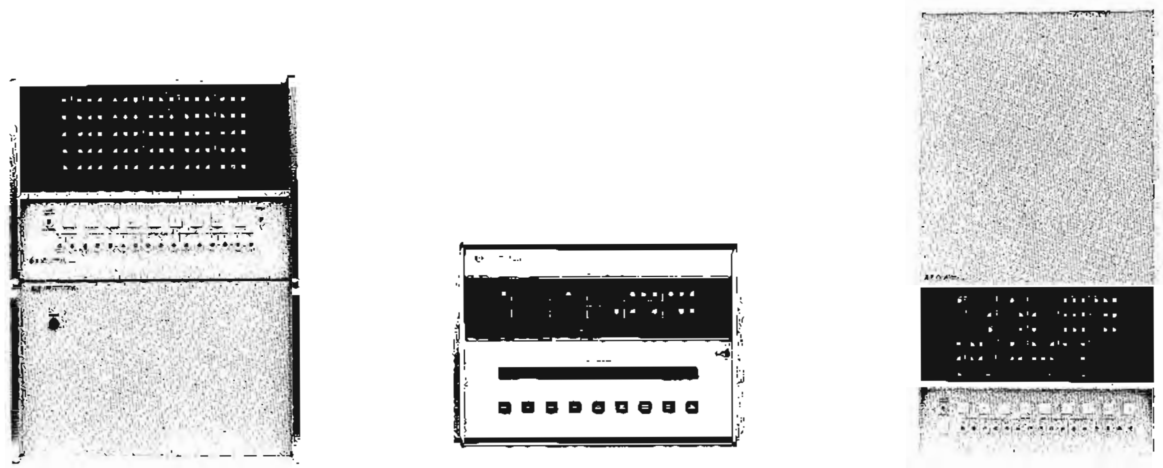
Software can be divided loosely into four classes:

a) Translators—programs which translate human-oriented languages into machine language.
b) Control systems—programs which take care of all the functions essential to operation of the computer system.
c) Utility routines—program editors, program debugging routines, hardware diagnostics.
d) Applications programs—these adapt the computer system for maximum effectiveness in a specific application.

COMPUTERS

For general computation and instrument systems

Models 2114A, 2115A, 2116B



2115A 2114A 2116B

The 2114A, 2115A, and 2116B are versatile general-purpose digital computers, particularly suited in computational power and input/output flexibility to scientific and industrial measurement applications. Each may be used as a free-standing system for solving scientific and engineering design problems, or in instrumentation systems, in combination with Hewlett-Packard measuring instruments, or many other devices to provide complete solutions in a broad spectrum of measurement tasks.

Each Hewlett-Packard computer is compact, flexible, and fast. The essential differences between the computers are: maximum memory size and cycle time, the number of priority interrupts, environmental tolerance, and price. Significant features of all three computers are indicated in the table on page 108.

Optional equipment to expand the power and versatility of each computer is available on a plug-in basis. For the 2115A and 2116B this includes disc memory, direct memory access, and an extended arithmetic unit which significantly reduces multiply and divide time, and also provides variable length, long shift and rotate instructions.

Hewlett-Packard computers are completely software compatible and offer a flexible instruction repertoire of 70 basic one-word instructions, with the capability of extensive microprogramming through one-word combinations of register reference instructions. The software package includes ASA Basic FORTRAN (Extended) and ALGOL compilers, an assembler, a symbolic editor, a basic control system, and conversational BASIC. Software is also furnished for reconfiguring the basic control system to accommodate changes in the I/O hardware system, program debugging, and diagnosing hardware malfunctions. All software except the ALGOL compiler and BASIC are fully operable in the minimum hardware configuration, consisting of 4096-word memory and teleprinter I/O. The ALGOL compiler and BASIC require 8K memory. In addition, a Real-Time Executive software system for the 2116B, in conjunction with disc memory and other peripherals, provides real-time execution of core and disc resident programs concurrently with background programs stored on disc or paper tape.

2114A

The 2114A is the most compact member of the Hewlett-Packard computer family, yet it contains the same multilevel priority interrupt system and uses the same powerful instruction set as the larger 2115A and 2116B Computers. Its extremely compact design allows the central processor up to 8K of memory (2 μs cycle time), 8 device interfaces, and all power supplies to be housed in a single, small cabinet. The 2114A also offers a unique multiplexed input/output system. This system consists of only one plug-in card and provides easy-to-use interfacing for the connection of up to 56 special or user-designed peripheral devices to the 2114A. Other standard features such as Power Fail Interrupt and lockable power switch and panel controls make it ideal for O.E.M. or systems applications.

2115A

The medium-sized 2115A Computer allows 4K or 8K of memory in the basic mainframe, a memory cycle time of 2 microseconds, and I/O slots for 8 device interfaces (expandable to 40 using an external extender). The computer is packaged in two small instruments: a 12¼″ tall processor and a 10½″ tall power supply. The unit offers both high-speed extended arithmetic and direct memory access (DMA) capabilities. These provide for high-speed computation and throughput rates for more demanding problems, as well as providing for effective use of external equipment such as high-speed recorders and disc memories. The two-channel DMA can be individually switched to any two I/O channels under program control and permits data transfer rates of 250 kHz per channel or 500 kHz using both channels. The 2115A includes other features found only in much larger computers.

2116B

The 2116B is the largest, most powerful Hewlett-Packard computer. It has a 1.6-microsecond memory cycle time, memory expandable to 32K in 8K modules, and 16 I/O slots in the mainframe for device interfacing. An additional 32 device interfaces can be accomodated in an optional I/O extender. The 2116B also makes provision for two program-selectable direct memory access (DMA) channels and an extended arithmetic unit. The high-speed 2116B memory provides DMA transfer rates of 312 kHz per channel or 625 kHz using both channels.

A Real-Time Executive software system makes the full potential of the 2116B realizable. This multiprogramming capability allows the running of foreground programs in real-time concurrently with background programs. The programs may be in (real-time) FORTRAN or Assembly language.

Standard systems are produced by Hewlett-Packard which contain the 2116B and reflect its power and versatility. These include: Data Acquisition Systems operating in real-time; a Time-Shared BASIC system which allows 16 users to program the 2116B, simultaneously, in the popular BASIC language; and a Digital Logic Module Tester using the 2116B for high-speed automatic testing of digital logic modules. Thus, the 2116B is truly a computer for complex scientific and industrial applications.

Input/Output flexibility

The computers operate through standard plug-in interfaces with all the standard computer peripherals, and virtually all Hewlett-Packard instruments capable of being programmed and/or providing a digital data output. General purpose plug-in interfaces are also available which enable the customer to operate a wide variety of devices of his own choosing with the computer. Besides the convenience of plug-in interface cards, the computers provide, as standard features, unique channel identification, an automatic multichannel identification and an automatic multichannel priority interrupt system. Priority levels can be altered simply by interchanging the positions of the interface cards.

Input/output channels may be run one at a time under program control, or simultaneously under interrupt control. Peripherals can be added, upgraded, or deleted, and service priorities changed on a plug-in basis—no wiring changes are involved. Interface circuitry to run a specific peripheral is contained on one or more cards that plug into any I/O slot in the computer or extender. To achieve this, all interface cards have identical pin assignments and the computer backplane is uniformly wired. Interconnecting cables mate directly with the I/O interface cards (see photo), reducing the number of mechanical connections in the system and minimizing the possibility of noise injection from the I/O device into the backplane. All peripherals draw their power directly from the power line; the interface cards are powered from the computer's internal power supply.

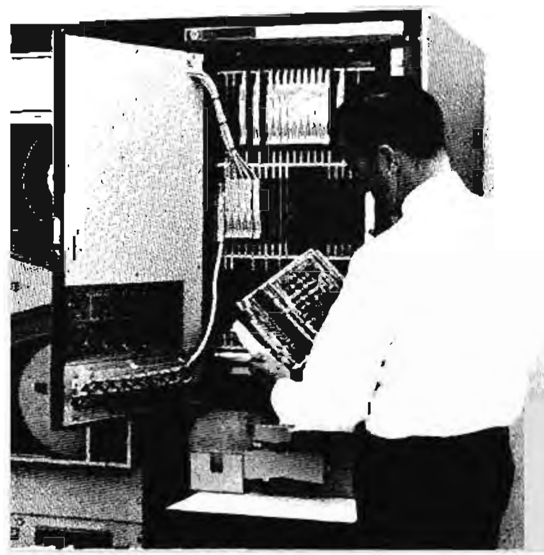
Multichannel priority interrupt capability is a standard hardware feature in each Hewlett-Packard computer; an interrupt channel associated with a unique memory location is provided with each I/O interface. That is, an interrupt request from an I/O device directly executes a location in memory uniquely associated with that I/O channel. This interrupt location will typically contain the entry instruction for a subroutine to service the I/O device. Priority level is determined by the I/O slot into which the interface card is installed, so priority levels can be rearranged simply by moving cards into different slots. Peripherals can also be programmed 'in' or 'out' of the interrupt chain under program control (The interrupt system can also be bypassed and all peripherals run under direct program control.)

Interrupts are recognized by the end of the current machine cycle. More important, overall response is fast. In a multidevice system, a service request by a higher priority device causes the first 'useful' instruction which communicates with that device to be executed in less than 7 microseconds for the 2116B. When operating with only one I/O device, the response time is less than 3 microseconds. Times of 8 and 4 μs, respectively, are required by the 2114A and 2115A. The multichannel interrupt feature and fast response promote efficient operation in a real time environment, as in instrumentation systems.

Machine organization

Each of the Hewlett-Packard computers has nine internal registers. Eight of these are flip-flop (integrated circuit) registers and the ninth consists of switches for manual data entry. The contents of all but one of the flip-flop registers are available to the programmer; the 2115A and 2116B displays these registers on the front panel. The 2114A displays two 16-bit flip-flop registers (Memory Data and Memory Address), two 1-bit registers (Extend and Overflow), and the switch register contents.

T register (memory transfer): All data transferred into or out of memory is routed through the T register. The T register display indicates the information that went into or out of a memory cell during the preceding memory cycle.



External devices are interfaced by inserting the appropriate interface card and connecting the device cable.

P register (program counter): Holds address of next instruction to be fetched from memory (or address of current instruction in the case of a multiphase instruction). The P register increments by one after the execution of each instruction (or by two if executing a skip instruction). A jump instruction can set the P register to any core location.

M register (memory address): Holds address of next memory cell to be accessed.

A and B registers (accumulators): The A and B registers execute and hold the results of arithmetic and logical operations performed by programmed instructions. The registers operate independently, allowing the programmer considerable freedom in program design. While they are flip-flop registers, they may be addressed by any memory reference instruction as location 00000 and 00001 respectively, thus permitting interregister operations such as "add (B) to (A)," "compare (B) with (A)," etc., using a single-word instruction.

E register (extend): A 1 bit register, used to link A and B registers by rotate instructions or to indicate a carry from bit 15 of the A or B register by any add or increment instruction (only) which references these registers.

OV register (arithmetic overflow): This 1 bit register indicates if an add or increment instruction referencing the A or B register has caused one of these accumulators to exceed the maximum positive or negative number which can be contained (+32767 or −32768, decimal). The overflow bit is not complemented if a second overflow occurs before it is cleared, by program instructions. It is not set by shift or rotate instructions.

I register (instruction): Decodes each of the memory reference instructions, and identifies the register reference and input/output instruction types. The I register also holds indicators to direct the computer to page zero or remain on the current page, and to denote direct or indirect addressing. (Contents of I register are not displayed.)

For general computation and systems
Models 2114A, 2115A, 2116B

S register (switch register): A 16-bit register which permits manual data entry through 16 switches on the front panel of each computer. The 2115A and 2116B contain toggle-type switches; the 2114A contains proximity-type sense switches. The setting of the switch register may be transferred into the computer in the following ways:

By program: Into A or B register using a load or merge instruction with the switch register's select code.

Manually: May be (1) loaded simultaneouly into the P and M registers, using the load address switch, thus directing the computer to a specific memory cell; (2) loaded into the memory cell specified by the M register, using the load memory switch, thus permitting the user to change the contents of any memory cell; (3) loaded into the A or B register, using the load A or load B switch on the 2115A and 2116B Computers.

Note: On the 2114A only, the contents of the A or B register may be output to the switch register and displayed by a programmed output instruction. Also, the contents of the A or B register may be displayed in the Memory Data register using the load address and display memory switches after clearing the switch register with the clear register switch.

Programming

The Hewlett-Packard computers all have 70 basic one-word (16 bit) instructions, all executable in one or two machine cycles (plus 1 cycle for each step of indirect addressing). These instructions are grouped in three types:

Memory reference (2 cycle), 14 total
Register reference (1 cycle), 43 total
Input/output (1 cycle), 13 total

The register reference instructions are micro-operations that can be combined to form over 1000 one-word, single-cycle instructions.

Word formats

Memory reference instructions

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	Instruction				Z/C	Memory address									

Register reference instructions

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Reg. ref. instruction				A/B	SR/AS	Micro-instruction									

Input/output instructions

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
I/O instruction				A/B	Instruction					I/O select code					

Full address

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
D/I	Page address					Word address									

D/I Direct/Indirect; Z/C Page Zero/Current Page; A/B Register Identifier; SR/AS Shift-Rotate/Alter-Skip Identifier

Data, fixed point

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Sign	Integer														

Data, floating point
(Magnitude, 23 bits & sign; Exponent, 7 bits & sign)

15	14 – – – – – – – – – – – – 0	15 – – – – 8	7 – – 1	0
Mag sign	Magnitude, most sig. bits	Mag, least sig. bits	Exponent	Exp sign

Instruction repertoire

Type	Mnemonic	Description	Machine Cycles
Memory Reference Instructions (14)	AND	'And' (M) to A; result in A	2
	XOR	Exclusive 'or' (M) to A; result in A	2
	IOR	Inclusive 'or' (M) to A; result in A	2
	JSB	Jump to subroutine	2
	JMP	Jump, unconditionally	1
	ISZ	Increment (M); skip if result zero	2.25
	ADA/B	Add (M) to A or B; result in A or B	2
	CPA/B	Compare (M) with A or B; skip if not equal	2
	LDA/B	Load (M) into A or B	2
	STA/B	Store (A) or (B) into M; A, B unchanged	2
Register Reference Instructions (43) — Shift-Rotate Group (20)	NOP	No operation	All 1*
	CLE	Clear E-Register	
	SLA/B	Skip if least significant bit of A/B is zero	
	A/BLS	A or B arithmetic lift shift one bit	
	A/BRS	A or B arithmetic right shift one bit	
	RA/BL	Rotate A or B left one bit	
	RA/BR	Rotate A or B right one bit	
	A/BLR	A or B left shift one bit (sign cleared)	
	ERA/B	Rotate E right one bit with A or B	
	ELA/B	Rotate E left one bit with A or B	
	A/BLF	Rotate A or B left four bits	
Register Reference Instructions (43) — Alter-Skip Group (19)	CLA/B	Clear A or B	All 1*
	CMA/B	Complement A or B (ones complement)	
	CCA/B	Clear, then complement A or B (sets A/B to −1)	
	CLE	Clear E-Register	
	CME	Complement E-Register	
	CCE	Clear, then complement E-Register (sets E to 1)	
	SEZ	Skip if E-Register is zero	
	SSA/B	Skip if sign of (A) or (B) is zero (A/B positive)	
	SLA/B	Skip if least significant bit of (A) or (B) is zero	
	INA/B	Increment (A) or (B) by one	
	SZA/B	Skip if (A) or (B) is zero	
	RSS	Reverse skip sense	
Overflow (4)**	STO	Set arithmetic overflow	All 1
	CLO	Clear arithmetic overflow	
	SOC	Skip if arithmetic overflow clear	
	SOS	Skip if arithmetic overflow set	
I/O Instructions (13)	HLT	Halt program	All 1
	STF	Set flag bit of selected channel	
	CLF	Clear flag of selected channel	
	SFC	Skip if flag clear	
	SFS	Skip if flag set	
	MIA/B	Merge contents of selected channel into A or B (inclusive 'or')	
	LIA/B	Load contents of selected channel into A or B	
	OTA/B	Output from A or B to selected channel	
	STC	Set control bit of selected device	
	CLC	Clear control bit of selected device	

*Register Reference Instructions can be combined to execute in 1 cycle. This allows, for example, shifts and rotations up to 8 places in 1 cycle.
**Coded under I/O group.
(M) = Contents of memory Location M.

Memory Reference: Memory addressing of HP computers is based on a 1024-word page structure. All memory reference instructions address either the current page or the base page, thus up to 2048 words are directly addressable. The large page size of Hewlett-Packard computers allows compact programs with a minimum of indirect addressing. Also, programs can share a large block of storage in the base page, easing communication between routines using common data. Accumulators are directly addressable as memory locations 0 and 1, enabling their contents to be added and compared. You can also load from one accumulator into the other.

Register Reference: Hewlett-Packard's extensive set of register reference instructions make it easy to edit character strings, shift data within and between accumulators, test the accumulators for condition (zero/non-zero, positive/negative, odd/even) and to clear, set, increment and form the one's and two's complement of the accumulator contents.

Software

Hewlett-Packard computers are supported by a full range of software, furnished in the form of punched tape or magnetic tape. The following software packages are available:

FORTRAN compiler	Basic Control System
ALGOL compiler	Hardware diagnostics
Assembler	Time-shared BASIC Executive
Symbolic editor	Real-Time Executive
Conversational BASIC	

With the exception of ALGOL, Conversational BASIC, and the large software executives, the software packages will run in the minimum hardware configuration—4K memory and teleprinter input/output. ALGOL and Conversational BASIC require 8K of memory. Programs written in FORTRAN, ALGOL or assembly language are independent of the hardware I/O configuration. All I/O devices are identified by logical unit numbers which the programmer uses to specify I/O operations.

At execution time the Basic Control System relates these logical unit numbers to physical numbers that correspond to the I/O slots occupied by the cards for the I/O device in question. The Basic Control System is therefore configured to suit a particular system.

An auxiliary software package, Prepare Control System, is furnished which allows the user to change his Basic Control System to fit different input/output arrangements. A dynamic program debugging package is also supplied.

FORTRAN compiler: Accepts source programs written in American Standards Association Basic FORTRAN. It produces a relocatable machine language object program that can be loaded and executed under control of the Basic Control System. In addition to the ASA Basic FORTRAN language, Hewlett-Packard's FORTRAN compiler includes a number of features that extend the flexibility of the system.

ALGOL compiler: Accepts source programs written in ALGOL. It produces a relocatable machine language object program that can be loaded and executed under control of the basic control system. Operable in 8K memory.

Assembler: Translates symbolic source language instructions into an object program for execution on the computer. The source language provides operation codes, assembly-directing pseudocodes, and symbolic addressing. The assembled program may be absolute or relocatable. The source program may be assembled as a complete entity or it may be divided into several subprograms (or a main program and several subroutines), each of which may be assembled separately. The loader of the Basic Control System loads and links relocatable programs; the basic binary loader loads absolute programs.

Symbolic editor: Enables the user to edit and update a symbolic file tape that can be an assembler program, a compiler program, or a data file. The editor produces an updated tape from the source tape and change instructions. Individual characters and entire source statements can be inserted, deleted, or replaced. The editor will also provide a listing of a symbolic file (sequentially numbering the statements). Diagnostic messages are produced for errors detected in format of edit control statements.

Basic Control System: Provides an efficient loading, input/output control and debugging capability for relocatable programs produced by the assembler, FORTRAN compiler, or ALGOL compiler. The system is modular in design and may be constructed or modified to fit the user's particular hardware configuration. The following modules are provided:

Relocating loader: Loads, links, and initiates the execution of relocatable object programs produced by the assembler or compiler.

Input/output control: Provides for general input/output device control and software buffered data transmission between I/O devices and computer memory.

Input/output drivers: Provide the instructions necessary to operate specific input/output devices, and serve as an interface between the I/O control system and the peripheral devices.

Two other software packages are associated with the basic control system. These are:

Prepare control system: Combines the basic control system component modules—loader, I/O control, and I/O drivers together with equipment tables—to generate a basic control system for a particular hardware configuration.

Debugging package: A relocatable program that interprets and executes machine instructions. Functions to be performed are normally selected by typing in control statements on the teleprinter.

Subroutines: The basic control system loads and links object code library subroutines according to calls generated by assembler or compiler programs. A complete library of mathematical and Input/Output subroutines are available.

BASIC Interpreter: One of the most useful languages available with Hewlett-Packard computers is "BASIC," developed by Dartmouth College. In the design of BASIC, primary emphasis was placed on ease of learning and ease of operation. The result was a language which could be learned in a few hours. Because of the ease with which it can be learned and retained it has become the most widely used language for people in engineering and the sciences.

BASIC is an interpretive language; the program is stored in the computer in a form similar to the original alphanumeric statements which are interpreted by the compiler at execution time. Since the program is stored in essentially its original form, program editing can be accomplished by simply adding new statements or modifying old ones without the need for recompiling the entire program. While this process is slower at execution time because the computer must generate the appropriate machine code for each statement during execution, the preparation of the program itself is significantly easier and typically requires only a fraction of the time required for other languages.

BASIC is also a conversational language; the computer responds to the programmer's inputs with English language statements. For example, the compiler checks each statement after it is entered for proper format, and any illegal syntax is immediately identified for the programmer with a diagnostic message. If errors are encountered during the program execution the computer types a diagnostic message and may halt or continue depending upon the type of error.

The combined features of the interpretive compiler and the conversationality serve to greatly reduce the effort required to prepare and debug programs. The proof of the power of the language as a computational tool is its predominance among the languages used by the non-professional programmers.

A complete description of Hewlett-Packard's Computers and Software packages is contained in a pocket book titled "A Pocket Guide to Hewlett-Packard Computers." This book is available free upon request. Just send a postcard to Computer Guide, Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, California 94306.

For general computation and instrument systems
Models 2114A, 2115A, 2116B

Specifications

	2116B	2115A	2114A
Memory			
Type	Core	Core	Core
Word size (bits)	16	16	16
Parity	Optional	Optional	Optional
Basic configuration size (words)	8K	4K	4K
Maximum size in mainframe	16K	8K	8K
Maximum size using extender	32K	–	–
Memory area protect	Optional	–	–
Cycle time (us)	1.6	2.0	2.0
Instruction execution speed (us)			
Store word	3.2	4.0	4.0
Add (full word)	3.2	4.0	4.0
Multiply (subroutine)	120	150	150
Divide (subroutine)	300	375	375
Multiply (hardware option)	19.2	24.0	–
Divide (hardware option)	20.8	26.0	–
Number of basic instructions	70	70	70
Accumulators			
Number	2	2	2
Addressable	Yes	Yes	Yes
Multilevel indirect addressing	Yes	Yes	Yes
Priority interrupt system			
Number of prewired input/output slots in mainframe	16	8	8
Maximum number of I-O slots using extender	48	40	8
Number of devices that can be interfaced using multiplexed I/O	–	–	56
Direct memory access			
Direct memory access channels in basic system	0	0	0
Maximum number of access channels available	2	2	0
Maximum word transfer rate (kHz)	625	500	–
Cycles required to initiate block transfer	13	13	–
Cycles stolen (from main program) per word transferred	1	1	–
Direct memory increment	Yes	Yes	No
Software			
ASA basic-FORTRAN extended compiler	Yes	Yes	Yes
ALGOL compiler	Yes	Yes	Yes
BASIC interpreter	Yes	Yes	Yes
Assembler	Yes	Yes	Yes
Real time executive	Yes	No	No
Hardware			
Circuitry	CTL I.C.	CTL I.C.	CTL/TTL I.C.
Power failure protection	Yes	Yes	Yes
Automatic restart	Optional	Optional	Optional
Height	31½"	12¼"	12¼"
Width	16¾"	16¾"	16¾"
Depth	19¾"	24⅜"*	24⅜"
Environmental temperature	0° to 55°C	10° to 40°C	10° to 40°C
Environmental relative humidity (at 40°C)	95%	80%	80%
Prices			
with 4K memory	–	$14,500	$ 9,950
with 8K memory	$24,000	19,500	13,950
with 16K memory**	34,000	–	–

*Power Supply Unit in 2115A is 10½" high, 16¾" wide, and 18⅜" deep.
**Prices for 2116B with 24K or 32K memory are available upon request.

Input/Output Options

Interface Kits for the following I/O options include software; I/O Driver tapes are not included in Interface Kits 12551B, 12554A, 12555A, 12561A, and 12566A. Orders for I/O options subsequent to original purchase of system must state computer model and serial number, so that proper software is furnished. Computer field service assistance is recommended for installation of I/O options subsequent to original purchase; consult computer sales engineer or factory for service charge involved. (Auxiliary HP 2160A power supply may be needed when using most of the available I/O slots in the 2115A/2116B Computer; consult computer sales engineer or factory.)

- Prices for the following options include both Interface Kit and Peripheral. When ordering, specify Interface Kit and Peripheral-Device numbers. For example: To order a 9-Channel Magnetic Tape Input/Output, specify Interface Kit 12559A and HP (H01) 3030G Magnetic Tape Unit.

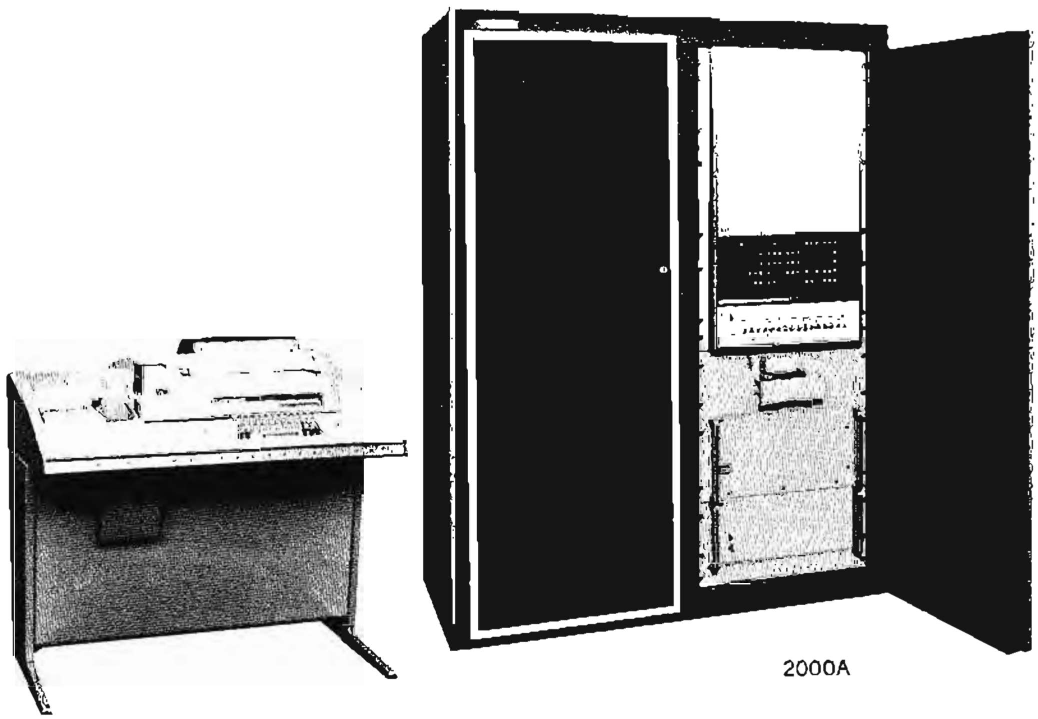
I/O OPTION	CAPABILITY	INTERFACE KIT	PERIPHERAL	PRICE	
				115 V, 60 Hz	230 V, 50 Hz
TELEPRINTER INPUT/OUTPUT	System records on typewriter and punched tape and inputs from keyboard and punched tape; 10 characters/sec. (ASCII code)	12531B	HP 2752A Teleprinter (modified Teletype ASR-33)	2,000	2,200
HEAVY-DUTY TELEPRINTER INPUT/OUTPUT	Similar to option above, except heavy-duty Teleprinter is furnished with sprocket-feed platen. Recommended where use exceeds 5 hrs/day or 30 hrs/week.	12531B	HP 2754B Teleprinter (modified Teletype ASR-35)	4,600	5,000
HIGH-SPEED PUNCHED TAPE INPUT	Paper tape input at 300 characters/sec. (ASCII code)	12532A	HP 2737A Punched Tape Reader (with accessory 12525A Tape Holder)	2,100	2,200
HIGH-SPEED PUNCHED TAPE OUTPUT	Paper tape output at 120 characters/sec. (ASCII code)	12536A	HP 2753A Tape Punch	4,100	4,150
LOW DENSITY MAGNETIC TAPE INPUT/OUTPUT	Computer records on, and reads from, IBM-compatible ½ inch 7-channel NRZI tape. Bit density 200 bpi. Speed 30 ips.	12538A*	HP (H26) 2020A Magnetic Tape Unit	12,500	12,700
DUAL DENSITY MAGNETIC TAPE INPUT/OUTPUT	Similar to option above, but Computer records and reads at both 200 and 556 bpi.	12538A*	HP (H26) 2020B Magnetic Tape Unit	15,000	15,200
DISC MEMORY (3.2 MEGABITS)	Provides storage for 174,080 words in 64-word addressable sectors. Transfer rate 3 megabits/second. Access time 33 ms max. Requires DMA.	12561A*	HP 2757A Disc Memory with HP 2756A Disc Memory Power Supply.	23,500	23,900
DISC MEMORY (6.4 MEGABITS)	Similar to option above, but 348,160 words	12561A*	HP 2757A-01 Disc Memory with HP 2756A Disc Memory Power Supply.	28,500	28,900
9-CHANNEL MAGNETIC TAPE INPUT/OUTPUT	Computer records on, and reads from, IBM-compatible ½ inch 9-channel tape. Bit density 800 bpi. Speed 75 ips. Requires DMA.	12559A*	HP (H01) 3030G Magnetic Tape Unit	18,500	18,700
AUXILIARY POWER	Supplements power supply in 2115A/2116B.	—	HP 2160A Power Supply	2,000	2,000

*Uses 2 I/O slots

- Prices for the following options are for the Interface Kit only; order by Interface Kit number. For example: To order the Relay Output Register, specify Interface Kit 12551B.

TIME BASE GENERATOR	Generates real time intervals in decade steps from 100 μs to 1000 sec (derived from crystal oscillator). Used as source of timed interrupts for software clock.	12539A	None required.	1,000	1,000
DATA PHONE INTERFACE	Interface computer with Bell System Data Phone service.	12540A	Bell System Data Set 103A.	1,000	Not Available
GENERAL PURPOSE DATA SOURCE INTERFACE	Permits input of 32 bits of information from external device (typically: 8 BCD characters). Kit includes mating connector.	12604A	Determined by user.	750	750
GENERAL PURPOSE DUPLEX REGISTER	Dual 16-bit flip-flop register. Permits bidirectional transfer of information between Computer and external devices. (Accessory kit includes 48-pin mating connector).	12554A	Determined by user.	750	750
RELAY OUTPUT REGISTER	Provides 16 form-A contacts for operating external devices. (Accessory kit includes 48-pin mating connector).	12551B	Determined by user.	600	600
D-A CONVERTER	Provides two D-A conversion channels, 8 bits/channel.	12555A	Determined by user.	750	750
MICROCIRCUIT INTERFACE	Dual 16-bit flip-flop register. Permits bidirectional data transfer between computer and external device at DTL/TTL voltage levels. (Interface Kit includes cable and mating connector.)	12566A	Determined by user.	750	750

TIME SHARED SYSTEM
Model 2000A



2000A

Time-shared basic

The HP 2000A Time-Shared "BASIC" System represents a new philosophy in the design of time-sharing computer systems. Most time-sharing systems have been characterized by their large size, multi-lingual capability, complex executive programs, and high cost. Experience with these systems has shown that most users pay a high price for system features they seldom use. Given a choice, most users prefer a simple, conversational language, usually BASIC. Yet the implementation of BASIC represents a relatively small fraction of the cost of a system.

The HP 2000A, on the other hand, doesn't try to do everything for everybody. What it will do is provide an economical BASIC language time-sharing system capability of efficiently serving up to 16 users simultaneously.

Time Sharing Benefits

In order to understand the utility of time-sharing it is helpful to list some of the features of time-sharing systems that have made them the success they are.

1. Time-sharing systems are economical to use; the power of a high speed processor is available to each user at a fraction of the total cost.

2. The user can perform his computations when he wants to without waiting for a turn in a batch system queue.

3. Conversational interpretive languages, not economically practical on a single terminal-per-processor basis because of their on-line program preparation and slower execution times, become powerful and practical tools when built into a time-sharing system. These languages, which can be learned in hours instead of weeks are perhaps the major factor in the success and growth of time-sharing.

4. Program debugging is greatly simplified by the combination of on-line, two-way communication and lower operating cost, which makes it possible for the user to debug a program on-line without repeated cycles through the batch queue.

5. In some applications time-shared operation makes it possible for many users to simultaneously access a large common data base.

System Hardware

The HP time-sharing system is built around the HP Model 2116B Computer with a 16-bit word length (plus parity) and 16,384 words of magnetic core memory. For time-sharing operation the computer is equipped with the following:

Internal

Direct memory access	Memory parity check
Extended arithmetic unit	Time base generator
Power fail interrupt	Teletype multiplexer

External

Magnetic disc memory	Power supply extender
High speed tape reader	Heavy duty teleprinter

The first four internal options provide the high speed data transfer and computation, and the internal checking of power levels and parity errors necessary for best efficiency and reliability. The time base generator provides a time base for determining time of day, for measuring system usage, and for timing the sharing of program execution time.

A special teleprinter multiplexer was developed for the system. Occupying a single input/output channel, it services simultaneously all 16 user channels, one with each bit of the 16-bit word. For maximum reading accuracy, the multiplexer samples each incoming bit eight times. Since the teleprinter's bit rate is 110 per second, a multiplexer sampling rate of 880 per second is required.

For bulk high speed memory, the system uses a magnetic disc memory with 348,160 words of storage. The disc is used by the system for storage of current programs (87,000 words), storage of a file copy of the system executive program (16,000 words), for storage of system tables, required for the library and accounting system (11,000 words), and for storage of saved user programs (235,000). Disc storage can be expanded by adding up to three more disc units providing over 1.25 million words of program storage. The 16-millisecond average disc access time, coupled with the executive's optimum timing techniques assure the efficiency required for handling the maximum 16 users at once.

The heavy duty teleprinter serves as the system control console and is connected to the computer through a separate I/O interface. It is used for operator communication with the system and for logging system information. Using this system control teleprinter, the operator can also control access to the system by assignment of user account numbers and passwords.

User Terminals

The teleprinters used as terminals with the system are the Teletype Models 33-ASR or 35-ASR. Communication with the system at rates up to 10 characters per second is possible through the keyboard, printer, or paper tape reader and punch. For local service, up to one mile, the terminals can be wired directly to the system. For longer distances or for greater operating flexibility, the terminals can be connected to the system through regular voice-grade telephone lines using coupling equipment such as the Bell System Data Set 103A. Use of the telephone system allows a greater number of terminals to be served by the system; up to sixteen users can be handled simultaneously on a first-call first-served basis.

General Specifications

Operating conditions: ambient temperatures 0° to 55°C (32° to 131°F), relative humidity to 95% at 40°C, except for disc memory, which is limited to ambient temperatures from 10 to 40°C (50° to 105°F) at relative humidity to 80%.

Equipment furnished

2000A Time-Shared BASIC System (with cabinet), $89,500 consisting of

- 2116B-02, 05, 08, 09, 011 Computer
- 2754B Teleprinter with 12531B
- 2737A Punched Tape Reader with 12532A
- 12539A Time Base Generator
- 2757A-01 Disc Memory with 2756A & 12561A
- 2160 Power Supply
- 12584A-01 Teletype Multiplexer
- 2992 Dual Bay Cabinet (with doors)

Options

2757A-01 Disc Memory with 2756A & 12561A	28,500
12584-8006 Data Set Cables	50
(H01) 3030G Magnetic Tape Unit	18,500
12584A-02 Telephone Auto-Disconnect	1,500

Power: 115/230 Vac, 50/60 Hz, 1650 watts.

Cabinet dimensions: 72″ high, 46″ wide, 30″ deep.

Net weight: 990 lb (449 kg)

Shipping weight: 1200 lb (554,8 kg)

Digital magnetic tape units

Both the 2020 and 3030 Series tape units are system oriented, designed as highly reliable, economical peripherals for computers and other digital systems.

The 2020 Series are slow-to-medium speed tape units, offering tape speeds to 45 ips—rack-mountable with the other components of your system (optional cabinet available). 2020's offer the maximum in economy, with prices starting at $4,500.

The 3030 Series offer tape speeds to 75 ips, providing data transfer rates in the medium-speed range (to 60,000 cps). Each tape unit in the 3030 Series is self-contained in a 30″ wide free-standing castered cabinet. Prices start at $7,000.

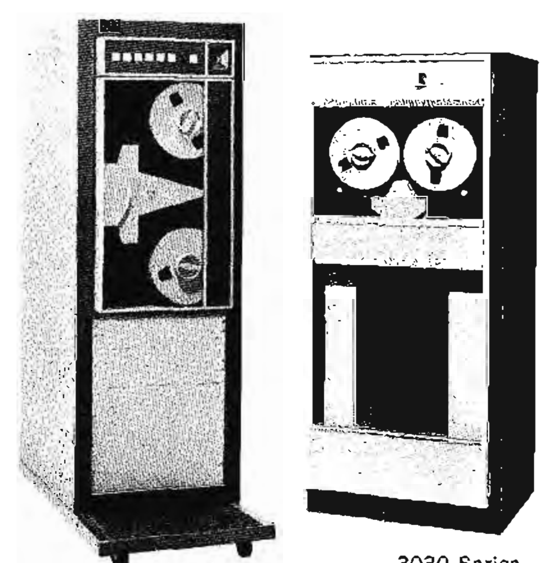
All Hewlett-Packard Digital Magnetic Tape Units are standardized on the industry-compatible IBM 7- or 9-track ½″ digital tape formats, with NRZI recording.

Hewlett-Packard offers 3 models of Digital Magnetic Tape Units for use in conjunction with Hewlett-Packard computers:

(H26)2020A, records on and reads from 7-channel tape at 200 bpi. Tape speed: 30 ips.
Price (complete with interface and software) $12,500*

(H26)2020B, similar to the 2020A, but records and reads at 200 and 556 bpi, switch selectable. Tape speed: 30 ips.
Price (complete with interface and software) $15,000*

(H01)3030G, records on and reads from 9-channel tape at 800 bpi. Tape speed: 75 ips. (Due to the speed of data transfer, an HP computer requires the Direct Memory Access option for operation with this tape unit.)
Price (including interface and software) $18,500*



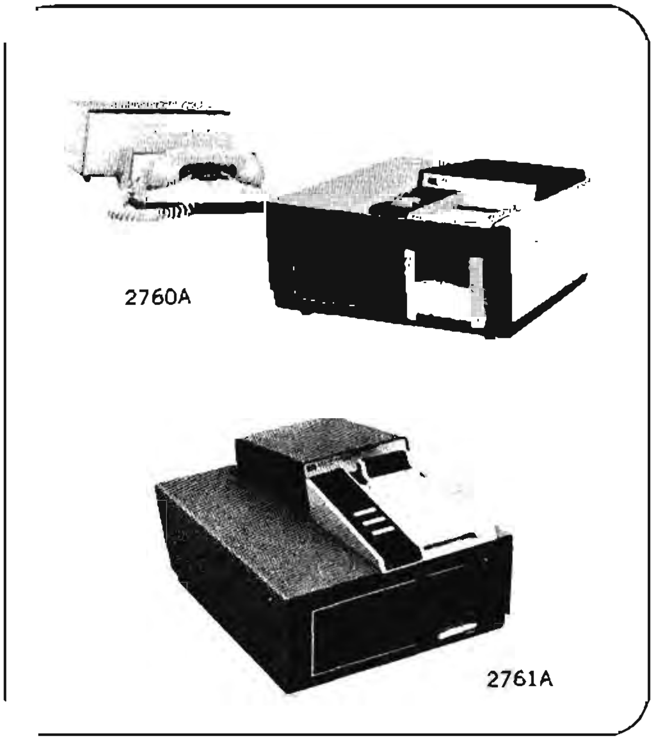
2020 Series   3030 Series

*Note: Prices are for 115 Vac, 60 Hz operation. For 230 Vac 50 Hz operation add $200.

OPTICAL MARK READER

For data entry and communication

Models 2760A, 2761A



The 2760A and 2761A Optical Mark Readers are low cost, desk-top, remote data-transmission terminals which read punched and marked tabulating cards. They are designed for use with standard telephone data sets in communication networks where limited information must be gathered from many sources; or where it is desirable to use the original document as direct input to the system, rather than punched cards, perforated paper tape, or manual entry of information by keystroke. The 2760A is a manual feed Reader. The 2761A provides the extra convenience of automatic card feed.

The Readers are human-oriented data entry systems that take advantage of two common and portable data entry devices—pencil and paper. The input document is a standard tabulating card, coded by marking lines through pre-printed boxes with a regular soft lead pencil. Up to 80 columns of alpha-numeric information may be marked or punched on a single card.

Since the tab cards are hand-marked, and are read directly as marked, keypunch operations are bypassed. This eliminates the cost, error potential, and noise associated with key-stroke equipment—and speeds delivery of data to the receiving terminal.

In application, immediate data transmission can speed input of orders, payroll charges, inventory entries, shipments, billings, and similar operating data to a central data processor. Because the Readers are low-cost portable units, it is practical to locate them for data entry at many remote points.

Tab Card Specifications

Data entry documents: Standard tabulating cards, printed with reflective ink visible to the eye, but not to the photosensors of the Reader. A row of "clock" marks printed on the cards synchronizes reading with the data entry marks on the card.

Card design: The information can be arranged in almost any manner, with considerable positional freedom in the horizontal direction. For example, the cards can be divided into data fields; they can include printed instructions for data entry; and space can be provided for handwritten information not to be read by the Readers.

Coding formats: Models of the 2760A/2761A are available to read any one of three formats:

Hollerith Punch Format: The Readers read holes and marks interchangeably, and both on the same card. Mark positions occupy the punch positions of a standard tab card.

Hollerith Mark-Sense Format: Mark positions are higher on the card, located midway between the rows of Hollerith punch positions.

Dial Code Format: Hewlett-Packard's new "dial" code uses a simple alphabetic coding, arranged in a manner like a familiar dial telephone.

Marking cards: Data is written on the cards by marking diagonal lines in pre-printed boxes enclosing the characters to be read, using a regular soft black lead pencil. Skipping a column enters a space.

Correction of entries: A feature of the optical mark system is easy correction of errors. When undesired marks are erased completely they are not read; new marks entered correctly will be read instead.

Pre-punched cards: Cards can be pre-punched or pre-printed with identifiers and routine information for turn-around applications, reducing the amount of hand-entered data, and assuring correct identification of the turn-around document.

Reader Specifications

Installation: The 2760A/2761A requires only connection to ac power and an interface cable between Reader and Data Set.

Receiver compatibility: The 2760A/2761A Optical Mark Readers transmit at 105 characters/second or 10 characters/second to receiving terminals equipped to accept data transmissions from Bell Telephone System type 202C or 103A Dataphones, or equivalent common carrier data transmission equipment. Many receiving terminals are compatible, including AT & T Dataspeed Type 11 and Teletype Telespeed 1050 Tape Receivers; and Teletype 33 and 35 Teleprinters. Many digital computers, including Hewlett-Packard's are compatible for direct input, making possible multi-terminal networks, automatic polling, multiplexing, and preliminary processing.

Environment: The 2760A/2761A Readers are rugged, electrically-conservative units designed to operate not only in office environments, but also in construction sites, machine shops; marine weather stations, and other locations where dirt, vibration, temperature, and humidity conditions are far from ideal. The Reader operates from 0 to 55°C; relative humidity to 95% at 40°C.

Overall dimensions: 2760A: 12¾" wide, 6⅞" high, 19½" deep (330 x 175 x 495 mm); 2761A is 9¼" (235 mm) high.

Weight: 2760A: net 22 lbs (10,0 kg); shipping 29 lbs (13,2 kg); 2761A: net 28 lbs (12,7 kg); shipping 37 lbs (16,8 kg).

Accessories available: HP 12657A Simultaneous Teletype Coupler for dual operation of Teletype and Reader through a single type 103A Dataphone, $150.

Price: HP Model 2760A for Hollerith formats, $2500; Model 2761A for Hollerith formats, $2850; dial code format adds $50.

DIGITAL-TO-ANALOG INTERFACE
High-speed, bipolar output
Model 6933A

One Package Includes:

- D/A Converter
- Storage Capability
- Built-in Power Supply and Reference Source
- Low Impedance Operational Amplifier output
- Isolation Between Input and Output
- Adapts To Wide Range of Digital Input Levels

Description

The Model 6933A is a small system in itself, for fast, trouble-free/analog programming by a digital system. With a bipolar output that can give a current of 10 mA throughout a swing from plus 10 to minus 10 V dc 50,000 times a second, the Model 6933A offers near ideal interface compatibility between a computer and a power supply—or any other analog input instrument.

Standard models accept inputs from either a binary or 8421 BCD format; other inputs are easily accommodated at the time of the order. A plug-in board design gives the flexibility needed to suit the coding and logic levels of most computers.

All Hewlett-Packard power supplies that feature external voltage programming can be programmed by the D/A Interface with little or no modifications.

There is no voltage overshoot during turn-on, turn-off, or sudden power removal, overshoot of any programmed output voltage (across a resistive load) will be less than 0.1% ±1m. In addition, short circuits across output terminals will cause no harm to the unit.

Specifications

DC analog output: −10 to +10 V dc (1 mV increments) at 0 - 10 mA (10 mA sinking).

AC power input: 115 V ac ±10%, 50 - 400 Hz.

Load regulation: less than 0.2 mV for a load current change of 10 mA.

Line regulation: less than 0.2 mV for a 10% change in the nominal line voltage.

Ripple and noise: less than 1 mV p-p at any line voltage and load condition within rating.

Transient recovery time: less than 10 μs is required for output voltage recovery to within 0.1% of the range setting following a change in output current equal to the current rating of the supply.

Temperature coefficient: less than 50 μV output change per degree centigrade change in ambient following 30 minutes warm-up.

Accuracy and resolution: 1 mV at 25°C ±15°C.

Programming speed: time required to attain 99.9% of programmed value.

Output voltage: −10 to +10 V or +10 to −10 V in less than 10 μs.

Voltage data transfer rate: greater than 50 K words/sec.

Input/output coding: other codes and levels available.

Input Description	Lines	Typical Levels and Coding: High	Low
Voltage magnitude (BCD form) (Binary)	16 14	Logical 0	Logical 1
Voltage polarity	1	+	−
Gate: starts processing of voltage magnitude and polarity data	1	Hold	Read
Total input lines	18		
Output Description			
Flag: notifies programmer that voltage magnitude and polarity data processing are complete	1	In-Process	Complete

Temperature ranges:

Operating: 0 to 55°C.

Storage: −40 to +75°C.

Controls: line switch (on-off)

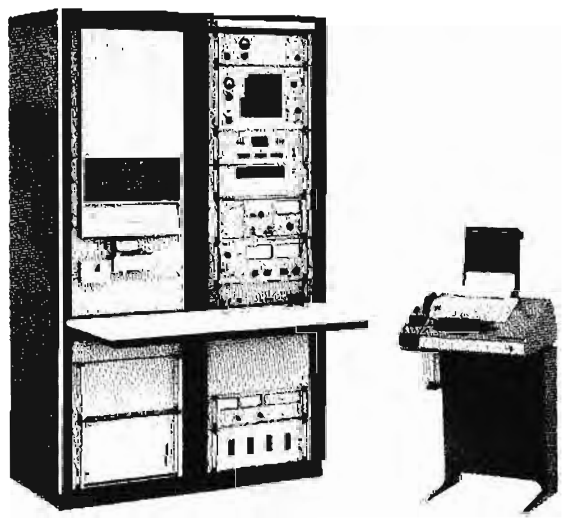
Rear output terminals: terminals for output, common, and ground. The *common* output terminal may be connected to ground through a separate ground terminal, or the output can float up to 300 volts off ground. Inputs enter the rear through a 50-contact ribbon connector.

Dimensions: 16¾" W x 3⅜" H x 13¼" D (42,5 cm W x 8,6 cm H x 33,7 cm D).

Price: HP Model 6933A, $1200.

Option 28: 230 V ac ±10%, single phase input. Factory modification consists of reconnecting the multi-tap input power transformer for 230 volt operation; price, $10.

STIMULI • RESPONSE MEASUREMENTS
Processing data • Recording results
DC to 500 MHz — Model 9500A



9500A

The Model 9500A Automatic Test System is a computer-controlled versatile test system using a family of Hewlett-Packard programmable instruments for providing output stimuli, response measurement, and processing and recording the resultant test data. The Model 9500A is suited ideally for production or assembly line testing where high reliability and little maintenance is required. It offers a number of options (as shown in the table) to suit most customer test requirements.

Software/Programming. The Model 9500A Automatic Test System uses a simple computer language called HP BASIC which enables the operator or programmer to write his programs in English-like statements. By using an interpretive compiler, resident in the System's computer memory at all times, an operator can become a "programmer" since a program can be written by typing instructions directly into the computer on the Teleprinter and then executing the program upon command via the same Teleprinter.

HP BASIC, used with the Model 9500A, consists of the popular BASIC language extended to include instrumentation control statements. This computer test language is so simple that it can be learned in approximately 4 to 8 hours.

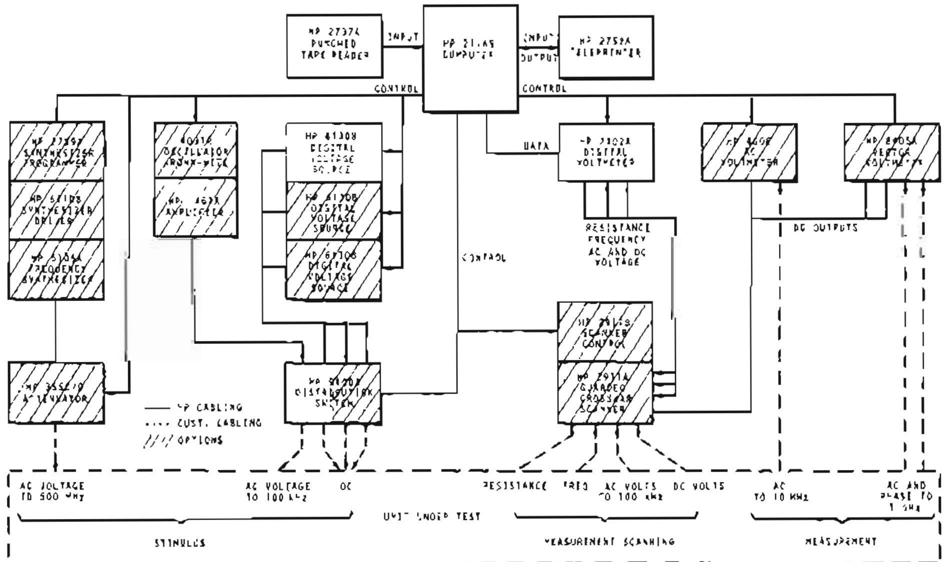
The test engineer using the Model 9500A is normally the most qualified person to write a test program since he is the one most familiar with the tests to be made. After a test program is written it can be checked immedately for inaccuracies and failures. Corrections can be made without time-consuming delays associated with off line compiling.

Hardware. The Model 9500A uses the HP 2116B Computer and other instruments from Hewlett-Packard's expanding family of programmable instruments. The table shows the instruments and components which comprise the Model 9500A.

System Operation. The block diagram shows the System complete with all options. System control is either through manual keyboard entry on the teleprinter or by previously prepared programs via the punched tape reader. The stimuli consists of dc, ac to 100 kHz, and ac to 500 MHz. DC and low frequency ac stimuli are routed through the distribution switch to the unit under test (UUT).

Measurement inputs consist of dc, ac to 1 GHz, ohms, and frequency. AC measurements above 100 kHz are recorded on the digital voltmeter (DVM) as a dc voltage by routing the dc outputs of the respective meters through the measurement scanner to the DVM. The input scanner also has signal switching to route ohms, frequency, and ac/dc inputs to the appropriate DVM connector for direct measurement.

The System (less options) is supplied with a two-section distribution switch, with one section for switching dc stimuli outputs to the UUT and one section to switch dc voltages to the DVM for measurement.



HIGH PERFORMANCE TO COST RATIO
Reliable • Easy to program
Modular • Computer-controlled

HP 9500A automatic test system data

Function	Key Specifications	*Instrument
	Standard system equipment	
Computer	8k memory, 16 I/O channels	HP 2116B
Teleprinter	Input typing: 100 words/min punched paper tape output=10 char/sec, printed page output=10 char/sec	HP 2752A (modified ASR-33)
Punched tape reader	300 char/sec, 1" paper tape	HP 2737A
DC stimulus	±50 V, 0.01 V resolution; ±10 V, 0.001 V resolution; 0 to 1A output, current limit programmable	HP 6130B
DC voltage measurement	100 mV to 1,000 V in 5 ranges, 5 full digits +over-range, 1 μV resolution on lowest range, guarded	HP 2402A
Distribution switch	Two relay trees, each with 1 four-wire input+16 four-wire outputs	HP 9400A
	System options	
DC stimulus (additional)	Same as above; 8 total (max.)	HP 6130B
Distribution switch (additional plug-in modules)	Relay tree, 1 four-wire input and 16 four-wire outputs, (HP 9400A holds 4 total, max.)	Switch modules
AC voltage stimulus to 100 kHz	0.1 to 99,900 Hz, 0.1% resolution; 0.00 to 9.99 V, 0.01 V steps; amplifier provides low output impedance	4031R (krohn-hite)
AC voltage stimulus to 500 MHz	0.1 Hz to 500 MHz, 0.1 Hz resolution; 0 dBm output into 50 ohms	HP 5105A HP 5110B HP 2759A
Attenuator	DC to 1 GHz, 0 to 132 in 1 dB steps	HP 355C/D (programmable)
	Options (continued)	
AC measurement to 100 kHz	50 Hz to 100 kHz, 1 V to 1000 V full-scale (750 V peak) (4 ranges); full 5 digit read-out with over-range; 10 μV resolution on lowest range	HP 2402A/02
AC measurement to 10 MHz	1 mV to 100 V full-scale—10 Hz to 10 MHz	HP 400E (programmable)
AC and phase measurement to 100 MHz	1 MHz to 1,000 MHz (10 bands) 0.1 mV to 1 V full-scale (9 ranges) ±180° phase measurement	HP 8405A (programmable)
Measurement scanning	200 three-wire channels, random access, 3-wire ac/dc, 2-wire freq., 6-wire ohms measurement	HP 2911B HP 2911A/M23
Frequency measurement	0.1 V to 100 V input, 5 Hz to 199.999 kHz, 1 Hz resolution	HP 2402/05
Resistance measurement	1 kΩ to 10 MΩ full-scale (5 ranges) 6-wire measurement, full 5-digit readout with over-range, 0.01Ω resolution on lowest range	HP 2402A/03
Cabinet	Mounting rails, power strip, caster base, fans, filters	1, 2, or 3 bays as req. All equip. installed
Additional 8k memory	Offers total of 16k memory system	HP 2116B/M5
Heavy duty teleprinter	When equipment usage exceeds 5 hrs/day or 30 hrs/week	HP 2754A (ASR-35) replaces HP 2752A

*Also includes computer I/O interface boards, cables, software driver, instrument modifications as required.

Highlights of HP automatic test systems

High Performance to Cost Ratio—HP Automatic Test Systems use standard programmable instruments and computers specifically designed for automated testing. I/O card interfaces are generally standard items. The HP BASIC language used for programming minimizes the cost of application software. Software and hardware training are also included in the price.

Reliability—Instruments and computers used in HP systems are the same proven reliable equipment in use in laboratory production test, and field service environments throughout the world.

Easy to Program—The new HP BASIC language provides easy programming and program change capability. By using an *on-line* interpretive compiler, each test statement is checked automatically for errors during programming and executed one step at a time. This eliminates off-line compiling and tedious debugging. Test operators familiar with the devices to be tested can do the actual programming with only four to eight hours of instruction in HP BASIC.

Modularity—The interface to instruments is made through standard I/O cards. Therefore, systems can be expanded or reconfigured as a customer's requirements change.

Computer-controlled—Most HP systems are controlled by a general-purpose digital computer along with a powerful language. This permits easy program branching to subroutine for fault isolation and offers an inherent system capability for calculating parameters on the devices under test. It also allows processing of data into test reports and statistical records for engineering or management evaluation.

Custom systems

Custom automatic test systems, similar to the HP 9500A, are being produced for module and component testing, R.F. and microwave testing, calibration of equipment, data acquisition and processing, nuclear instrumentation, and avionics and communications devices. These systems are most useful when large quantities or varieties of items must be tested rapidly and the results made available immediately.

Hewlett-Packard will assume system responsibility for interfacing equipment supplied and any required instrument software drivers.

DIGITAL DATA ACQUISITION SYSTEMS

Instrumentation systems for data acquisition can be categorized into two basic classes: digital and analog. An analog system generally consists of a separate signal conditioning, measuring and recording channel for each input (usually a transducer). The system may include an on-line analog computer. In digital systems, multiple inputs are sequentially applied to one set of measuring and recording equipment; with some transducers, signal conditioning equipment may also be shared. A digital computer may be included for both on-line computation and system control.

Analog systems are used mainly where only a few channels are involved (roughly, ten or fewer) and where the real-time equation-solving capability of an analog computer can be brought into play.

Digital systems offer a much greater range of capability in resolution, accuracy and speed, and much lower cost for large numbers of inputs (sometimes as many as 1000 channels). Information in digital form intrinsically offers enormous flexibility in storage and manipulation. For these reasons digital systems are able to fill a much broader range of needs than analog systems.

Hewlett-Packard specializes in digital data acquisition systems, in two major categories:

a) Low-speed systems, operating at speeds up to 40 channels/second. These systems offer high accuracy and resolution (to 6 digits), common mode and superimposed noise rejection, and the ability to handle ac, resistance and frequency inputs as well as dc voltages. These systems are used for measuring slowly changing phenomena, or static analysis.

b) High-speed systems, operating at speeds to 100,000 channels/second (100 kHz), with resolution in the order of 3 to 4 digits. These systems are able to dissect phenomena lasting only seconds, or varying analog signals, taking samples as short as 50 nanoseconds; they are therefore used for dynamic analysis.

In the low-speed area, Hewlett-Packard has complete, packaged systems offering a choice of capabilities in speed, accuracy, resolution, and types of inputs that can be measured, to suit the user's particular applictaion. Benefits of the "standard system" approach are:

a) Better specifications: each system is a thoroughly engineered, tested package, and is completely specified on a data sheet.

b) Greater reliability—through the use of production techniques as applied to standard Hewlett-Packard instruments.

c) Shorter delivery: because systems are composed of standard instruments produced in volume.

d) Easy expandability: systems are offered with many standard, data sheet options allowing easy reconfiguration, even after initial purchase, to suit changing needs. This also makes it easier, and less expensive, to satisfy special requirements.

There are four series of slow-speed systems to choose from. All offer the following types of output: printed strip, typewritten sheet, punched tape, magnetic tape, punched cards. The prinicipal differences lie in the system "front ends".

The 2010 series (pages 124, 125) use the 2401C Integrating Digital Voltmeter as the digitizing element, along with the 2901A Input Scanner. The 2010 series are characterized by exceptional common mode and superimposed noise rejection, selectable integration time, built-in programming capability, and options for measuring ac, ohms, frequency and period.

2014 systems (not detailed in this catalog) are built around the new 3450A Multi-Function Meter. 2014 systems also measure dc, ac and resistance inputs, but can additionally measure dc, ac and resistance *ratios*.

2012 systems (pages 126, 127) are designed principally for applications requiring the ability to measure millivolt-level dc signals at higher speeds than the 2010, 2014 systems—up to 40 channels/second. 2012 systems are furnished with either the 2911 Crossbar Scanner or 2912 Reed Scanner, and can measure ac voltage, resistance and frequency inputs as well as dc voltages.

Low speed 2300 Series Data Acquisition subsystems (pages 128, 129) combine with a Hewlett-Packard digital computer. The 2402A or 3450A Digital Voltmeter and 2911 or 2912A Scanner form "front ends" for any one of the three computers detailed on pages 104-109. The computer provides total control of all system operating functions, in real time, along with on-line computation of data taken from one or a number of channels. A unique 'executive' software program affords the user direct control of the system through a keyboard. Unlike many other computerized data acquisition systems, the 2018 allows easy expansion or reconfiguration, because the software is modular as well as the hardware.

High-speed 2300 Series Data Acquisition subsystems (pages 128, 129) are similarly composed from standard components, such the HP 5610A A-D Converter (pages 122) or HP 1256A A-D Converter (page 119). Because of the very high data rates involved, a Hewlett-Packard computer is used to provide high speed core memory storage, backed up by disc or (digital) magnetic tape bulk storage.

Digital data system elements

Elements making up a digital system may include all or some of those shown in Figure 1. Essential functional operations within a digital system include handling analog signals, making the measurement, handling digital data, and internal programming and control. The function of each of the system modules illustrated is:

Transducer. Translates physical parameters to electrical signals acceptable by the data acquisition system. Typical parameters include temperature, pressure, acceleration, weight, displacement and velocity. Electrical quantities such as voltage, frequency or resistance also may be measured directly.

Signal Conditioner. Performs complementary functions for transducers, such as reference junction for thermocouples, or excitation, balancing and calibration for strain gages.

Scanner. Accepts multiple analog inputs and sequentially connects the signals to one measuring instrument. Inputs may be in the form of millivolt or high level dc or ac voltage, resistance, frequency, period, time interval or events occurring in a specified time interval.

Signal Converter. Translates the analog signal to a form acceptable by the analog-to-digital converter. Examples are conversion of ac voltage or resistance inputs to dc voltage equivalents.

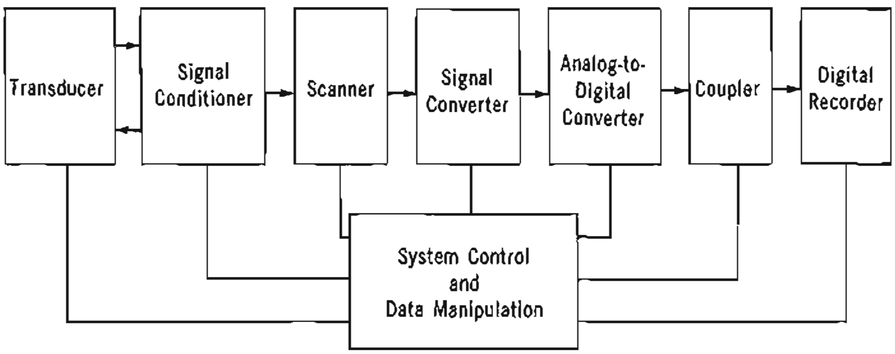


Figure 1.

Analog-to-Digital Converter. Converts the analog signal to its equivalent digital form, for direct printout or recording for subsequent processing. A visual display may be included for operator convenience.

Coupler. Receives digital information from the analog-to-digital converter and translates it to the proper form for entry into a digital recorder. This conversion function can be performed by a coupling instrument or by a computer. The capability to record manually-entered information and time-of-day along with the acquired data may also be provided by the coupler (or computer).

Recorder. Records digital information on punched cards, perforated paper tape, magnetic tape, continuous printed paper strips, typewritten pages or combinations of these media.

System Control and Data Manipulation. Selects system functions such as channels to be measured, type of measurement, comparison limits, etc. Can be performed by a hardware (e.g. pinboard or punched tape) programmer, or by a digital computer. System operation can be correlated with time-of-day by a digital clock, or by the computer. The computer offers unlimited flexibility of system control, but at higher cost.

Data manipulation covers measurement comparison against preset limits, and computation ranging from simple scaling or normalizing to solving of equations such as strain gage rosettes. A comparator may be used if only hi/go/lo comparison capability is required, but if computation is involved a computer should be used, its versatility outclassing the limited capabilities of lower-cost, hard-wired instruments for data manipulation.

Input noise

Data acquisition systems are frequently used to measure signals contaminated with noise arising from various causes, all of which end up as periodic or random disturbances on the real signal.

The most obvious noise sources are electromagnetic or electrostatic pickup on the signal leads (referred to as normal mode noise). While this can to some extent by alleviated by shielding of leads, two principal techniques are employed in analog-to-digital converters to reduce the effects of superimposed noise: filtering and active integration.

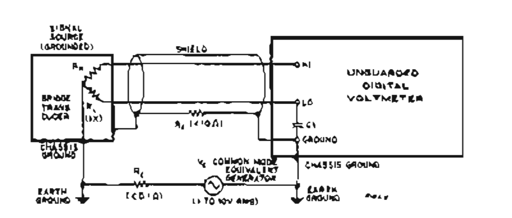
Filters are effective, but have the serious disadvantage that system speed is slowed considerably—typically down to 1 channel per second or less. Integration, as employed in HP digital voltmeters, completely eliminates noise at power line related frequencies (the usual source of ripple) and provides rejection equivalent to that of a filter at other frequencies. And—integration doesn't slow down the system.

Another source of noise, especially prevalent in transducer systems, is common mode noise, which is noise appearing at the digitizer input terminals as a result of circulating ground currents between the system and signal source ground points. This effect can be so severe that a signal of a few millivolts, such as from a thermocouple, may be totally obscured by a common mode input of *several volts*. The problem is insidious because the user never knows to what extent it is present.

Using a heavy ground buss or shield usually will not reduce common mode pickup appreciably and may even increase it, due to magnetic pickup from the ground loop formed. A conventional floating input can reduce common mode noise, but is limited in effectiveness by the capacitance between the measuring circuit and chassis (Figure 2a).

There are two methods to circumvent common mode noise: use of a differential input and guarding. A differential input is used, for example, in the 2212A Voltage-to-Frequency Converter and 2470A Data Amplifier. Guarding is used in all the HP integrating digital voltmeters. It consists of a guard shield which completely isolates the voltmeter measuring circuit from the chassis, breaking the common mode ground loop (Figure 2b).

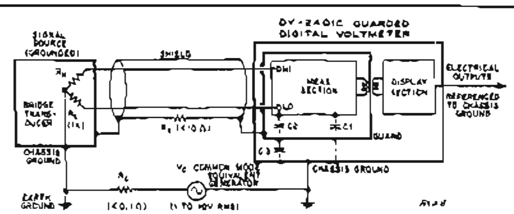
Guarding provides an absolute solution to the problem of common mode pickup from grounded signal sources. This is especially valuable in systems applications where the alternative solution, floating the signal sources, would be extremely troublesome.



R_L = Source ground led resistance
R_s = Shield or ground bus resistance
C1 = Capacitance, measuring circuit to chassis ground (typically 0.1 μf).

Common mode ac current caused by Vc flows in loop Rc, RL, C1 developing spurious input voltage across RL. Current through Rs is negligible due to high input impedance of voltmeter. Typically large value of C1 limits common mode rejection to about 29db with RL = 1K. Shield provides negligible improvement because of low value of Rc.

Figure 2a.



C1 = Stray capacitance, measuring circuit to chassis (< 2.5 pf).
C2 = Stray capacitance, measuring circuit to guard (.002 μf approx.)
C3 = Stray capacitance, guard to chassis (.002 μf approx.),

With guard, ground current is shunted away from measuring circuit through Rs, C3. Resultant current through RL, C2 develops voltage across RL << 10^{-7}v for typical conditions indicated. Guarding reduces value of C1 below 2.5pf, resulting in common mode rejection of 120db at 60cps (with RL = 1K). At dc, resistance from LO to chassis is greater than $10^{11}\Omega$, providing rejection of 160db. Note that average-reading characteristic of DY-2401C provides additional noise rejection.

Figure 2b.

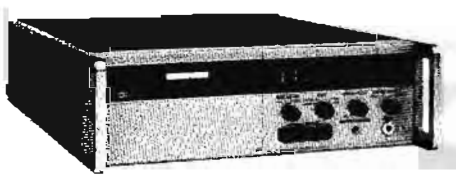
DATA SYSTEM ELEMENTS

Instrumentation for system benefit

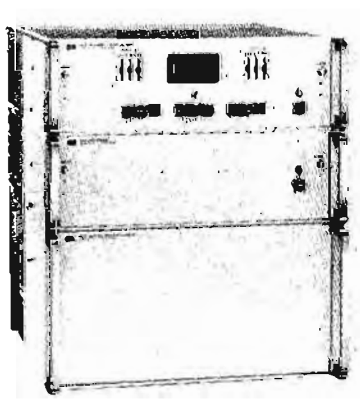
Input scanners

2912A Reed Scanner, a high-speed, multi-function scanner. Transfers guarded 3-wire inputs at speeds to 40 channels per second. Interchangeable modules plug into the mainframe:

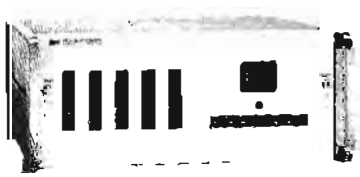
10 channels of low level dc with the 2921A
10 channels of high level dc and ac with the 2922A
9 channels of frequency with the 2923A



2912A



2911A,B,C,



2901A

Up to four modules can be installed; further input expansion is through 2920A Scanner Extenders which hold up to 10 modules each. As many as 10 extenders can be controlled by a 2912A, for 1000 channel scanning capacity.

Integrity of millivolt level signals, such as those from strain gage bridges or thermocouples, is preserved through the scanner.

System programming capability is a built-in feature of the 2912A. Diode pinboards, conveniently located behind the front panel, provide easy control of all DVM functions. Additionally, channels may be individually selected for measurement or skip-over by front panel switch selection. Groups of 10 channels may be handled in the same manner. Upper/lower scan limits select the first and last channel address, and operating modes include single and continuous scan, manual scan and signal channel monitor.

Optional interface for H-P digital computer is available to provide the greatest amount of scanner flexibility. Panel height of 2912A or 2920A 5¼" (113 mm). Prices: 2912A Scanner, $3500; 2921A Low-Level DC Module, $600; 2922A DC-AC Module, $600; 2923A Frequency Module, $600; 2920A Extender, $1500.

2911 Guarded Crossbar Scanner offers user choice of 600 1-wire, 300 2-wire, 200 3-wire, or 100 6-wire inputs. Permits guarded 2-wire voltage or 4-wire resistance measurements. Lower and upper scan limits selectable at front panel, with random access to any channel. Channel being monitored is indicated by in-line visual display and 4-2'-2-1 BCD (optionally 8-4-2-1) output. Roller-mounted switch withdraws from rear for easy cabling. Maximum scanning rate is 30 channels/second. Interface for HP computers available. Panel height 14" (355 mm). Price 2911, $5100.

2901A Input Scanner/Programmer as used in the 2010 series, scans 25 3-wire inputs and programs all functions of associated system. May be expanded to 100 channels with 2902 Slave Units. Easy system set-up with individual quick-release input connectors and pushbutton selection of channels to be scanned. System functions and measurement delay are programmed individually for each channel with built-in pinboard. Maximum scanning rate is 12 channels/second. Panel height 7" (177 m). Prices: 2901A Master, $2375; 2902 Slaves (25 channels each), $1975.

Signal converters

2410B AC/Ohms Converter (page 246) is used in conjunction with 2401C Digital Voltmeter for measurement of ac voltages and resistances. Converter features floated, guarded input compatible with the voltmeter. Combined common mode rejection is 110 dB at 60 Hz. 2410B is fully programmable for systems use. Converter function and range information included in voltmeter display and recording outputs. Panel height 7" (177 mm). Price: HP 2410B, $2350.

2411A Guarded Data Amplifier (page 246). This floated and guarded amplifier provides the 2401C Integrating Digital Voltmeter with a full-scale input of ±10 mV, overranging to ±30 mV. Ideal for measurements of thermocouples, strain gage bridges and other low-level signal sources. Input impedance is greater than 10^{10} ohms. Combined common mode rejection with 2401C is 134 dB. 2411A features very low noise and zero drift, short settling time for fast data sampling. Panel height 3½" (88 mm). Price: HP 2411A, $1250.

Analog-to-digital converters

2401C Integrating Digital Voltmeter (page 246). Features floated and guarded input and is average-reading, yielding an effective common mode noise rejection better than 140 dB at all frequencies, including dc. All operating functions may be controlled manually or by external contact closures to ground, enabling it to be used on the bench or in systems. BCD outputs provided. Panel height 7" (177 mm). Price: 2401C, $4100.

2402A Integrating Digital Voltmeter (page 244) combines 40 samples per second measuring speed with 5 digit resolution. Get low-level measurements without preamplification. Common mode noise rejection >120 dB is provided by guarding and integration. Optional plug-in circuit cards for ac, resistance and frequency measurements yield a multimeter useful for both bench and system applications. Panel height 5¼" (133 mm). Price: 2402A, $4800.

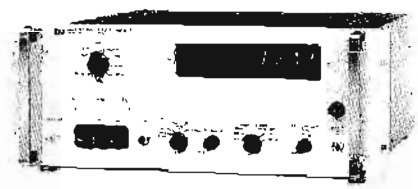
3450A Digital Multi-Function Meter (page 241) is basically a five-digit intergrating DVM with five dc voltage ranges from 100 mV to 1000 V. Guarding and integration provide 140 dB CMR at dc, 120 dB at 60 Hz, at speeds to 15 measurements per second. Isolated four terminal dc voltage ratio measurements are standard; options expand instrument to ac and ac ratio (true rms response), ohms and ohms ratio, hi-go-lo comparison on all functions including ratios. Panel height 3½" (88 mm). Price from $3150.

5601A High-Speed A to D Converter (page 122) for measurements at rates to 100 kHz of signals to ±1 V full scale (optionally ±2.5 V, ±10 V). Used in data systems employing a digital computer. Resolution is 9 bits plus sign and aperture time with sample and hold is 50 ns. Multiplexer capability available for 1, 8 or 16 channels with 100 kHz throughout rate. Panel height 5¼" (133 mm). Price: $2000.

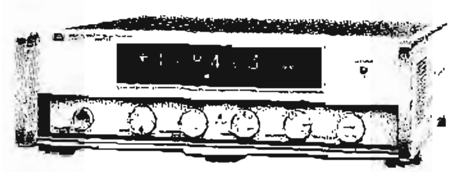
12564A High-Speed A to D Converter is a plug-in circuit card for use with HP 2116B, 2115A and 2114A Digital Computers. Makes 10 V or 1 V (switch selectable) full scale single-ended measurements at rates to 50 kHz. Resolution is 9 bits plus sign, and aperture time is 17.6 μs with 2116B, 22 μs with 2115A or 2114A. Price, 12564A, $1100.

Auxiliary equipment, programmers

2539A Digital Comparator compares BCD information against single or dual preset limits, providing Hi/Go/Lo lamp indications and electrical outputs. Comparisons take <3 ms. Instrument can be operated either manually or by external signals. The 2539A provides for 12 different comparison conditions, handles any combination of limit relative magnitudes and signs likely to be encountered in practical measurement situations. All solid state, features data storage for fast system operation. Panel height 3½" (88 mm). Price: 2539A, $2650 for 6-digit comparison plus sign.



2401C



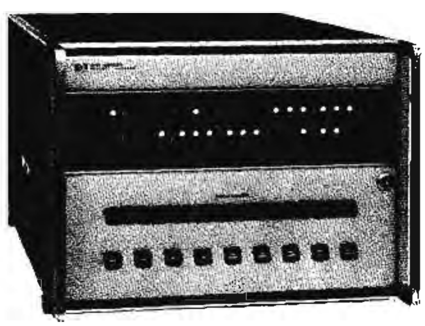
2402A

3450A

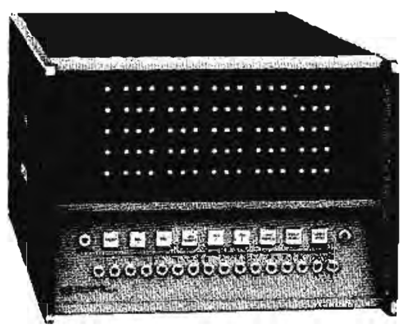
5610A

Instrumentation for system benefit

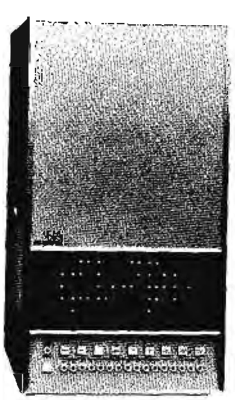
2539A



2114A



2115A



2116A

2911C Programmer operates with the 2911 Guarded Crossbar Scanner. It offers a convenient means of storing and selecting, by channel groups, the system measurement function (e.g., ac/dc voltage, resistance, frequency) and DVM range, and also enables channels to be skipped individually. Programming is accomplished by inserting diode pins into internal program boards which are easily accessible from the front panel while the instrument is installed in position. 2911C is all solid-state. Panel height 5¼" (133 mm). Price: HP 2911C, $3725.

2560A Programmer reads instructions punched on paper tape and governs all aspects of system operation. Programmer selects measurement functions, scanner input channel on a specific channel or group-channel basis, and controls data recording. Also programs system comparator and governs data recording in accordance with comparison result. Operation of the entire system can be changed simply by changing programming tape. 2560A is all solid-state. Panel height 5¼" (133 mm), tape reader, 7" (177 mm). Price: 2560A, $4270 including 2737A tape reader.

2114A, 2115A or 2116B Digital Computers (page 104) provide methods for flexible, sophisticated system control. Timing and sequencing of the input scanner, measuring and recording functions is controlled by the computer. It can also perform limit comparison, code conversion and output formatting otherwise accomplished by separate instruments. Data manipulation such as solving multiple variable equations on stored data or measured inputs from one or more channels is easy when the system includes one of these devices.

In high speed system applications, the computer serves additionally as a data buffer storage unit to permit accumulation of data at rates beyond that of the fastest recording devices. Convenience of operation and system programming and input/output flexibility are paramount in the design of these system elements. Price: 2114A with 4096 word memory, $9950; 2115A with 4096 word memory, $14,500; 2116B with 8192 word memory, $24,000.

Output coupler, recorders

2547A Coupler operates with a variety of input and output devices. As a data acquisition system element, it translates BCD information from a digital voltmeter into the correct code and format for the following digital recorders.

Kennedy 1406 or 1506 Incremental Magnetic Tape Transport. Records on ½ inch mag tape, IBM compatible format at 500 characters per second, 200 or 556 BPI density.

HP 2753A Tape Punch. Records on 1 inch paper tape in IBM 8-level code at 120 characters per second.

HP 2752A and 2754A Teleprinter (modified ASR-33, ASR-35). Records on typewriter and punches tape in ASCII at 10 characters per second.

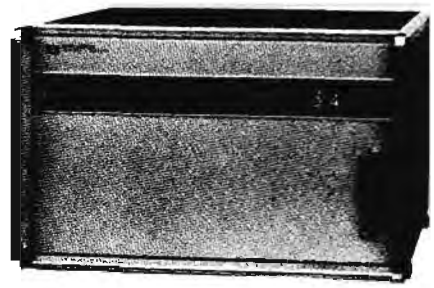
Typewriter (modified IBM Model B). Records at 10 characters per second.

Flexowriter (modified Friden model 2303). Records on typewriter and punches tape in IBM 8-level code at 12 characters per second.

Card Punch. Junction panel with shoe connector provided to drive IBM 526 Summary punch, in Hollerith code at 17 characters per second.

Interchangeable circuit card construction makes it possible to change output recorders in minutes. Plug-in versatility also applies to interconnection with input devices.

When used in data systems, the 2547A can optionally be equipped to provide input scanner channel identification data to the recorders. A thumbwheel-switch panel for manual entry of numerical data may be installed in the instrument front panel. A digital clock may be similarly installed to provide visual display and electrical recording outputs. Time is recorded in response to an input scanner command or on manual command.

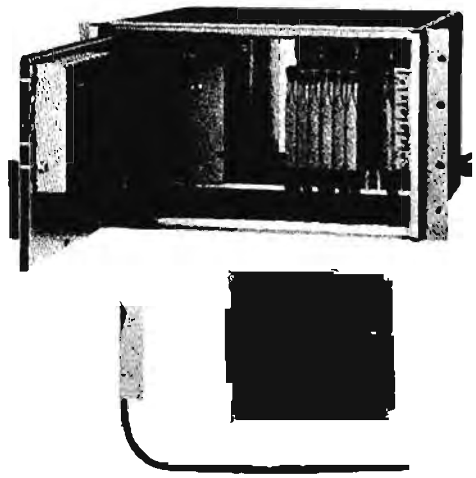


2547A

Digital scanners

Aside from data acquisition applications, the 2547A Coupler can be used to scan data output from up to six digital measuring instruments such as electronic counters, digital voltmeters, nuclear scalers and quartz thermometers. Input devices can be of mixed types providing they have similar output coding and votlage swings. Up to 10 characters per instrument can be processed.

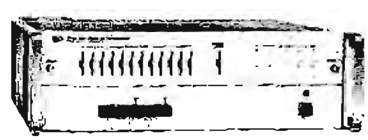
Since data inputs to the coupler are through individual plug-in printed circuit cards, system expansion is easy. Cables to the input sources plug into the front of the coupler and are accessible even when the coupler is rack mounted. Scanning priority is determined by the location of the circuit card within the coupler.



2547A showing interface cards

Scanning of data sources is automatic. Data from free-running or externally triggered instruments is recorded at random as it becomes available. Panel height 10½" (266 mm.) Price: 2547A Magnetic Tape output, $8125 to $9472; 2547A Punched Tape output, $5675; 2547A Teleprinter output, $4150 to $6850; 2547A Typewriter output, $4900; 2547A Flexowriter output, $8125; 2547A Card punch compatible, $3600; Manual data input, $1000; Digital clock $1500 to $2100.

2515A Digital Scanner transmits digital data from multiple digital measuring instruments to a single recording device at a transfer rate up to 10 sources per ms. The 2515A provides for scanning, in programmable sequence, of electronic counters, nuclear scalers, digital voltmeters or complete digital systems. It couples their outputs into a single recording device such as a digital recorder, card or tape punch or magnetic tape recorder.



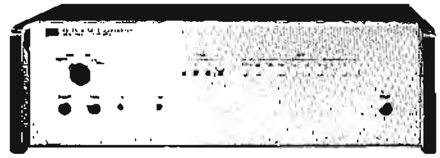
2515A

The basic 2515A accepts up to 12 digits of BCD data (10 data digits, 2 source ID digits) from up to 3 sources. Modifications expand this to 6 sources. By bussing scanner output lines, data from more sources can be transferred to a single recorder. The 2515A interrogates all selected data sources in programmed sequence and transmits this data directly to recorder by solid-state switch. It accommodates a variety of input levels and provides uniform input to recorder. Panel height 5¼" (133 mm). Price 2515A, $4475.

DATA ACQUISITION

High speed, general purpose ADC

Model 5610A



5610A

Analog-to-digital converter Model 5610A

The Model 5610A Analog-to-Digital Converter is a general purpose ADC that offers the following features: 100 kHz throughput rate for a 10-bit word (including sign); a sample-and-hold amplifier that provides an extremely short (50 nanosecond) aperture time; a 1, 8 or 16-channel capacity; a choice of input levels (the standard ±1 volt level for full scale at 100 megohms input impedance or the optional ±2.5 or ±10 volt levels for full scale at 25 K ohms input impedance) and either sequential or random access.

The Model 5610A can operate in an internally sequenced mode, an externally sequenced mode, or a random access mode, either with or without an encode command required. The encode command is requested and the operating modes are determined by a seven-bit command word from the associated computer. The converter samples the analog signal on each of the input channels and converts it to a binary number to be read into computer memory. After a channel is sampled in the internal sequencing mode, the converter automatically samples the next channel. The external sequencing mode permits one channel to be sampled as many times as desired; the converter only transfers to the next channel when an "external sequence pulse" is provided. For either mode, the converter can be wired on site to recycle after any number of channels. The random access mode allows any channel to be sampled by supplying the appropriate channel number in binary code as part of the command word. In any mode, an encode command is required for each conversion unless the command word specifies a free running condition. If free running is specified, a conversion is made every 10 microseconds with no requirement for an encode command.

Digital outputs include the ten data bits, four bits for channel identification, a flag bit that specifies when the data is ready, and one line with clock pulses from the internal 8 MHz clock.

When the 5610A is used with any Hewlett-Packard computer, an interface kit is available, consisting of the interface printed circuit card and cable, as well as a Basic Control System (BCS) driver program and a test program. The BCS driver makes it easy to program the 5610A in FORTRAN or ALGOL. The test program provides an easy, efficient means to check out the performance of the converter. An extremely accurate internal calibration voltage facilitates either manual or automatic checking of converter electrical accuracy.

Specifications

Input

Input range: ±1 V full scale (±2.5 V or ±10 V optional).

Resolution: 9 bits plus sign.

Accuracy: for calibration at 25°C; ±2.75 mV, 10 to 40°C, worst case.

Crosstalk with 16-channel multiplexer: −80 dB at 1000 Hz.

Aperture time: instrument aperture time is less than 50 nanoseconds.

Input impedance: 10 megohms standard (25 K ohms on ±2.5 V or ±10 V range, optional).

Channel capacity: 1, 8, or 16 channels.

Maximum input voltage: 5 times full scale, ±5 V with ±1 V full scale, ±50 V with ±10 V full scale.

Logic interface

Levels: logic levels are Transistor-Transistor Logic. A binary "1" is +2.4 V to +5.0 V. A binary "0" is 0.0 V to +0.4 V.

Output drive capability: A "1" output can supply up to 400 μa and remains above 2.4 V. A "0" output can sink up to 16 ma and remains below 0.4 V.

Commands

Encode: a transition from "1" to "0" is required. This starts the internal clock and initiates sample and hold. Sampling begins 2.0 μsec after the encode is received. Hold occurs 3.0 μsec after encode.

Command word: the command word is 7 bits long. Bits 0, 1, 2 and 3 are the random access address. Bit 4 is random access enable. Bit 5 is free run enable. And bit 6 is internal or external sequence enable. The External Sequence pulse line is not part of the command word.

Operating modes:

Function	Command word		Encode Required
Bit number	6	543 210	
Random Access	Y	00X XXX	Yes
Internal Sequence	1	01Y YYY	Yes
Free run, int. seq*	1	11Y YYY	No
External sequence	0	01Y YYY	Yes
Free run, ext. seq	0	11Y YYY	No
Free run, random access	Y	10X XXX	No

Where X XXX–Selects the desired channel.
Y–Indicates the bit doesn't matter.

*Note that this is the case for no connection also.

Outputs

Data outputs: 10 parallel lines at logic interface. Negative numbers are represented by the binary two's complement of the positive number.

Flag or data ready: a transition from "0" to "1" is provided. (A "1" to "0" is a hard-wired option.) The flag is automatically cleared in free run mode and is otherwise cleared by the encode command.

Channel ID: 4 parallel lines at logic interface.

Clock standard: 8.000 MHz ±0.006 percent, 0-55°C. Clock standard is capable of delivering 1.2 ma at >2.4 V and sinking 48 ma at <0.4 V.

General

Internal calibration: A—.998 V ±.2 mV at 25°C internal calibration is provided. TC is ±5 μV/°C. Provision is made for internally connecting two input channels to the zero and cal signals for calibration under computer command.

Operating temperature range: 0-55°C.

Size: Hewlett-Packard full module, 5¼" high, 11¼" deep, 16¾" wide (135 x 290 x 432 mm).

Weight: Approximately 16 pounds (7,3 kg).

Power: 115/230 V ±10 percent, 50/60 Hz, 90 watts.

Connectors: two 36-pin rear panel printed circuit connectors are used—one for analog input and one for digital input/output.

Price: HP Model 5610A A to D Converter including power cable and two mating connectors for analog input and digital input/output cables, $2000.

Option 01: Multiplexer sequencer, required when using one or any combination of two of the following options, $300.

Option 02: Eight channels of ±1 volt full scale input, $200.

Option 03: Eight channels of ±2.5 volt full scale input, $300.

Option 04: Eight channels of ±10 volt full scale input, $300.

Model 12600A: Interface Kit consists of an interface card, interconnecting cable, BCS Driver and Test program, $1000.

LOGIC MODULE TEST SYSTEM

Model 2060A

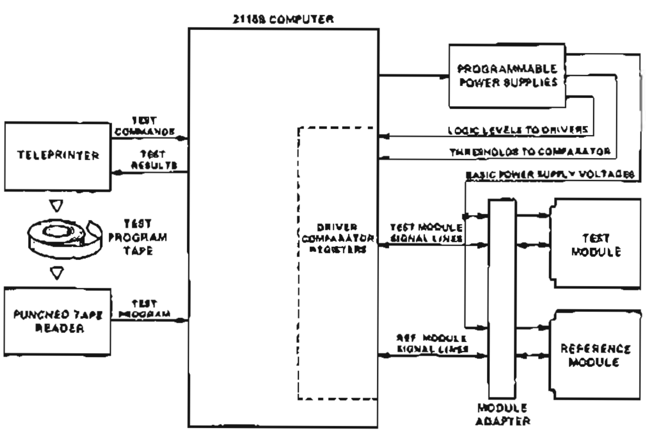
The HP 2060A Digital Logic Module Test System is a computer-controlled automatic system engineered to be easy to put to work and efficient to use. The fast test capabilities of this system will help you to: cut test costs, break production test bottlenecks and improve product reliability.

The system employs a comparison technique in which the responses of 'test' modules are checked against responses of a known-good 'reference' module. The same test inputs are applied to both modules in a programmed sequence, and responses at all module pins are compared simultaneously, at rates to 10,000 tests per second. As shown in the block diagram, the system controller is the HP 2116B Digital Computer, (page 104), with driver—comparator registers forming the heart of the system. The output signals from the two modules are tested to see if there is an error that is outside the programmable tolerance of the comparator. Results, based on success or failure of comparison on a pin-by-pin, test-by-test basis, are logged by the system on a teleprinter for reporting of module faults. The comparison technique does not require test responses to be specified in the test program—a significant shortening of test programming time.

Test conditions are program specified. High and low logic levels, positive and negative current limits, and test tolerances are generated according to test program instructions. Thus, the 2060A System can test a wide variety of logic circuits without special adaptation. The system can be equipped to generate up to four separate sets of test conditions simultaneously, for testing different types of logic (DTL, CTL, TTL, RTL, ECL, etc.) on the same module.

The system operates in accordance with programming instructions written in a new, test-oriented software language —AuTest—, which takes advantage of the benefits of comparison testing. The language minimizes the time spent learning programming, and maximizes the number and scope of tests performed. These features result in savings to the user in startup and operation costs, and minimum disruption of the users normal production line functions.

AuTest speaks the language of digital design engineers and technicians. Less than one day of instruction is necessary to learn the statements needed to write usable test procedures. To effectively program the system, the programmer



does not have to know the function of the board for which he is writing a program; he only need be familiar with the functions of digital logic.

Actual time spent programming is a function of the complexity of the module to be tested. With experience, even the most complex modules can be programmed in a couple of days time.

The language is powerful. Permute statements permit a few program statements to produce thousands of individual tests, a powerful multiplication of the programmers time.

The 2060A is capable of two modes of operation. A 'run' mode is used for quickly sorting modules on a production run basis. Each module to be tested is plugged into a test fixture, and the system is commanded on the Teleprinter to run the test. At the end of each test, the system prints out the module defects, detailed down to the connector pins which represent the faulty circuit. At this point, the system can be used in a 'conversational' mode to help debug module faults. The operator can modify test conditions, specify additional tests, and set up special sequences to provide repetitive waveforms for oscilloscope display.

The 2060A system is flexible. In its minimum configuration, it tests up to 16 module connector pins; it can be easily expanded to 256 pin capacity in 8-pin increments for checkout of the most complex modules. Interchangeable plug-in module test fixtures and fast read-in of test programs convert the system easily and rapidly to changing module configurations, making it economical to test small batches of modules.

DATA ACQUISITION SYSTEMS

Accurate measurement of many noisy signals

Models 2010K, 2010L

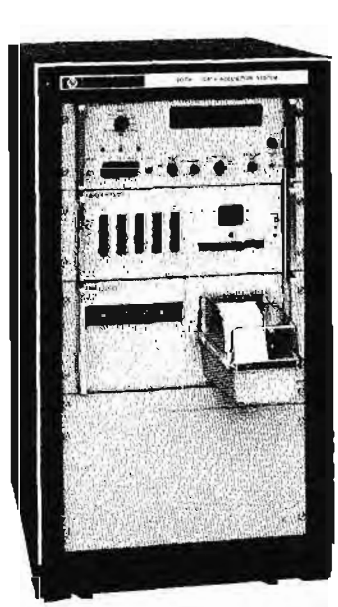
2010 Data Acquisition Systems measure multiple analog inputs and display and record the measurement results. A wide choice of output recorders is offered. For direct reading, a printout on paper tape or typed page is available. Data to be entered into a computer may be recorded on punched tape, punched cards, or digital magnetic tape.

Typical inputs are dc and ac voltages, frequencies, resistances and physical parameters that are convertible by transducers to these analog forms.

Optional additions to the system allow measurements to be compared against preset upper and lower limits; time-of-day correlation of data recordings and timed triggering of system operation; and manual entry of run identification or other numerical information with systems recording on magnetic tape, punched tape, punched cards, or typewritten page.

The digital techniques achieve high measurement resolution and accuracy, high sampling speeds, and the ability to transfer the measurement results easily to a wide variety of digital recording devices. In particular, the HP 2010 series of data acquisition systems utilize the HP 2401C Integrating Digital Voltmeter (page 246) as the A to D Converter. This instrument features a floated and guarded input, permitting accurate low-level measurement in the presence of severe common mode noise—a frequent problem with grounded transducers.

Noise rejection. A high degree of noise rejection is provided through two features of the HP 2401C Integrating DVM. First, the voltmeter is average-reading, thereby greatly reducing the effects of noise superimposed on the signal. Second, errors due to common mode pickup (ground loop currents, usually at power line frequencies) are reduced to negligible proportions by guarding. The guard completely isolates the HP 2401C measurement circuit from the chassis, breaking the common mode loop. The guard connection is carried through the input scanner to the signal source.



2010K

Averaging and guarding together provide an effective common mode rejection of 105 dB minimum for any noise frequency. In practical terms, 1 volt of common mode noise at any frequency will cause less than 6 microvolts error in reading. The system may be used in electrically noisy environments, with no restrictions in regard to grounding of the signal sources.

Input scanning: The system uses a 2901A Input Scanner/Programmer (page 118) to accommodate up to 25 signal sources. Input capacity can be increased at any time to 50, 75 or 100 channels by adding slave scanners.

Each input channel consists of a floated signal pair and shield: Individual quick-release connectors are provided for each input channel. Since the voltage measurement circuit is floated, data sources at potentials up to 500 V with respect to ground can be connected. Input channels are preselected for measurement by front panel pushbutton switches, individually numbered for each channel. A digital display indicates the channel number being monitored.

System programming. The systems include the capability to select the appropriate type of measurement, sample period, and settling delay for each channel. Programming is accomplished by inserting diode pins in a pinboard within the scanner. The scanner front panel swings down for convenient access to the program board.

Output recording. Six types of output recorders are available. The HP 2010K outputs only on printed paper tape. The HP 2010L outputs on either typed log, punched cards, punched tape, and magnetic tape. All of the 2010L systems are optionally capable of recording on printed paper tape as well as their principal medium.

Systems options. The HP 2010K and 2010L Data Acquisition Systems measure and record multiple input signals which may be low or high level dc voltages and frequencies. AC voltages and resistances may be measured with optional additions to the basic system.

Measurement results can optionally be compared digitally against a 6 digit preset limit to obtain a HI, =, or LO output, or against a pair of limits to obtain a HI, GO, or LO output. This is accomplished by an HP 2539A Digital Comparator (page 119). The comparison result is signalled by front panel lamps, and is included in the data recording. The comparator includes a contact closure output for operation of external warning circuits.

Manual data entry is available in 2010L systems. This option consists of 12 thumbwheel switches on the 2547A Coupler (page 120). Manual data may be recorded under pushbutton control, or automatically at the start of each scan. In 2010L systems, an optional digital clock can be installed in the 2547A Coupler; time-of-day is recorded automatically at the start of each scan.

Specifications, 2010 series

DC voltage measurements

Noise rejection:

Overall effective common mode rejection (ratio of common mode signal to its effect on readings): 105 dB at all frequencies, 100 dB at dc; (0.1 sec sample period); amplifier option reduces CMR by less than 6 dB.

Common mode rejection (ratio between common mode signal and voltage it superimposes on source): 85 dB at 60 Hz, 100 dB at dc with 1000 ohms between ground and low side of input (resistances up to 10 k).

Superimposed noise rejection (ratio of superimposed noise to its effect on readings): Combined amplitude of signal and superimposed noise can equal ±3 times full scale for any signal amplitude.

Voltage ranges: five ranges from 0.1 V to 1000 V full scale; polarity sensed and indicated automatically; amplifier (option) provides 10 mV full scale; auto-ranging available.

Overranging: to 300% of full scale except on 1000 V range; input attenuator switched to 1000 V range if overload exceeds 310%.

Input impedance: 10^7 ohms on 10, 100, 1000 V ranges; 1 megohm on 1 V range; 100 k on 0.1 V range; 10^9 ohms with amplifier option for inputs up to 3 V.

Resolution: depends on sample period, maximum of 0.1 μV.

Sample periods: 0.01, 0.1 and 1 sec.

Internal calibration standard: provided for self-calibration; voltage reference is derived from a specially aged and stabilized reference diode; can be used to maintain specified accuracy for 6 months.

Absolute accuracy: (specifications hold for ±10% line voltage variation and 6 months operation, assuming daily calibration against internal standard).

Basic accuracy: ±0.01% reading ±0.01 full scale ±1 count (0.1 V range); ±0.01% reading ±0.005% full scale ±1 count (1/10/100/1000 V range).

Temperature effect: ±0.0015% reading per °C, 10 to 50°C, when calibrated against internal standard at operating temperature; ±0.002% reading ±0.0005% full scale per °C (0.1 V range); ±0.002% reading ±0.0002% full scale per °C (1/10/100/1000 V ranges), when not calibrated at operating temperature, over range 10 to 50°C.

Frequency measurements

Range: 5 Hz to 300 kHz.

Resolution: for 1, 0.1, 0.01 sec sample periods, has 1 Hz, 10 Hz, 100 Hz resolution respectively.

Accuracy: ±1 count ± time base stability (2 PPM per week) over 20° to 30°C temperature range, ±100 ppm over 10° to 50°C.

Input amplitude range: 0.1 to 100 V rms.

Input dynamic range: 100:1 at any attenuator setting.

Impedance: 10^6 ohms shunted by 1000 pF. Each slave scanner adds 250 pF.

Period measurements (optional)

Range: 5 Hz to 10 kHz.

Resolution: for 100, 10 and 1 periods averaged, has 1 μsec, 10 μsec and 100 μsec resolution respectively.

Input: same as frequency measurements.

Accuracy: ±1 count ± time base stability ± trigger error divided by number of periods averaged.

Trigger error: 0.3% maximum for 0.1 V rms sine wave with 40 dB signal-to-noise ratio, decreasing with increasing signal amplitude and frequency.

AC voltage measurements (optional)

Noise rejection:

Comon mode rejection: 75 dB at 60 Hz; decreasing 6 dB per octave for noise frequencies above 60 Hz, with 1000 ohms between ground point of source and low side of system input.

Voltage ranges: 0.1, 1, 10, 100, 1000 V full scale; maximum input, 750 V peak, 530 V rms.

Frequency range: 50 Hz to 100 kHz.

Input impedance: 10^6 ohms on all ranges, shunted by 1000 pF.

Accuracy: 50 Hz to 1 kHz ±0.05% full scale ±0.1% of reading; 10 kHz ±0.05% full scale ±0.1% of reading, 100 kHz ±0.1% full scale ±0.3% of reading. Temp. effect 0.02%/°C maximum.

Response and ripple effects: normal response (frequencies below 400 Hz) output settles to ±0.2% of final value in 500 ms; fast response (frequencies above 400 Hz): output settles to ±0.2% of final value in 200 ms.

Resistance measurements (optional)

Noise rejection: resistance measurement circuit is guarded which minimizes the effect of common mode noise on resistance measurements when guard is connected to low side of test resistance

Ranges: six ranges from 0.1 k to 10 M ohm full scale.

Overranging: to 300% of full scale on all ranges except 10 megohm.

Resistance measurement accuracy: (specifications hold for ±10% line voltage change, 6 months operation, assume daily calibration against internal standard).

RANGE	MEASUREMENT CURRENT	ACCURACY AT 25°C			
		70% HUMIDITY		95% HUMIDITY	
		± % rdg	± % fs	± % rdg	± % fs
0.1 k	10 mA	.02	.51	.02	.51
1 k	1 mA	.02	.06	.02	.06
10 k	100 μA	.02		.03	
100 k	10 μA	.02		.12	
1 M	1 μA	.03	.01	1.0	.01
10 M	1 μA	.12		10	

Temperature effect: .005% rdg ± .001% fs. per °C difference of ambient from 25°C.

Output recorder, system speed

2010K: H006-5050A Digital Recorder produces printed strip, 12-character word length 6.3 channel/second max. speed. Price, $8980.

Note: The 2010L incorporates a 2547A Coupler (page 120) which accepts any one of six fully-interchangeable output sets, providing a selection of six recorders as follows:

2010L with magnetic tape output: drives a Kennedy 1406 or 1506 Incremental Magnetic Tape Recorder at 400 or 500 character per second rate; records on ½" magnetic tape in 7 channel NRZI IBM-compatible format. System speed: 9 channels per second. Price with 1406, $14,925.

2010L with high speed punched tape output: drives an HP 2753A Tape Punch at 120 characters per second; records on 1" paper tape in IBM 8-level code. System speed: 9 channels per second. Price, $12,475.

2010L with Teleprinter output: drives an HP 2752A or 2754A Teleprinter at 10 characters per second; records on 1" punched paper tape in ASCII 8-level code and on typewritten sheets. System speed: 50 channels per minute. Price with 2752A, $10,950.

2010L with electric typewriter output: drives IBM Model B Output Writer at 10 characters per second. System speed 50 channels per minute. Price, $11,700.

2010L with Flexowriter output: drives Friden Model 2393 Flexowriter; records on 1" paper tape in IBM 8-level code and on typewritten sheets at 12 characters per second. System speed: 1 channel per sec. Price, $14,925.

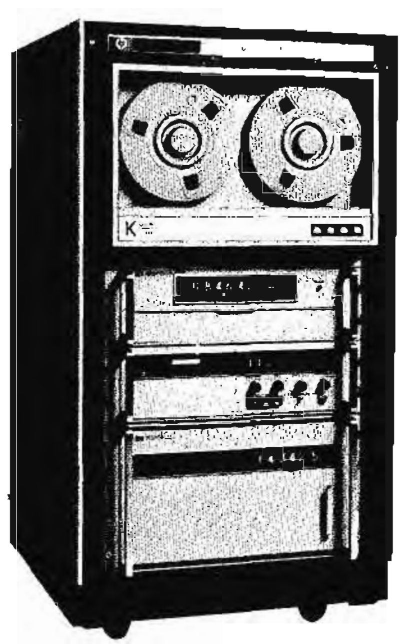
2010L with punched card output: drives IBM 526 Summary Punch; records at 17 characters per second on tab cards in 10-line output code with overpunching necessary to produce special characters. System speed: 1.6 channels per second. Price, excluding card punch, $10,400.

Simultaneous recording on a Hewlett-Packard H006-5050A Digital Recorder is available. Recording speed: up to 9 words/second.

General

Display: 6-digit in-line readout; polarity, decimal point measurement units, and overload; scanner accepts 25 channels standard; expands to 50, 75 or 100; provides indication of channel being monitored.

DATA ACQUISITION SYSTEMS
Rapid, accurate measurement; output flexibility
2012 Series



2012D

Application of the 2012 Data Acquisition Systems is similar to that of the 2010 Series discussed on page 124. Operations performed by the systems include scanning of multiple inputs, digitizing and measuring the signal with a 2402A Integrating Digital Voltmeter (page 244) and recording the output on a wide variety of devices. Recording media includes magnetic or punched paper tape, printed strip, typewritten sheet with or without simultaneous punched tape, teleprinter and punched card.

The 2402A IDVM provides floated and guarded input circuitry in combination with integration. It uses techniques which permit measuring rates to 43 samples per second while providing noise rejection. The result is a system which can measure low level signals rapidly and accurately—even in the presence of large noise signals, without requiring preamplifier modules or filters.

All DVM operating functions are programmable, and programming does not affect the system's excellent noise rejection properties. An optional autoranger is available to relieve range programming.

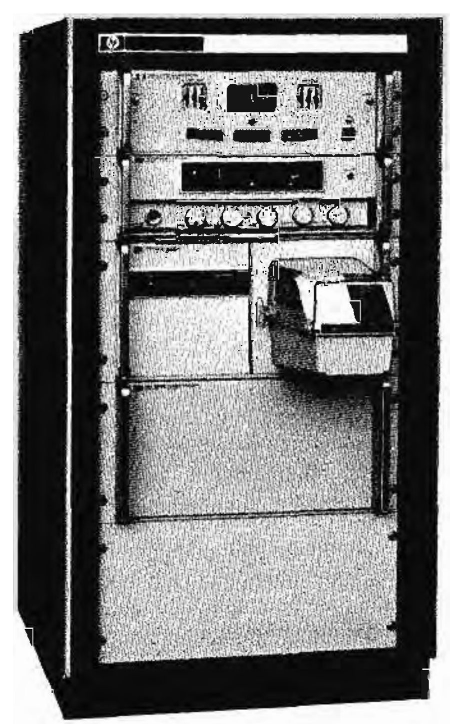
Input scanners

A choice of input scanners is available to match system speed and number of input channels to user requirements. A 2911 Guarded Crossbar Scanner (page 118) is used in the 2012A and B systems to measure large numbers of channels at speeds to 18 channels per second. The 2912A Reed Scanner (page 118) normally measures fewer channels at higher speeds—to 40 channels per second.

Expansion

Standard options permit system expansion from a basic dc measuring system to one accepting ac voltage, resistance and frequency—easily and economically. Circuit cards plug into the integrating digital voltmeter to add measuring capability without increasing system size or operating complexity. Noise rejection is retained with these additions. Circuit cards may be added by the user at any time without system modification.

Additional standard optional equipment includes digital hi-go-lo comparison equipment, pinboard or paper tape system programmers, digital clock and manual data entry. The latter two devices plug into the 2547A Coupler (page 122) and



2012A

add to system capability without adding to size. The digital clock provides visual display and electrical outputs for recording time along with measured data. It also provides the capability to start the system data-gathering sequence at predetermined time intervals.

Specifications, 2012 Series

DC voltage measurements

Noise rejection: overall effective common mode rejection (ratio of common mode signal to its effect on digital display): 2012A, B: 120 dB at dc, 110 dB for all frequencies above 30 Hz; 2012C, D: 110 dB, dc to 500 Hz. Common mode rejection (ratio between common mode signal and voltage it superimposes on source): 2012A, B: 130 dB at dc, 104 dB at 60 Hz; 2012C, D: 110 dB at dc, 94 dB at 60 Hz, both with 1000 ohms between ground and low side of input. Superimposed noise rejection (ratio of superimposed noise to its effect on display): >48 dB for 60 Hz noise frequencies.

Voltage ranges: five ranges from 0.1 V to 1000 V full scale: polarity indicated automatically, autoranging available.

Overranging: to 130% of full scale except on 1000 V range; protected from overload if input exceeds 136%.

Input impedance: 10^7 ohms ±.1% on 100 V, 1000 V ranges; 10^{10} ohms on .1 V, 1 V, 10 V ranges.

Resolution: 1 part in 130,000 on 6-digit display. 100 mV range displays readings to 1 μV.

Internal calibration standard: provided for self-calibration derived from a specially aged and stabilized reference diode operating in a constant temperature oven, can be used to maintain specified accuracy for 6 months.

Overall dc accuracy for 2012 Systems: (specifications hold for ±10% line voltage change and 6 months operation).

Range	100 mV ①	1 V, 10 V, 100 V, 1000 V
ACCURACY ② (at 25 ±1°C)	.01% rdg ±.006% fs or .016% rdg in overrange	.01% rdg ±.003% fs or .013% rdg in overrange

① Accuracy from 0 to 30 mV is 4 μV ±.015% rdg; above 30 mV, accuracy is as stated above.
② When 2402A is calibrated at other than 25 ±1°C, add .0006% rdg ±.0001% fs per °C difference from 25°C. For temperature change after calibration, see TEMPERATURE EFFECT below.

TEMP EFFECT	Per °C change from calibrate temperature	
15 to 40°C	.0015% rdg ±.0006% fs	.0015% rdg ±.00015% fs
10 to 15°C or 40 to 50°C	.002% rdg ±.0006% fs	.002% rdg ±.00015% fs

Frequency measurements (optional)

Range: 5 Hz to 199.999 kHz.

Resolution: 1 Hz.

Accuracy: ±1 count ± time base stability; time base aging rate: 2 ppm per week over temperature range 20° to 30°C; temperature effect, ±100 ppm over 10° to 50°C range.

Input amplitude range: 2012 A, B: 0.1 to 100 V rms; 2012 C, D: 0.5 to 70 V rms.

Impedance: 2012 A, B: 10^6 ohms shunted by 250 pF; 2012 C, D: 10^6 ohms shunted by 230 pF with 9-channel input, plus 25 pF for each additional 9-channel module.

AC voltage measurements (optional)

Common mode rejection: 2012 A, B: 120 dB at dc, 104 dB at 60 Hz; 2012 C, D: 110 dB at dc, 94 dB at 60 Hz, with 1000 ohms between low side of source and low side of input.

Voltage ranges: 1, 10, 100, 1000 V max input, 750 V peak.

Input impedance: 909 x 10^3 ohms all ranges, 2012 A, B: 450 pF shunt; 2012 C, D: 390 pF shunt.

Resolution: 1 part in 130,000 on standard 6-digit display, 10 μV on 1 V range.

AC accuracy

SIGNAL FREQUENCY ①	60 Hz		100 Hz		10 kHz		30 kHz		100 kHz	
	%rdg	% fs	%rdg	% fs	%rdg	% fs	%rdg	% fs	%rdg	% fs
ACCURACY ② (at 25 ±1°C	.09	.05	.06	.03	.06	.03	.09	.05	.14	.09
RIPPLE ERROR ③	.03	–	.02	–	–	–	–	–	–	–
TEMPERATURE EFFECT ④ (Per °C change in ambient from 25°C, over 10 to 50°C range)	.004	.003	.004	.003	.004	.003	.007	.003	.013	.003

① Straight line interpolation holds for frequencies between points.
② Does not include .02% rdg maximum response error, applicable only to step input (received from data system signal scanner); also see response time and measurement speed, below.
③ Ripple error decreases 18 dB per octave above 85 Hz, is zero at 60 Hz because of superimposed noise rejection of basic instrument.
④ Assumes calibration of 2402A against internal standard at 25°C ambient. Calibration of 2402A at operating temperature decreases % rdg temperature effect .0009%.

Transient error: output settles to ±0.02% of final value in 500 ms.

Resistance measurements (optional on 2012 A, B only)

Noise rejection: resistance measurement circuit is guarded, which minimizes the effect of common mode pickup on resistance measurements when guard is connected to low side of test resistance.

Ranges: five ranges from 10^3 to 10^7 ohms full scale.

Overranging: to 130% of full scale; self protected against up to 50 V applied across leads.

Resolution: 1 part in 130,000 on standard 6-digit display, 0.01 ohm on 1 K ohm range.

Resistance measurement accuracy: (specifications hold for ±10% line voltage change, 6 months operation. Assume daily calibration against internal standard).

Range	Measurement current	Accuracy at 25°C			
		70% Humidity		95% Humidity	
		± % rdg	± % fs	± % rdg	± % fs
1 kΩ	1 mA	.01	.01	.01	.01
10 kΩ	1 mA	.01	.005	.02	.005
100 kΩ	100 μA	.01		.10	
1 MΩ	10 μA	.02		1.0	
10 MΩ	1 μA	.12		10.0	

Temperature effect: .004% rdg ±.002% f.s. per °C, difference of ambient with respect to 25°C over 10 to 50°C range

General

Display: 6-digit in-line readout; polarity, decimal point measurement units, and overload; scanner provides in-line digital indication of channel being monitored.

	2012A	2012B						2012C	2012D					
Number of input channels	Guarded crossbar scanner; up to 200 3-wire inputs. Also 100 6-wire, 300 2-wire inputs.							Reed scanner; expands from 10 to 1000 channels in 10 channel increments. 3-wire channels.						
Programming	Pinboard or punched tape programmer may be added to handle mixed signal types and levels.							Self-programming permits measurements of mixed types and levels of signals.						
Effective common mode rejection	120 dB							110 dB						
Measurement speed (max dc volts)	9 chan/sec	18 chan/sec	10 chan/sec	50 chan/min	50 chan/min	1 chan/sec	1.4 chan/sec	20 chan/sec	40 chan/sec	10 chan/sec	50 chan/min	50 chan/min	1 chan/sec	1.5 chan/sec
Output	Digital printer	Magnetic tape	Punched tape	Tele-printer	Type-writer	Flexo-writer	Punched card	Digital printer	Magnetic tape	Punched tape	Tele-printer	Type-writer	Flexo-writer	Punched card
Price	$12,240	$18,350	$15,900	$14,375	$15,125	$18,350	$13,825	$11,405	$17,350	$14,900	$13,375	$14,125	$17,350	$12,825
Options	AC, Ohms, frequency measurement; time of day; manual data entry; programmers, limit comparison, cabinet													

COMPUTER SYSTEMS

For data acquisition and control

2300 series subsystems

Computer-controlled systems for low and high speed data acquisition, and for control of external equipment, may be configured from the modules diagrammed below. One or more analog subsystems can be combined with a high-speed digital computer and appropriate input/output peripherals to suit the specific measurement and control application.

The major benefits of computerized systems are:

a) Raw data is processed as it is taken, yielding meaningful information on-the-spot. Besides shortening overall times to complete projects, this immediacy of feedback allows equipment set-ups to be changed if necessary during critical tests, while conditions still prevail.

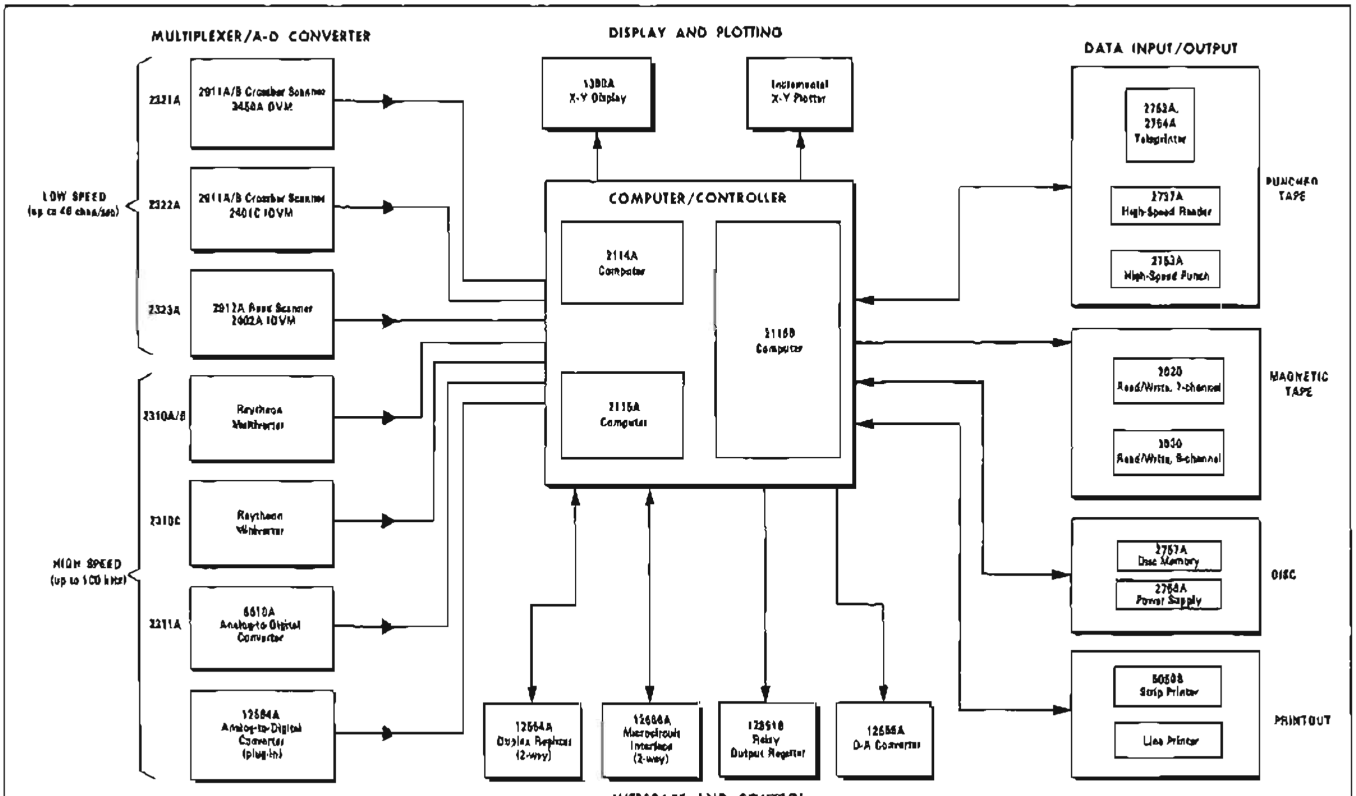
b) Total flexibility is provided in data gathering. Under computer control, sampling rates for various inputs to the system can be automatically adjusted to follow the rates at which input values may change. Data from several sources can be correlated and the sequence and nature of measurements and computations changed accordingly, in the course of a test.

c) Much greater versatility in data input/outputting is possible. Data can be entered, recorded and displayed concurrently in many different forms.

For signal multiplexing and analog-to-digital conversion, a choice of three analog "front-end" subsystems are offered in the low speed range—up to 40 channels per second. Multiplexing is performed by a mechanical (crossbar switch or reed relay) scanner, and analog-to-digital conversion by an integrating-type digital voltmeter. Models 2321A and 2322A accept up to 200 inputs of dc/ac voltage, resistance and frequency. Maximum sampling rate is 15 channels/second for dc inputs (rates for other inputs are lower). Channel capacity for Model 2323A is expansible from 10 to 1000 channels using 10-channel plug-in modules. Sampling rate is 40 channels/second for dc inputs. All three subsystems provide 5-digit resolution, averaging of superimposed noise, and rejection of common mode noise by guarding.

For measurement of dynamic parameters there are five high-speed analog subsystems to choose from, with multiplexed sampling rates ranging to 100 kHz. Model 2310A consists of a successive-approximation analog-to-digital converter (ADC) available in 14-bit and 12-bit (including sign) versions, with conversion rates of 19 kHz and 64 kHz respectively. Aperture time is 50 nanoseconds. Model 2310B includes multiplexing capability to 64 channels, in 8-channel increments. Throughput rates are 18 kHz and 50 kHz, respectively, for the 14-bit and 12-bit versions. Model 2310C is a lower cost multiplexed ADC offering 12-bit (including sign) resolution, 100 nanosecond aperture, and 35 kHz throughput rate.

Model 2311A is a successive-approximation ADC with optional 8-channel or 16-channel multiplexer. It is available with ±1 V full scale input, compared with ±10 V for models 2310A/B/C above. Resolution is 10 bits (including sign), aperture time is 100 nanoseconds, throughput rate 100 kHz. Model 12564A is a single-channel, successive-approximation ADC contained on one card that plugs into the computer I/O system. The 12564A provides 10-bit (including sign) resolution in a conversion time of 17.6 or 22 microseconds, depending on the model of computer with which it is used. Selectable sensitivity is ±1 V or ±10 V full scale. For precise timing of samples, a 2718A Pacer may be used with these high-speed analog subsystems.



COMPUTER SYSTEMS FOR DATA ACQUISITION AND CONTROL

Peripherals for data input/output include low and high speed paper tape readers and punches, 7- and 9-channel magnetic tape units, fast-access fixed-head disc memories and, in addition to printout available from the teleprinter, there is a 20 lines/second strip printer and a 300 lines/minute line printer. Graphical presentations may be obtained with a CRT display and, for a permanent record, a drum type X-Y recorder. All these devices are interfaced with the computer simply through standard plug-in cards, installed either in the computer or an optional I/O extender.

For interfacing user-furnished equipment, a dual 16-bit register may be used for bidirectional data transfer. Two versions are available, to mate with transistor and micro-circuit equipment respectively. For control of external equipment, there is a hard-contact 16-bit relay output register. Modular software drivers for all these peripherals allow easy expansion or reconfiguration of the software operating system; source programs are not burdened with the minutiae of driving these peripherals. Multilevel priority interrupt is standard; service priorities are changed simply by transposing the corresponding interface cards.

Any one of the Hewlett-Packard digital computers—Model 2114A, 2115A or 2116B (page 104) — may be used as a system controller. Selection of the appropriate model will be based on I/O capacity, memory size and speed capability (usually in that order), with consideration for probable future expansion.

The 2114A and 2115B are available with 4K or 8K internal memory; cycle time is 2 microseconds. The larger 2116B is available with 8K or 16K memory, externally expandable to 32K; cycle time is 1.6 microseconds. Main frame I/O capacities are: 8 channels for the 2114A, 2115A, and 16 channels for the 2116B. A 32-channel extender can be used with the 2115A and 2116B. Plug-in options for the 2115A and 2116B include an Extended Arithmetic Unit for high-speed multiply/divide and long shift/rotate instructions—recommended for applications involving substantial on-line computation, and Direct Memory Access, required for high-speed data acquisition.

All are 16-bit machines, sharing the same word structure, instruction repertoire and software. Assuming the equivalent memory configuration and mainframe options are used, programs are interchangeable from one model to another.

System Software: The data acquisition process is completely under computer control, along with data reduction, logging and control of external equipment. Source programs to solve given data acquisition problems may be written by the user in standard ASA Basic FORTRAN, in which he controls instruments through simple read/write statements. Convenient extensions to the standard language include free-field input, which allows information to be entered via the keyboard or punched tape without regard for character spacing or decimal positioning.

In addition to the basic software for the computer (detailed on page 104) a Data Acquisition Executive is available which simplifies the preparation and checkout of source programs. The Executive enables the operator to change signals to be measured, frequency of sampling, computation constants, etc., by entering new values through the teleprinter keyboard, instead of modifying and recompiling his original program.

For applications where maximum simplicity of programming is desired, BASIC language is offered as an alternate to FORTRAN. Drivers for many Hewlett-Packard measuring instruments (including analog subsystems) and input/output peripherals are available. (When not available they can be furnished on a contract basis.) BASIC allows the user to exercise his system in "conversational" mode, debugging and modifying his program as he develops it. While BASIC is intrinsically not a real time system, some control of system timing is afforded in Hewlett-Packard BASIC through a "wait" statement, which allows the user to specify delays between execution of his instrument commands.

Typical computer-controlled low-speed data acquisition system.

The full power of the computer-controlled system is realized with the Hewlett-Packard Real Time Executive software system—usable on the 2116B Computer with 16K core memory and 3.2 megabit disc memory. The Real Time Executive permits real time execution of core and disc resident programs concurrently with background programs stored on disc or punched tape. Programs may be in real time FORTRAN or Assembly language. Multipriority scheduling of all programs and disc swapping of real-time programs make this an extremely flexible system. Re-entrant library routines and I/O drivers add to system efficiency.

CALCULATORS

COMPUTING CALCULATOR
Scientific and engineering problem-solver
Model 9100A

9100A

Uses

Statistical and economic analysis
Coordinate geometry calculations
Solution of transcendental equations
Numerical integration
Vector and complex arithmetic
Network analysis
Solution of differential equations

Description

The 9100A is a programmable, electronic calculator which performs operations commonly encountered in scientific and engineering problems. Its log and trig functions are each performed with a single key stroke, providing fast, convenient solutions to intricate equations. Computer-like memory enables the calculator to store instructions and constants for iterative solutions. The easily-readable cathode ray tube instantly displays entries, answers and, when desired, intermediate results.

Operations

Direct keyboard operations include

Arithmetic: addition, subtraction, multiplication, division and square-root.

Logarithmic: log x, ln x and e^x.

Trigonometric: sin x, cos x, tan x, $\sin^{-1}x$, $\cos^{-1}x$ and $\tan^{-1}x$ (covers all quadrants and any size angle in degrees or radians).

Hyperbolic: sinh x, cosh x, tanh x, $\sinh^{-1}x$, $\cosh^{-1}x$, and $\tanh^{-1}x$.

Coordinate transformation: polar-to-rectangular, rectangular-to-polar, cumulative addition and subtraction of vectors.

Miscellaneous: other single-key operations include taking the absolute value of a number, extracting the integer part of a number, and entering the value of π. Keys are also provided for positioning and storage operations.

Decimal point

Selectable fixed-point or floating-point notation for display of entries and answers.

Fixed-point display: typical display 1234.567890

Up to 10 significant digits with automatic decimal placement and alignment.

Decimal wheel selects 0-9 decimal places, with automatic rounding to the number of places selected.

Left overflow automatically forces display to floating-point notation to allow completion of calculation with no loss of information.

Floating-point display: typical display

1.234 567 890 03

(interpreted as 1.234567890×10^3 or as 1234.567890.)

Dynamic range: accommodates numbers over the range, 10^{-99} to 10^{99}.

Up to 10 significant digits with automatic decimal placement and alignment.

Numerical entry

Fixed-point: digits of number are entered from left to right; keying decimal point in its proper position.

Foating-point: significant digits are entered from left to right, exponent of 10 is entered separately.

Memory

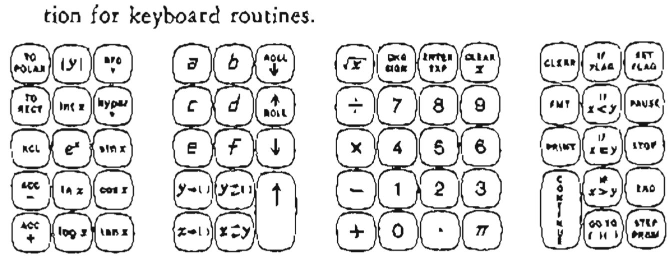
Magnetic core memory contains 19 registers:

3 display registers (keyboard, accumulator, temporary).
16 storage registers, with store/retrieve controls.
Total of 2,208 bits in core memory.

Registers: may be used to store 16 constants, or 196 program steps plus 2 constants, or a combination of constants and program steps.

Capacity: register accommodates floating-point number with 12 significant digits (including 2 undisplayed guard digits) plus 2-digit exponent. Alternately, register accommodates 14 program steps.

Read-only memory: contains over 32,000 bits of fixed information for keyboard routines.



Speed

Maximum times for total performance of typical operations, including decimal-point placement:

- **Add, subtract:** 2 milliseconds.
- **Multiply:** 22 milliseconds.
- **Divide:** 27 milliseconds.
- **Square-root:** 30 milliseconds.
- **Sin, cos, tan:** 330 milliseconds.
- **ln x:** 70 milliseconds.
- **e^x:** 130 milliseconds.
- **Coordinate transformation:** 280 milliseconds.

These times include core access of 1.6 microseconds.

Programming

The program mode allows entry of program instructions, via the keyboard, into program memory. Programming consists of pressing keys in the proper sequence, and any key on the keyboard, except step program, is available as a program step. Program capacity is 196 steps. No language or code-conversions are required.

A self-contained magnetic card reader/recorder records programs for program memory onto wallet-size magnetic cards for storage. It also reads programs from cards into program memory for repetitive use. Two programs of 196 steps each may be recorded on every reusable card. Cards may be cascaded for longer programs.

Program Instructions

- **Conditional branching:** "If" statements make the comparisons—less-than, equal-to-, greater-than—and can be programmed to branch to any of the 196 program addresses.
- **Unconditional branching:** GO-TO statement can be programmed to branch to any of the 196 program addresses. (Also used for manual addressing and correction of individual program steps.)
- **Flag:** provides conditional branching dependent on manual or programmed setting of flag.
- **Stop:** halts program for data entry or display.
- **Pause:** brief display of interim results in computation.
- **Step program:** operator may step through program for visual verification of instructions.

Program library

The program library furnished with the 9100A includes programmed solutions to practical problems in a wide range of scientific and engineering fields. It serves both as an illustration of programming techniques and as a source of ready-to-use programs. Program library holders also receive the *Hewlett-Packard Keyboard*, a periodic publication which provides updating information and a forum for the exchange of programs by 9100A users. Program categories include:

Business	Life Sciences	Statistics
Chemistry	Mathematics	Structures
Electronics	Mechanics	Surveying
Fluid Mechanics	Physics	Thermodynamics

General

Weight: net, 40 lbs (18,1 kg); shipping, 65 lbs (29,5 kg).

Power: 115 or 230 V ±10% (slide-switch), 50 to 60 Hz, 400 Hz, 70 watts.

Dimensions: 8¼" high, 16" wide, 19" deep (210 x 406 x 483 mm).

Accessories furnished at no charge:

09100-90001	Operating and Programming manual, $2.50.*
09100-90002	Program library binder containing sample programs, $30.*
5060-5919	Box of 10 magnetic program cards, $10.*
09100-90003	Pad of 100 program sheets, $2.50.*
09100-90004	Magnetic card with pre-recorded diagnostic program, $2.50.*
9320-1157	Pull-out instruction card mounted in calculator, $5.*
4040-0350	Plastic dust cover, $2.50.*

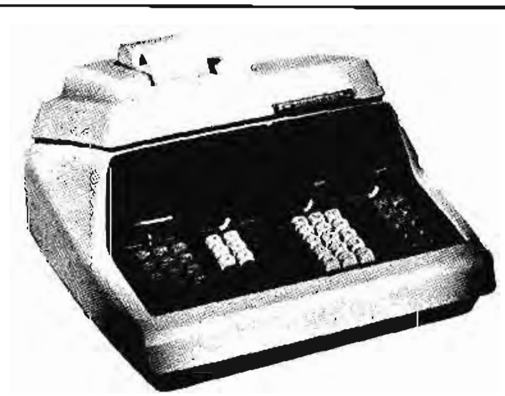
Additional accessories available:

5000-5884	Single magnetic card, $2.
09100-90000	Box of 5 program pads, $10.

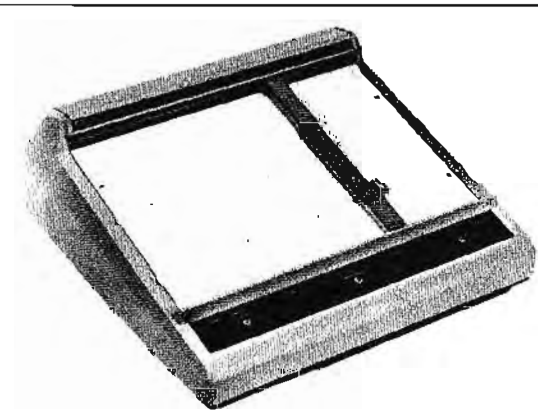
Price: HP 9100A, $4900. Option 001: Pull-out instruction card in French. Option 002: Pull-out instruction card in German. Option 003: Pull-out instruction card in Italian.

*If ordered separately.

Peripherals



9100A with 9120A



9125A

Model 9120A Printer: attaches to the top of the calculator and can be added at any time. Prints contents of display registers X, Y, Z, singly or in any combination, upon manual or programmed command. Also lists program upon command. Uses electrostatic principle for silent operation. Available, fall of 1969.

Model 9125A Plotter: plugs into rear connector on calculator and can be added at any time. Plots upon manual or programmed command, employing calculator's FMT (format) key, 11" x 17" page size. Available mid-1969.

Digital recorders

It frequently is expedient or necessary to obtain permanent records of rapidly changing phenomena measured by electronic counters, digital voltmeters or other digital devices. Often it is desirable to relate this permanent data record to time or translate it to analog form. Hewlett-Packard digital recorders and accessories are designed for this purpose.

Hewlett-Packard digital recorders are electro-mechanical devices which provide printed records of digital information from electronic counters, digital voltmeters, scaler-timers, etc. The two major HP digital recorder categories are the 20 line/s Model 5050B and the 5 line/s Models 561B, 562A and 565A. The common characteristics of all HP digital recorders are (1) parallel entry (i.e., the input data for all digits must be present at the time printing is commanded); (2) a manual paper advance aids observation of last printout; (3) paper is 3" wide fan-folded tape (561B, 562A and 565A also use roll paper) and is easily changed; (4) holdoff signals from the recorders (except 565A) prevent external equipment from changing input data while print wheels are being positioned, and a print command pulse is required from the data source to initiate a recorder print cycle; (5) standby, momentary and print-on-command operation is manually selectable; (6) the recorders are designed for continuous unattended operation; the printing mechanisms are designed for simplicity, durability, and trouble-free operation with little maintenance required.

An analog output, suitable for driving either potentiometer or galvanometer recorders is optional for those 562A's with either 4-2-2-1 or 8-4-2-1 BCD column boards installed. Analog output is very useful for continuous analog plots of data variations such as oscillator drift where the important information is in the printed record's last few digits. HP can also supply separate digital-to-analog converters (Models 580A and 581A).

20 line/s Model 5050B

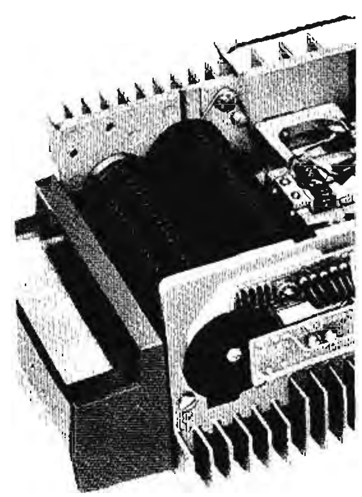
This recorder prints up to 18 columns at 20 lines/second. It can accept a total of 20 columns of 4 bit BCD data from 1 or 2 sources.

The user can easily change the code base of his recorder to use the 4-2-2-1 "1" state positive or 8-4-2-1 "1" state positive or negative codes. The Model 5050B is a simple code comparator which uses an inexpensive, substitutable code disc as a reference. The same column boards are used with all code discs.

The user can easily substitute different print wheels to use mixed codes, that is, to have a different code base and/or character set in each column.

The Model 5050B has two, general purpose character suppression features which have many uses. A typical use is to suppress the printing of leading zeros. By arranging plug-in diodes, the user can suppress the printing of any one of the 16 possible characters in any column (a different character can be suppressed in each column). The other feature (using plug-in jumper wires) makes the suppression of a character conditional—the character is suppressed only if it is a leading character (an insignificant "zero" for example).

The 5050B operates very reliably, due mainly to the simplicity of its design. By being based on an optical code comparator scheme, the 5050B is electrically simple and has very few moving parts. Data storage and built-in digital clock are optional.



5050B printing mechanism

5 line/s printers

(Models 562A, 561B and 565A)

These printers record up to 11 columns of data (12 on special order) and all utilize the same basic printing mechanism. Model choice is usually based upon the flexibility required, input codes, and the cost of equipping the instrument to operate with the printer. A wide variety of special print wheels is available.

Model 562A

This printer requires a parallel-entry, 4-line, binary-coded-decimal input (or 10-line decimal; see options on 562A catalog page). The 562A (utilizing plug-in column board input circuitry) is extremely flexible, allowing operation from two unsynchronized sources. Interchangeability of column boards allows complete mixing of the available codes among the columns. A storage feature in the 562A permits the driving source to transfer BCD data into the 562A binaries in 2 milliseconds, thus freeing the source to initiate a new measurement.

Model 561B

The 561B requires a "10-line" input for each column of information from the data source; thus, each print wheel position is controlled by a separate line. Digital recorder kits for field installation in HP counters are available to permit operation with the 561B: for 521D and 521E counters, kit 521D-95B, $45; for 523C, kit 523C-95B, $65; for 524C, kit 524C-95B, $165.

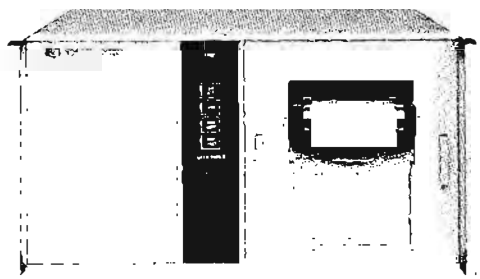
Model 565A

The HP Model 565A is the basic printer mechanism used in the 562A and 561B digital recorders. Data entry is parallel, and one line is needed for each position on each print wheel. Control cables and driving electronics must be fabricated for each 565A application. Front panel appearance of the 565A is similar to the right-hand half of the 561B, and is 9¾" deep behind the front panel.

Digital clocks

For providing time-of-day reference to recorded data, the 5050B, 561B and 562A can have a digital clock installed. The 571B Digital Clock is used with the 561B Recorder, the H03-571B is used with the 562A Recorder, Option 55 clock is for the 5050B Recorder. All time digits are available for printing. The location and number of time digits on the printed record are determined by connector arrangements on the rear of the digital recorders. Clocks also issue timing signals.

DIGITAL RECORDER
20 lines/s; quiet; versatile
Model 5050B



5050B

Advantages:

Inexpensive mixed codes column by column
Versatility of quick-change code discs
Few moving parts
Quiet operation
Data storage and digital clock optional

This recorder is compatible with HP solid state and integrated circuit instruments, and its versatile circuitry adapts it for use with a wide variety of other equipment and data systems. It prints up to 18 columns of 4 line BCD data from one or two sources up to 20 lines/s.

The user can easily change the code base to 8421+, 8421−, or 4221+ by an inexpensive substitutable code disc. In addition, the user can change print wheels to have a different code base and/or character set in each column.

Character suppression allows the user to determine which character is suppressed in each column and whether or not only leading characters are suppressed; typical use is to suppress leading zeros.

A reduction in moving parts leads to reliable operation. Particular attention has been paid to ensuring quiet operation.

Data storage options reduce data loading time from 50 ms to 0.1 ms and decrease input voltage requirements. A built-in digital clock is also optional.

Specifications

Accuracy: identical to input device used.

Printing rate: 20 lines per second, maximum (asynchronous).

Column capacity: to 18 columns.

Print wheels: 16 positions, numerals 0 through 9, −, +, A, V, Ω, *; other symbols available.

Input requirements—without data storage

Data input: parallel entry, BCD (8421, 4221), "1" state must differ from "0" state by at least 4.5 V but by no more than 75 V.

Reference voltages: BCD codes require both "0" and "1" state references; reference voltages may not exceed ±150 V to chassis; "0" and "1" reference voltage must differ by at least 4.5 V; amplitude of each ref. voltage must not exceed its like-polarity data input level by more than 0.5 V.

Hold-off voltage: both polarities are available simultaneously for BCD codes and are diode-coupled; 10 mA maximum load ±15 V open circuit from 1 kΩ source.

Print command: + or − pulse, 4.5 to 20 V amplitude, 1 V/μs minimum rise time, 20 μs or greater in width, ac coupled. Input impedance is approximately 1500 Ω.

Input requirements—with data storage options

Data input: parallel entry, BCD, "1" state must differ from "0" state by at least 1.3 V but by no more than 35 V. Input drive ≥100 μA. Data must be on lines when print command occurs and remain until release of hold-off (85 μs after print command).

Reference voltages: the data source must provide reference voltages, either both levels (High and Low) or one level (Low). If both levels are provided, maximum reference voltage may not exceed ±50 V to chassis. Load between the reference lines: 20 kΩ. Internal control can vary BCD trigger level within reference voltages. If Low reference voltage only is provided, maximum reference voltage may not exceed ±20 V to chassis. The reference line must be able to supply up to 20 mA. The minimum BCD High voltage is approximately 2.1 V above the reference voltage. The maximum BCD Low voltage is approximately 0.8 V above the reference voltage.

Hold-off voltage: both polarities are available simultaneously for BCD codes and are diode coupled; 10 mA max load ±15 V open circuit from 1 kΩ source.

Print command: + or − pulse, 2 to 20 V amplitude, 1 V/μs minimum rise time, 6 μs or greater in width, ac coupled.

Transfer time: 50 ms without storage, 0.1 ms with.

Line spacing: adjustable, 3.5 to 4.5 lines/inch.

Inking: ink roller or pressure sensitive paper. Pressure-sensitive paper should be used where the 5050B is idling more than printing, or for temperature extremes. Conversion between ink and pressure sensitive operation can typically be performed in five minutes.

Operating temperature: −20°C to +55°C with pressure sensitive paper, +10°C to +40°C with ink roller.

Power: 115 or 230 V ±10%, 50 to 60 Hz, approx. 100 W idle, 190 W at 20 lines/sec. 50 Hz model with 20 prints/sec available.

Dimensions: cabinet: 16¾" wide, 8½" high, 18⅜" deep (426 x 226 x 467 mm).

Weight: net, 40 lbs (18 kg); shipping, 53 lbs (24 kg).

Accessories furnished: one pack fan fold paper, one pack folded pressure sensitive paper, ink roller, rack mount kit.

Price: HP 5050B, $1900; Option 01, 02, or 03 must be specified at time of order (no charge). Column boards (one required for each two columns to be operated), $100 each.

Accessories available: fan fold paper HP 9281-0386, $1.50; Pressure sensitive paper HP 9281-0387, $4.00; (15,000 prints per pack). Ink roller (black) HP 9260-0071, $10.00. Input cables, $50 (accommodates 10 input columns from HP solid-state instruments). Input cable for IC counters, $65.

Options: 01 - 8421 "1" state positive code disc.
02 - 8421 "1" state negative code disc.
03 - 4221 "1" state positive code disc.
All three code discs are supplied with each 5050B at no charge. However, one of the above options must be specified so 5050B can be delivered with desired disc installed.
10 - 50 Hz operation, add $15.
50 - Storage for 20 columns, add $400.
51 - Storage for 10 columns, add $200. (Only 10 columns can then be operated.)
55 - Digital clock, installed at time of manufacture, $950. Also available as field installation kit.

DIGITAL CLOCKS

Time recording and print-rate control

Model 571B; Option 55 for Model 5050B

Option 55 for 5050B recorder

Option 55 Clock, for use with the HP 5050B Digital Recorder, provides a convenient method for recording time while also serving as a programmer for the measuring-recording system. Integrated circuits and transistors perform all timing and logic functions. Column boards required for 5050B operation are built into the clock.

Easy-to-read display tubes indicate time to 23 hours, 59 minutes, 59 seconds. In the printout there is a seventh digit available for indicating tenths of a second. The BCD output code of the clock is selectable to be either +8-4-2-1 or −8-4-2-1, but information is easily adaptable to any other code used on the recorder.

As a programmer, the clock is extremely versatile. Print intervals of 1 second, 10 seconds, 1 minute, 10 minutes, or 1 hour are chosen by a front panel switch. Rates as high as 20 prints per second, determined by an external signal, are acceptable.

The clock is available in kit form for model 5050A or may be installed at the factory in new 5050B Recorders.

Specifications, Option 55

Time base: selectable to be 50 Hz, 60 Hz or external. External requires 10 pps negative pulse.

Print interval:

Internal: selectable to be 1 s, 10 s, 1 min., 10 min., or 1 hour between prints.

External: rates up to 20 prints per second.

Time-of-measurement accuracy: time recorded may be 0.1 s less than correct time ± line accuracy.

Visual indication: 6 in-line digital display tubes indicate to 23 hours, 59 minutes, 59 seconds.

Printed output: seven digits indicate to 23 hours, 59 min, 59.9 s.

BCD output code: +8-4-2-1 or −8-4-2-1 selectable. Output adaptable to other recorder codes.

Print format: time printable in any recorder columns.

Clock set: 4 switches electronically set clock to desired initial time.

Power: 115 V or 230 V ±10%, 50 Hz or 60 Hz.

Weight: net, 3 lbs (1,4 kg).

Price: HP Option 55 (factory installed), $950.00. Price of kit for field installation available on request.

571B clock

The 571B Digital Clock, which mounts in the left side of the 561B Digital Recorder provides time-of-day information and controls the rate at which measurements are made. Time is indicated in hours, minutes, and seconds on a 24 hour basis.

The display is available for printing alongside other data. Location and number of time digits on the printed record are determined by connector arrangements on the rear panel of the digital recorder.

The rate at which sampling and printing occur can be controlled by the clock or by an external device. The clock provides five rates selectable by a front panel switch.

A modified 571B (H03-571B) is available for use with the HP 562A Digital Recorder.

Specifications, 571B

Indication: 6 display tubes to 23 hours, 59 min, 59 s; 12 hour format on special order.

Time base: front-panel switch selects: (1) 60 Hz (50 Hz on special order), (2) counter (1 pps, HP vacuum tube counters), external (5 V positive pulses, 200 μs long, 1 pps; input impedance approx. 500Ω).

Time-of-measurement accuracy: time recorded may be up to 1 s less than correct time.

Print control: print rate controlled by clock or by external device. Internally generated rates are 1 per second, 6 per minute, 1 per minute, 6 per hour, and 1 per hour.

Time print format:

In 561B: six time digits recorded in right-hand columns of recorder with clock connected to J101; with clock connected to J102, time recorded in 5 left-hand columns without tens of hours.

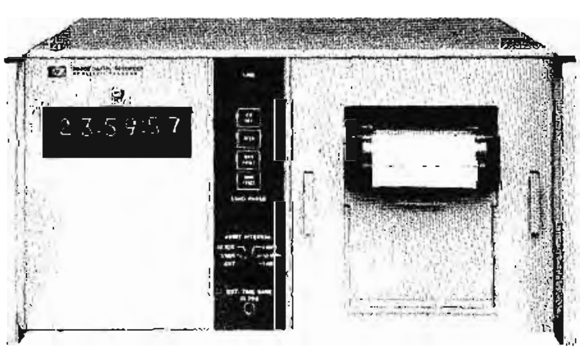
In 562A: recording format (all columns) is set up by plug-in connectors and column boards in 562A.

Weight: net 20 lbs (9 kg); shipping 26 lbs (12 kg).

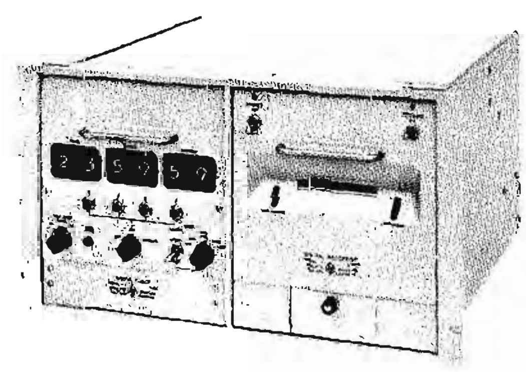
Power: ac and dc supplied by digital recorder; approximately 15 watts.

Price: Model 571B, $1100.00.

Because of the many options available for the 571B clock, please contact your HP sales office when ordering.

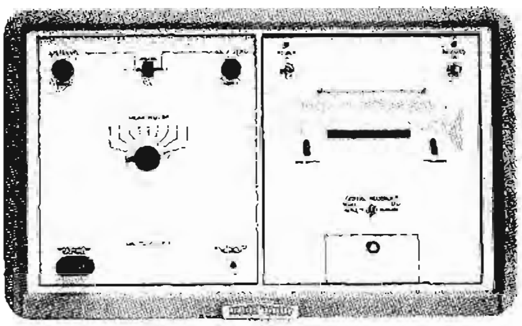


Option 55 with 5050B



571B with 561BR

DIGITAL RECORDER
Flexible data input with information storage
Model 562A



562A with analog output option.

HP Model 562A Digital Recorder is a solid-state electromechanical device providing a printed record of digital data from any of a number of sources. Parallel data entry and low-inertia moving parts allow printing rates as high as 5 lines per second, each line containing up to 11 digits. Twelve-digit capacity is available on special order.

Data enter the unit through rear-mounted 50-pin connectors. Internal plug-in connectors route the information to any desired sequence of print wheels. A separate storage binary unit is associated with each individual print wheel for 4-line BCD input codes.

Model 562A may be equipped to translate 4-2-2-1 BCD, other 4-line codes or 10-line code by substituting plug-in column boards and input connector and cable assemblies.

Specifications

Accuracy: identical to input device used.

Printing rate: 5 lines per second, maximum.

Column capacity: to 11 columns (12 available on special order).

Print wheels: 12 positions, numerals 0 through 9, a minus sign and a blank; other symbols available.

Input requirements

Data input: parallel entry, BCD (4-2-2-1, 8-4-2-1, 2-4-2-1) or 10-line, see Options; "1" state must differ from "0" state by at least 4 Volts but by no more than 75 Volts.

Reference voltages: BCD codes require both "0" and "1" state references; 10-line codes require reference voltage for "0" state; reference voltages may not exceed ±150 V to chassis; input impedance is approximately 270 k ohms.

Hold-off signals: both polarities are available simultaneously for BCD codes and are diode-coupled; 10 mA maximum load +15 V open circuit from 1 k source, −5 V open circuit from 2.2 k source (160 msec hold-off is provided for 10-line codes).

Print command: + or − pulse, 4.5 to 20 volts amplitude, 1 V/μs minimum rise time, 20 μs or greater in width, ac coupled.

Analog output (optional): (from 4-2-2-1 or 8-4-2-1 boards) accuracy is ±0.5% of full scale or better; 100 mV for potentiometer recorder; 50 k ohm minimum load resistance; 1 mA into 1.5 k ohm maximum for galvanometer recorder.

Transfer time: 2 ms for BCD codes.

Paper required: HP folded paper tape (15,000 prints per packet with single spacing) HP Stock No. 560A-131A or standard 3-inch roll tape. 24 packet carton, $21.00.

Line spacing: single or double.

Power: 115 or 230 V ±10%, 50 to 60 Hz, approx. 130 W. (4 prints/s at 50 Hz; 50 Hz model with 5 prints/s available.)

Dimensions: cabinet: 20¾" wide, 12½" high, 18½" deep (527 x 318 x 470 mm); rack mount: 19" wide, 10-15/32" high, 16½" deep (483 x 266 x 419 mm).

Weight: net 35 lbs (16 kg), shipping 80 lbs (36 kg) (cabinet); net 30 lbs (13 kg), shipping 63 lbs (31 kg) (rack mount).

Price: HP 562A, $1185 (cabinet); HP 562AR, $1160 (rack mount); basic unit with 11-column capacity; column boards, input connector assemblies and cables required for operation are not included, see Options.

Options, Group 1

(Completely equips 562A for operation with Hewlett-Packard and Dymec instruments.)

Option 11. For 6-column operation from 4-2-2-1 "1" state positive code, add $555.00.

Option 12. For 9-column operation from 4-2-2-1 "1" state positive code, add $780.

Option 13. For 11-column operation from 4-2-2-1 "1" state positive code, add $1023.

Option 14. For operation with 5245L; 10-column operation; prints measurement unit and indicates decimal position — e.g., 16942.496 kHz would be printed as 3 kHz 16942496; the first digit shows how far to move the decimal to the left; add $880.

Options, Group 2, column boards

Option 21. 4-2-2-1 "1" state positive, $75 each.
Option 22. 8-4-2-1 "1" state positive, $75 each.
Option 23. 8-4-2-1 "1" state negative, $75 each.
Option 24. 4-2-2-1 "1" state negative, $75 each.
Option 25. 10-line "1" state positive (no storage), $50 each.
Option 26. 10-line "1" state negative (no storage), $50 each.
Option 27. 2-4-2-1 "1" state negative, $75 each.

NOTE: Input connector assemblies and input cables (Group 3 options) are required for use with Group 2 column boards.

Options, Group 3, connector assemblies

Option 30. BCD input connector assembly for up to 9 columns, $55.

Option 31. BCD input connector assembly for up to 6 columns, $43.

Option 32. Input cable, for up to 10 BCD columns or three 10-line columns, $50.

Option 33. 10-line input connector assembly for up to 3 columns, $35.

Option 34. BCD input connector assembly for up to 10 columns, $60.

Option 35: Input cable 10513A for IC counters, $65.

NOTE: More than one input connector assembly and input cable are required for: 1. more than nine BCD columns; 2. operation from two sources; 3. more than three 10-line columns.

Options, Group 4

Option 41. Analog output (from 4-2-2-1 boards), $175.
Option 42. Analog output (from 8-4-2-1 boards), $175.

DIGITAL RECORDERS
Print 10-line data at 5 lines/sec
Models 561B, 565A

The 561B Digital Recorder accepts only 10-line decimal code inputs, but is otherwise similar in operation to the HP 562A. The HP 565A Printer Mechanism, mechanically similar to the mechanism in the 561B and 562A, is available for use in custom systems.

Specifications, 561B

Column capacity: 11 columns (12 available on special order).

Print rate: 5 lines per second.

Print wheels: 12 positions having numerals 0 through 9, a minus sign and a blank; other symbols are available on special order.

Input: decimal code, 10 lines plus 2 lines for blank and minus sign for each column.

Driving sources: HP electronic counters (521D, 521E, 523C) with recorder kits, 405CR Digital Voltmeter, stepping switches, relays, beam switching tubes, contact closures, or −15 to −100 volts connected to appropriate input wire.

Print command signal: ±15 volts peak, 10 μs or greater in width, 1 V/μs minimum slope; manual control with momentary-contact switch.

Line spacing: zero, single or double; in "zero" does not print, paper does not advance.

Paper required: 560A-131A folded paper tape or standard 3" roll; tape sufficient for 15,000 single-spaced lines.

Power: 115 or 230 volts ±10% approximately 75 W, 50 to 60 Hz (4 prints/s maximum at 50 Hz): 50 Hz model available which retains 5 print/s capability.

Dimensions: 20¾" wide, 12¾" high, 18½" deep (527 x 324 x 470 mm) (cabinet); 19" wide, 10-15/32" high, 16½" deep (483 x 266 x 419 mm) (rack mount).

Weight: 561B, net 42 lbs (19,7 kg), shipping 70 lbs (31,5 kg) (cabinet mounted); 561BR, net 30 lbs (18 kg), shipping 65 lbs (29,2 kg) (rack mounted).

Accessories furnished: 9281-0018 folded paper tape, one packet, 9283-0002 inked ribbon, 560A-95N Digital Recorder Service Kit; 561B-16A Cable, accommodates 6 columns, connects to Option 02.-equipped vacuum tube counters.

Price: HP 561B, $1250 (cabinet); HP 561BR, $1235 (rack mount).

Accessories available: 560A-131A folded paper tape, 24-packet carton $19.50. Inked ribbon 9283-0002, $3.50. 561-B-16A Cable, 6 ft., 6 columns, $100, 561B-95D Connectors (mates with J101 or J102), $8.50

Specifications, 565A

Number of columns: 11 (12 available on special order).

Data entry: parallel entry to all columns; one line required for each position of each print wheel to be operated.

Maximum print rate: 5 lines per second.

Standard characters: 0 through 9, minus sign and blank (others available on special order); dimensions: approximately 0.085" wide, 0.1" high.

Column spacing: ¼".

Line spacing: 5/32" single space; 5/16" double space.

Power

Motor: 115 V ±10%, 60 W, 50 to 60 Hz (50 Hz provides 4 prints/s max.).

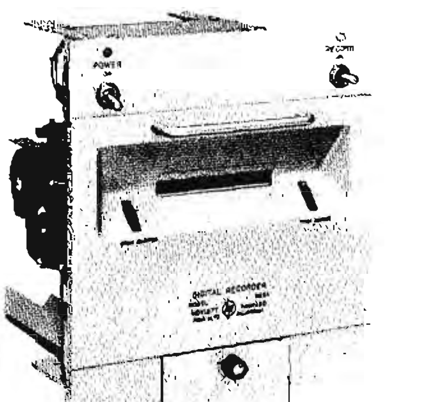
Clutch solenoid: 240 to 260 V dc, 75 mA (operates for approx. 15 ms to start printing cycle); coil designed for vacuum tube switching networks; lower voltage coils are recommended and available on special order for transistor switching.

Pawl magnets: 60 to 70 V dc, 15 mA (operate when needed during printing cycle); coils designed for vacuum tube switching networks; lower voltage coils are recommended and available on special order for transistor switching.

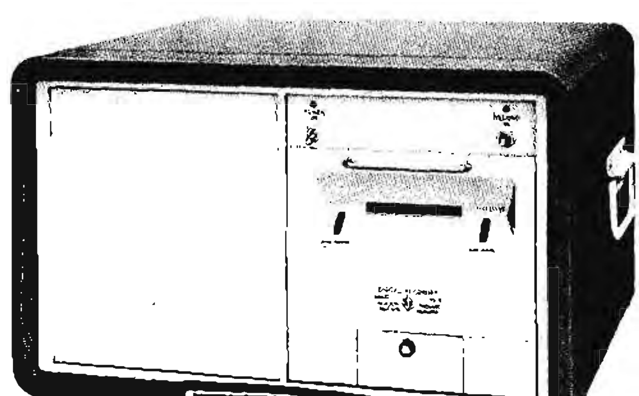
Dimensions: 9¾" high, 8⅜" wide, 9¾" deep (248 x 213 x 248 mm).

Weight: net 15 lbs (7 kg); shipping 28 lbs (12,7 kg).

Price: HP 565A (with high-voltage clutch and pawl coils for vacuum tube drive), $800; for 115 V, 50 Hz operation with 5 prints/s capability specify H27-565A, $835; for 230 V 50 Hz operation with 5 prints/s capability specify H24-565A, $825.



565A



561B

DIGITAL TO ANALOG CONVERTERS

For high resolution recording

Models 580A, 581A

Digital-to-Analog Converters make possible automatic, high-precision analog records from electronic counters, digital voltmeters and other devices providing the proper 4-line BCD output code. These converters operate directly with HP Quartz Thermometers, HP Nuclear Scalers and most HP solid-state counters; output kits are available for HP vacuum tube counters. Since the digital-to-analog converters tolerate a wide range of input voltages, they are suitable for use with other tube and solid-state devices.

Output signals for strip-chart or x-y recorders of both the potentiometer and galvanometer types are available, and controls for recorder calibration and zero adjustment are provided. A 50-pin connector accepts 4-line data from a maximum of nine decade counting units. This information is transferred to storage binary units upon receipt of a command pulse from the counting source. The stored data are then translated and weighted to provide the proper analog output voltage or current.

Any three successive digits (or the right-hand two) of the input may be chosen for analog output. By selecting the two or three least significant digits, analog records of high resolution and accuracy may be obtained with conventional strip chart and X-Y recorders. For example, recording the three right-hand digits of eight- or nine-column data can provide an analog record with resolution of 1 part in 10^8.

Since the data in three successive columns can range only from 000 to 999, automatic zero-shifting is inherent in the output, keeping the record "on scale" at all times. As an example, consider successive readings of: 000, 120, 257, 496, 732, 998, 1024. Except for the last reading, the analog record would proceed up-scale to 998 (99.8% of full scale). Recording of the 1024 value would be made at 024 (2.4% of full scale). The quick transition of the pen from 998 to 024 would serve to indicate that the range has been shifted up by 1000. Down-scale shifts of zero are similarly indicated.

Specifications, 580A, 581A

Accuracy: 0.5% of full scale or better.

Potentiometer output: 100 mV full scale; minimum load resistance 20 K; calibrate control; dual banana plugs front and rear; typical 5 mV residual output at "000".

Galvanometer output: 1 mA full scale into 1500 ohms; zero and calibrate controls; phone jack front and rear.

Driving source: parallel entry 4-line BCD 4-2-2-1 (9 digits maximum); "1" state +4 to +75 volts with reference to "0" state.

Reference voltages: reference voltages required for both the "0" and "1" state, reference voltages not to exceed ±150 V to chassis.

Command pulse: positive or negative pulse, 20 μs or greater in width, 6 to 20 volts amplitude.

Transfer time: 1 millisecond.

Power: 115 or 230 volts ±10%, 50 to 1000 Hz, 11 W.

Options: please specify one of the following input code options (Option 01, 02, or 03):

01: 1-2-2-4 BCD code "1" state positive; "1" state +4 to +75 V with reference to "0" state. No additional cost.

02: 1-2-4-8 BCD code "1" state positive (voltages same as above). No additional cost.

03: 1-2-4-8 BCD code "1" state negative; "0" state +4 to +75 V with reference to "1" state. No additional cost.

04: Special input cable 10513A for HP integrated circuit counters (e.g., 5221B, 5216A, 5331A/B, 5332A/B, 5325A) in lieu of 562A-16C input cable normally supplied. Add $15.00.

Dimensions:

580A (rack mount): 16¾" wide, 3-15/32" high, 11¼" deep (425 x 88 x 286 mm).

581A: 7-25/32" wide, 6-3/32" high, 8" deep (198 x 155 x 203 mm).

Weight:

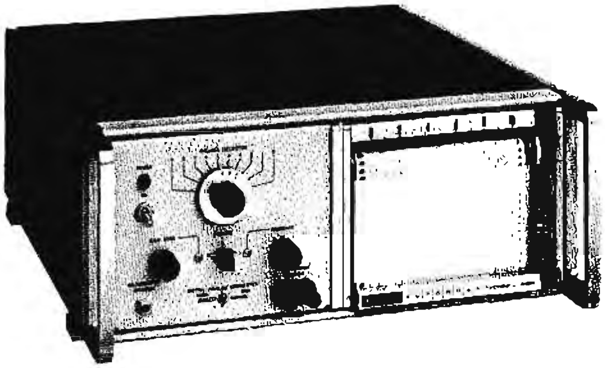
580A:
net: 13 lbs (6 kg)
shipping: 16 lbs (7,2 kg)

581A:
net: 8 lbs (3,5 kg)
shipping: 13 lbs (6 kg).

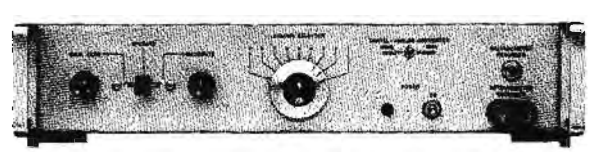
Accessory furnished: 562A-16C Cable, 6' (1830 mm) long with an Amphenol 57-30500 connector at each end. See also Option 04.

Price:

Model 580A, $575.00
Model 581A, $575.00.



581A with 680 Recorder



580A

X-Y RECORDERS

X-Y RECORDERS

The Cartesian coordinate graph is one of the most effective methods for presenting related data clearly. As a result, X-Y recorders have found wide application in areas from general purpose laboratory use to a specialized system readout. Plotting E vs I at the lab bench, or plotting the output of a Multichannel Pulse Height Analyzer, such as the HP Model 5400A, are typical of these applications. Recorder usage is extremely effective where precise X-Y plots are needed, either to obtain accurate data or to allow rapid interpretation of data. An X-Y recorder automatically and conveniently plots the value of an independent variable versus a dependent variable, directly on conventional graph paper, working from readily derived electrical signals.

Over 15 years of experience in pioneering and manufacturing X-Y recorders has made Hewlett-Packard recorders the most useful of their kind.

Basic operation of X-Y recorders

The X-Y recorder uses closed loop servo systems to produce a pair of crossed motions, moving a pen to write precise X-Y plots. It consists of basic balancing circuits, plus auxiliary elements to make the instrument versatile.

Common controls and circuits used to provide versatility are:

1. A stepped attenuator for each axis so that input voltages from the microvolt range to 500 volts may be handled directly.
2. A variable attenuator which provides continuous adjustment to allow a transducer's output to directly correspond to the paper's coordinates in the desired units of measurement (psi, °C, etc.).
3. A zero control which allows the plotting origin to be placed anywhere on the paper or suppressed electrically off the paper.
4. A time base is often incorporated since it is frequently desirable to plot a function against time.

Main features

Long Life Slidewires. All Hewlett-Packard X-Y recorders use accurate, stable wire-wound slidewires which, through a proprietary manufacturing and cleaning process, eliminate the common problem of "dirty" slidewires. The slidewires are linear and open (with dust cover) potentiometers located adjacent to the pen tip affording the best possible linearity and minimum hysteresis.

Paper Holddown. Paper holddown for X-Y recorders must accomplish two basic functions: 1) Hold a reasonable size of standard graph paper, and 2) Hold the paper securely so that it cannot accidentally be moved while making notes, etc. Hewlett-Packard's proprietary electric paper holddown (Autogrip) holds any size paper securely through a combined electrostatic and electrodynamic effect. Autogrip is completely silent, maintenance-free, and does not require special paper.

Reliability. Hewlett-Packard recorders incorporate the results of conservative mechanical and electrical design plus thorough life and environmental testing. All critical parts, including slidewires and motors, are designed and manufactured in-house, resulting in optimum performance, quality, and reliability. Reliability is assured through: 1) Maintenance-free electric paper holddown, 2) Long life slidewires, 3) Hewlett-Packard environmental testing, and 4) Hewlett-Packard Quality Control.

Accessories/Options. Flexibility and useful life are assured through the availability of numerous accessories and options compatible with each recorder model. Examples are the 17108A Time Base which attaches to the low cost 7035B X-Y Recorder, and the 17005A Chart Advance which converts 11" x 17" X-Y Recorders to 10" Strip-Chart Recorders.

Selecting an X-Y recorder

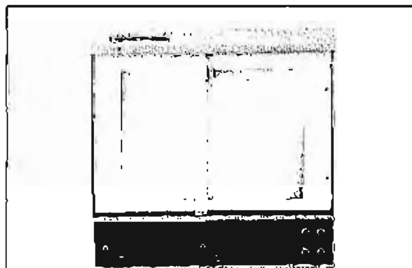
Hewlett-Packard X-Y Recorders may be selected among models in three basic chart sizes, and three basic levels of performance. The basic chart sizes are 8½" x 11, 11" x 17", and 30" x 30". The basic levels are general purpose, high sensitivity, and high performance.

The general purpose recorders are intended for average laboratory use where neither high sensitivity nor high dynamic performance are required. This group is comprised of a low cost type (Models 7005B, 7035B), a general purpose with time base (Models 135, 135A), two-pen (Models 2FA, 136A), and large display (Model 7).

The high sensitivity type is intended for applications requiring the direct plotting of very low level signals (microvolt range) as well as for general purpose usage. This group is comprised of the Models 7000A, 7001A, and 7030A.

The high performance type is intended for applications requiring fast pen response in addition to general purpose usage. This fast response is effected through the use of a very low inertia drive system providing high slewing speed and extremely high acceleration. These units also incorporate input plug-in modules which provide versatility, allowing inexpensive plug-ins to be purchased to accommodate changing applications. This group is comprised of the Models 7004A and 7034A.

To further increase the versatility of these recorders, various accessories and options are available.



7004A

Accessories and options

The available accessories include curve follower, roll chart adapter, incremental chart advance, printers for high speed point plotting, logarithmic converters, keyboard control for plotting tabular data, and a self-contained external time base.

Options include rack mounting (standard on most models), metric calibration and scaling, retransmitting potentiometers, event markers, special input characteristics, rear input connectors and others. The range of accessories is constantly being augmented.

Hewlett-Packard X-Y Recorders

Performance Level	Model	Chart Size	Page	Max. Sensitivity (mV/in)	Other	Price
General Performance	7005B	11×17	139	1.0	①	$1195
	7035B	8-1/2×11	139	1.0	①	$ 985
	135A	8-1/2×11	140	0.5	Time Base	$1650
	7	30×30	140	0.5	①	$4450
	2FA	11×17	141	0.5	Two pen and	$3375
	136A	8-1/2×11	141	0.5	Time Base	$2650
High Sensitivity	7000A	11×17	142	0.1	AC/DC Converter and Time Base	$2495
	7001A	11×17	142	0.1	Time Base	$2175
	7030A	8-1/2×11	142	0.1	Time Base	$1895
High Performance	7004A	11×17	143 thru	0.5②	Very fast response	$1295②
	7034A	8-1/2×11	145	0.5②	Input plug-in modules	$1195②

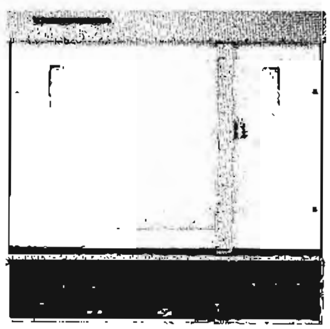
①External time base available (Model 17108A)
②Depends on plug-in selected

GENERAL PURPOSE
Low cost
Models 7005B and 7035B

The Models 7005B (11" x 17") and 7035B (8½" x 11") are low cost, solid-state X-Y Recorders for general purpose applications. Each axis has an independent servo system with no interaction between channels. The recorders will draw a graph of two related functions from two dc signals representing each of these functions. The ultra-compact design is convertible to rack mounting with only the addition of two wing brackets which are supplied. Metric scaling and calibration are optional.

The input terminals accept either open wires or plug-type connectors. Five calibrated ranges from 1 mV/in to 10 V/in are available in each axis. A variable range control allows any voltage, within the recorder limits, to be adjusted for full scale deflection. Standard features include high input impedance of one megohm (all but the first two ranges), floating and guarded input, 0.2% accuracy, Autogrip electric paper holddown, electric pen lift, adjustable zero set, lockable zero and variable range controls, and rear input connector. A plug-in time base (Model 17108A) is available and operates on either axis to provide five sweep speeds from 0.5 to 50 s/in.

Each closed loop servo system employs a high gain solid-state servo amplifier, Hewlett-Packard manufactured servo motor, long life balance potentiometer, photochopper, low pass filter, guarded inputs, precision attenuator and balance circuit. Both models are designed for easy maintenance with most components mounted on a printed circuit board and accessible by removing only the rear cover. Both balance potentiometers are accessible for inspection or cleaning by simply removing a trim strip requiring no tools. Also included are snap-on side panels and maintenance-free Autogrip paper holddown.



7005B 11" x 17"

7035B 8½" x 11"

Specifications

Input ranges: English: 1, 10, 100 mV/in; 1 and 10 V/in; Metric: 0.4, 4, 40, 400 mV/cm and 4 V/cm. Continuous adjustment between ranges with vernier controls.

Type of Inputs: floating differential. Terminals may be placed 500 V dc from ground. Critical circuit areas are guarded with guard terminal on front panel. Rear input connector.

Input resistance:

Range	Input resistance
1 mV/in (.4 mV/cm)	Potentiometric (essentially infinite at null)
variable	11 k
10 mV/in (4 mV/cm)	100 k
variable	100 k
100 MV/in (40 mV/cm)	1 meg
variable	1 meg
1 MV/in (400 mV/cm)	1 meg
variable	1 meg
10 V/in (4 V/cm)	1 meg
variable	1 meg

Input filter: >30 dB at 60 Hz; 18 dB/octave above 60 Hz.

Maximum allowable source impedance: no restrictions except on fixed 1 mV/in (.4 mV/cm) range. Up to 20 k ohm source impedance will not alter recorder's performance.

Accuracy: ±0.2% of full scale.

Linearity: ±0.1% of full scale.

Resettability: ±0.1% of full scale.

Standardization: continuous electronic Zener reference with temperature stability better than 0.002%/°C.

Zero set: adjustable zero may be up to one full scale in any direction from zero index. Lockable zero controls.

Slewing speed: 20 in/s, 50 cm/sec. nominal at 115 V.

Paper holddown: Autogrip electric paper holddown grips any size charts up to maximum size of platen (8½" x 11", or 11" x 17").

Pen lift: electric pen lift capable of being remotely controlled.

Interference rejection: conditions for the following data is line frequency with up to 1 k ohm between the negative input and the point where the guard is connected. Maximum ac common mode voltage is 500 volts peak. Maximum dc common mode voltage is 500 volts.

Range		DC (CMR)	AC (CMR)
English 1 mV/in.	Metric 0.4 mV/cm	130 dB	100 dB
10 mV/in.	4 mV/cm	110 dB	80 dB
100 mV/in.	40 mV/cm	90 dB	60 dB
1 V/in.	400 mV/cm	70 dB	40 dB
10 V/in.	4 V/cm	50 dB	20 dB

Dimensions: 7005B: 17½" (445 mm) high, 17½" (445 mm) wide, 4-5/16" (110 mm) deep. 7035B: 10-15/32" (266 mm) high, 17½" (445 mm) wide, 4¾" (121 mm) deep.

Weight: approximately 18 lbs. (8 kg) net; shipping 24 lbs. (10,9 kg).

Power: 115 or 230 V ±10%, 50 to 60 Hz, approximately 45 VA.

Time base accessory: Model 17108A self-contained external time base has five sweep speeds. Price $ 175

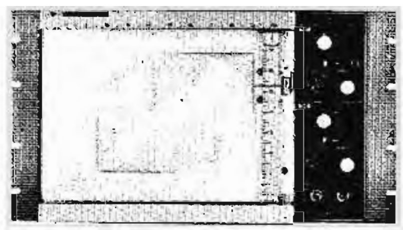
Price:

Model 7005B — 11" x 17" Chart Size	$1195
Model 7035B — 8½" x 11" Chart Size	$ 985

Options:

01.	Metric calibration	N/C
03.	Retransmitting potentiometer on X-axis, 5 k ±3%	$ 75
04.	Disposable pen tips	N/C
05.	Cartridge ink supply	N/C

GENERAL PURPOSE
8½" x 11" and built-in time base
Models 135 and 135A



135, 8½" x 11"

The Models 135 and 135A X-Y recorders are adaptable to almost any laboratory, field or system application. The 135 and the 135M (metric) feature 16 dc input voltage ranges on each axis with a minimum input resistance of 200,000 ohms/V full scale. The 135A and 135AM (metric) feature 11 calibrated voltage ranges with 1-megohm resistance at null.

Standard features include transistor circuitry, calibrated time base on the X-axis, zero set and zero suppression, split potentiometric input mode, scale factor vernier and Autogrip electric paper holddown which holds any chart up to 8½" x 11".

Specifications

Input ranges:

Model 135: (English) 0.5, 1, 2, 5, 10, 20, 50 mV/in, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 V/in.

Model 135M: (Metric) 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100 mV/cm; 0.2, 0.5, 1, 2, 5, 10, 20 V/cm.

Model 135A: (English) 0.5, 1, 5, 10, 50 mV/in, 0.1, 0.5, 1, 5, 10, 50 V/in.

Model 135AM: (Metric) 0.2, 0.5, 2, 5, 20, 50 mV/cm; 0.2, 0.5, 2, 5, 20 V/cm.

All models: vernier control permits arbitrary full scale range setting. Potentiometric mode on Y-axis, obtainable on X-axis on most sensitive range of 135 and four most sensitive ranges of 135A.

Type of inputs: floating up to 500 V dc above ground.

Input resistance:

Model 135: 200,000 ohms/V full scale through 1 V/in range; 2 megohms on all higher ranges.

Model 135M: 200,000 ohms/V full scale through 0.5 V/cm range; 2.5 megohms on all higher ranges.

Models 135A/135AM: one megohm at null on all fixed ranges. Variable range control mode, 100,000 ohms on four most sensitive ranges and one megohm on all other ranges.

Maximum allowable source impedance

Model 135/135M: no restrictions on calibrated ranges; up to 1,000 ohms on most sensitive range (potentiometric input).

Model 135A/135AM: up to 10,000 ohms on four most sensitive ranges; no restrictions on higher ranges.

Slewing speed: 20 in/s, maximum, each axis for 60 Hz; 16 in/s, maximum for 50 Hz.

Accuracy: 0.2% of full scale.

Linearity: 0.1% of full scale.

Resettability: 0.1% of full scale.

Zero offset: adjustable zero may be set up to one full scale in any direction from the zero index.

Standardization: Zener diode controlled temperature stability better than 0.002%/°C.

Time sweeps: (X-axis only) Model 135: 0.5, 1, 2, 5, 10, 20, 50 s/in. Model 135M: 0.2, 0.5, 1, 2, 5, 10, 20 s/cm. Model 135A: 0.5, 1, 5, 10, 50 s/in. Model 135AM: 0.2, 0.5, 2, 5, 20 s/cm. Accuracy 5% of full scale.

Paper holddown: Autogrip electric paper holddown grips charts 8½" x 11" or smaller.

Pen lift: local and remote pen lift.

Power: 115 or 230 V, 50 to 60 Hz, approximately 120 VA.

Dimensions: (bench) 17⅞" (454 mm) wide, 10-15/32" (265 mm) high, 4¾" (121 mm) deep. (Rack) 19" (483 mm) wide, 10-15/32" (266 mm) high, 4½" (114 mm) deep.

Weight: 20 lbs (9 kg); shipping 32 lbs (13,6 kg).

Prices

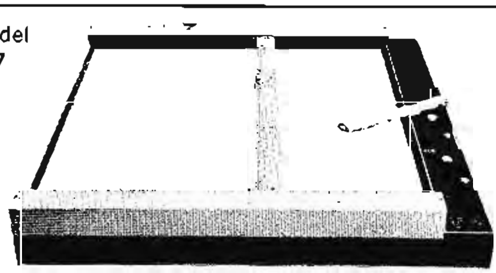
Models 135/135M/135A/135AM		$1650

Options:

02	Rear input connectors (with mating connector)	$ 15
04	Cartridge ink supply	N/C
05	5 k retransmitting potentiometer (X-axis)	$100
06	3.5 k retransmitting potentiometer (Y-axis)	$100
07	Retransmitting potentiometer (both axes)	$200
08	Disposable pen tips	N/C

LARGE DISPLAY X-Y RECORDER
30" x 30" Model 7

Model 7



The Model 7 is an X-Y recorder especially designed for large systems display in console, wall or special floor stand mountings. The Model 7 is ideal for display of data plotted with digital to analog conversion equipment. It incorporates tachometer damping, adjustable on the front panel, which allows the user to optimize the writing characteristics to meet his own demands.

Specifications

Input ranges: 1, 2, 5, 10, 20, 50 mV/in; 0.1, 0.2, 0.5, 1, 2, 5, 10 V/in. Variable range control; potentiometric input on most sensitive range.

Input resistance: 200,000 ohms/V, full scale up to 0.5 V/in; 3 megohms on all higher ranges.

Slewing speed: 20 in/s maximum pen speed, each axis.

Accuracy: better than 0.1% of full scale, resettability better than 0.05% of full scale.

Power: 115 V, 60 Hz, approx. 185 VA.

Dimensions: 40⅜" (1026 mm) wide, 7-1/16" (180 mm) deep, 37-5/16" (948 mm) high.

Paper size: standard 32" x 32" graph paper with 30" x 30" (762 x 762 mm) plotting area; vacuum holddown.

Weight: net 90 lbs (40,5 kg); shipping 180 lbs (81 kg).

Price:

Model 7		$4450

Option:

01	230 volt operation	$ 100

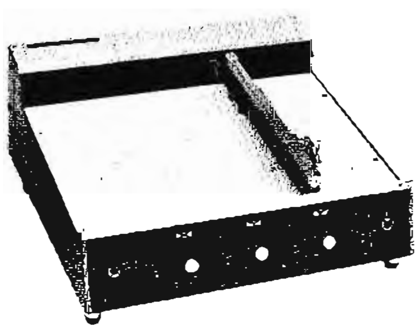
TWO PEN X-Y_1, Y_2

Simultaneous plotting of three parameters

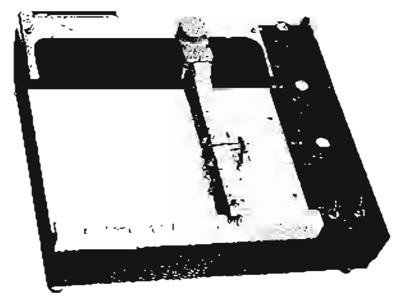
Models 2FA and 136A

The 2FA (11" x 17") and 136A (8½" x 11") are two-pen X-Y_1, Y_2 graphic recorders available with English or Metric scaling and for bench or rack mounting. Standard features include a built-in time base on the X axis with 5 calibrated sweeps; 11 input voltage ranges with a continuous vernier that fits arbitrary maximum voltages within the recording limits of the paper; a full scale zero set and suppression; local and remote electric pen lift and potentiometric inputs. The two pen capability makes these recorders extremely useful for plotting 3 parameters simultaneously.

The two pens traverse the full X axis with no more than 0.1 inch horizontal separation. The servo drives are independent and free of electrical ground. The servo amplifiers and power supplies are combined in a single compact modular unit. A simplified self-balancing system using linear slidewires and a continuous zener-controlled reference provides for non-interacting and accurate recording versatility. Exclusive Autogrip electric paper holddown capability provides a positive hold of chart paper up to the maximum size of the platen. Operation is silent with no moving parts and is maintenance free.



2FA Series 11" x 17"



136A Series 8½" x 11"

Specifications

Input ranges: 0.5, 1, 5, 10, 50 mV/in; 0.1, 0.5, 1, 5, 10, 50 V/in. Metric models: 0.2, 0.5, 2, 5, 20, 50 mV/cm; 0.2, 0.5, 2, 5, 20 V/cm. Variable range mode all positions. On the Model 2FA, potentiometric input is available on the four most sensitive ranges of each axis by removing an internal buss on the attenuators. On the Model 136A, potentiometric input is available on the four most sensitive ranges of the X-axis by removal of an internal attenuator buss and on both Y axes by a front panel switch.

Type of inputs: dc floating up to 500 V above ground.

Input resistance: one megohm at null on all fixed ranges. Variable range mode, 100,000 ohms on four most sensitive ranges and one megohm on all others. Potentiometric input operation draws essentially zero current at null.

Maximum allowable source impedance: up to 10 k ohm source impedance will not alter recorder's performance on the four lowest ranges. No source impedance restrictions are on ranges above 10 mV/in.

Slewing speed

2FA series: 60 Hz operation: 10 in/s (25 cm/s) on the X-axis; 20 in/s (50 cm/s) on Y_1 and Y_2 axes maximum. 50 Hz operation: 8 in/s (20 cm/s) on the X-axis; 16 in/s (40 cm/s) on Y_1 and Y_2 axes maximum.

136A/AM: 60 Hz operation: 20 in/s (50 cm/s) on the X-axis; 15 in/s (38 cm/s) on Y_1 and Y_2 axes maximum. 50 Hz operation: 16 in/s (40 cm/s) on the X-axis; 12 in/s (30 cm/s) on the Y_1 and Y_2 axes, maximum.

Accuracy: 0.2% of full scale.

Linearity: 0.1% of full scale.

Resettability: 0.1% of full scale on all ranges.

Standardization: Zener diode controlled. Temperature stability better than 0.002%/°C.

Time sweeps: on X axis only: 0.5, 1, 5, 10, 50 s/in; metric: 0.2, 0.5, 2, 5, 20 s/cm. Accuracy 5% of full scale.

Paper holddown: Autogrip paper holddown electronically grips charts of any size up to maximum size of platen.

Pen lift: local and remote.

Power: 115 or 230 V, 50 or 60 Hz, 130 VA.

Dimensions: 2FA/2FAM (bench): 18¼" (464 mm) deep, 17½" (445 mm) wide, 8⅛" (206 mm) high; 2FRA/2FRAM (rack): 8" (203 mm) deep, 19" (483 mm) wide, 19-7/32" (488 mm) high; 136 A/M (bench): 14" (355 mm) high, 17⅞" (454 mm) wide, 6-3/16" (157 mm) deep; (rack) 14" (355 mm) high, 19" (483 mm) wide, 6-3/16" (157 mm) deep.

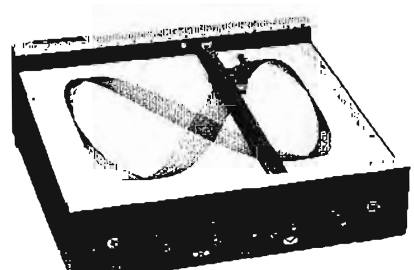
Weight: 2FA series net 42 lbs (18,9 kg); 55 lbs (24,75 kg) gross. 136A/AM net 34 lbs (15,45 kg), shipping 47 lbs (21,3 kg).

Price: 2FA/2FRA (English), 2FAM/2FRAM (Metric) $3375
136A/136AR (English), 136AM/136AMR (Metric) $2650

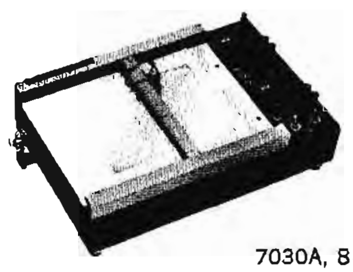
Options:

2FA Option Number	136A Option Number	Description	Price
01	02	Rear input connectors (Both sets supplied with mating connectors)	$15
02	–	Event marker	$100
–	03	5 k ohm retransmitting potentiometer-X axis	$100
03	04	Disposable pen tips	N/C

HIGH SENSITIVITY
100 μV/inch
Models 7000A, 7001A and 7030A



7000A, 11" x 17"



7030A, 8½" x 11"

The 7000A 11" x 17" X-Y recorder has high sensitivity, high common mode rejection and accepts either ac or dc signals on either or both axes. The 7001A is identical to the 7000A except for the omission of ac input ranges. The 7030A is similar to the 7001A except for the chart size (8½" x 11"). Specially guarded and shielded circuitry provides one megohm input resistance at null on all ranges. Units are available for bench or rack mounting and with metric or English scaling.

Any chart is held smoothly and firmly by the Autogrip electric platen which is silent in operation and maintenance-free. Flexibility is built into the electronic time base which may be switched to operate in either axis. Sweep features include automatic reset, adjustable sweep length, and automatic recycling.

Zero offset for each axis may be preset, in 5-inch calibrated steps, up to 4 full scale lengths in Y and 3 full scale lengths in X with continuous adjustability between steps. A dc accuracy of 0.2% of full scale holds when switching between ranges, making recalibration unnecessary during operation. All models display extremely good retrace characteristics.

Ac sensitivity up to 5 mV/in (2.5 mV/cm) on the Model 7000A is a convenience when using Hewlett-Packard Model 1110A and 456A ac clip-on current probes for plotting currents without additional amplification.

Specifications

DC input: (English) 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 mV/in; 0.1, 0.2, 0.5, 1, 2, 5, 10, 20 V/in. (Metric) 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25 mV/cm; 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10 V/cm. Continuously adjustable between ranges with vernier control.

AC Input: (7000A only) 5, 10, 20, 50 mV/in; 0.1, 0.2, 0.5, 1, 2, 5, 10, 20 V/in. (Metric) 2.5, 5, 10, 25 mV/cm; 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10 V/cm.

Type of inputs: dc floating up to 500 V above ground; guarded and shielded. Ac input (7000A only) is single-ended, capacitor coupled.

DC input resistance: one megohm at null on all calibrated and variable dc ranges. Potentiometric input on 6 most sensitive ranges by disconnecting an internal buss wire (front panel switch optional).

AC input impedance: (7000A only) one megohm on all calibrated ac ranges.

Maximum allowable source impedance: up to 10 k ohm source impedance will not alter recorder's performance on the first six ranges. Higher source impedances will cause an increase in dead zone and a decrease in pen speed. No source impedance restrictions on ranges above 5 mV/in.

Interference rejection: dc common mode rejection 140 dB on 3 most sensitive ranges; 120 dB at power line frequency on 2 most sensitive ranges.

Slewing speed: 20 in/s, maximum, each axis for 60 Hz; 16 in/s, maximum for 50 Hz.

Accuracy: dc — 0.2% of full scale; ac — 0.5% of full scale, 20 to 100,000 Hz.

Linearity: dc — 0.1% of full scale; ac — 0.2% of full scale; time sweep — 1% of full scale.

Resettability: 0.1% of full scale on all ranges.

Standardization: continuous electronic reference, zener diode controlled. Temperature stability better than 0.005%/°C.

Time sweeps: may be applied to either axis: 0.5, 1, 2, 5, 10, 20, 50, 100 s/in. Metric models: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 s/cm.

Time base accuracy: 2% of full scale.

Zero set (dc range only): continuously adjustable with 5" (10 cm) calibrated steps for up to 3 full scale lengths on X and 4 on Y. Zero check push button switches on each axis.

Power: 115 or 230 V, 50 to 60 Hz, approximately 120 VA.

Dimensions: 7000A/AM, 7001A/AM (bench): 6½" (165 mm) high, 17½" (445 mm) wide, 17" (432 mm) deep. 7000AR/AMR, 7001AR/AMR (rack): 17-7/16" (443 mm) high, 17¾" (451 mm) wide inside rack clearances, 5⅜" (136 mm) deep.
7030A/AM: (bench) 12-1/16" (306 mm) high, 17⅞" (454 mm) wide, 4¾" (121 mm) deep. (Rack) 4¾" (121 mm) deep, 10-15/32" (265 mm) high, 19" (483 mm) wide.

Weight: 7000A/7001A series: net 38 lbs (17,2 kg); shipping 46 lbs (20.9 kg). 7030A series: net 27 lbs (12,2 kg); shipping 33 lbs (15 kg).

Prices: 7000A/AR (English), 7000AM/AMR (Metric)
11" x 17" chart size $2495
7001A/AR (English), 7001AM/AMR (Metric)
11" x 17" chart size $2175
7030A (English), 7030AM (Metric) 8½" x 11"
chart size $1895

Options:

Option Number			Additional Price	
7000A/ 7001A Series	7030A	Description	7000A/ 7001A Series	7030A
01	01	Potentiometric switch for 6 most sensitive ranges	$55	$55
04	05	5 K ohm retransmitting potentiometer on X-axis	$75	$150
05	06	Rear input terminals	$50	$50
	07	3.5 K ohm retransmitting potentiometer on Y-axis		$150
06		5 K ohm retransmitting potentiometer on Y-axis	$75	
07	08	Retransmitting potentiometers on both axes	$150	$300
09		Event marker (X-axis)	$100	
	09	Remote sweep capability	Standard	$75
10	10	Disposable pen tips	N/C	N/C

HIGH PERFORMANCE
Plug-in versatility and fast response
Models 7004A and 7034A

The 7004A (11" x 17") and the 7034A (8½" x 11") are designed with flexibility for the constantly changing requirements of laboratory measurements. Plug-in modules plus a variety of accessories provide a versatile X-Y Recorder with high dynamic performance. Electronic circuitry common to all plug-in modules (power supplies, interfacing, etc.) is located in the main frame. This allows the user to purchase additional low cost plug-ins at a later date to expand the measurement capabilities of the system. The plug-in approach also allows the user to initially purchase only the capabilities required.

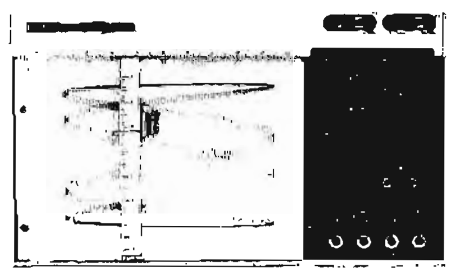
The high dynamic performance is best illustrated by the high slewing speed and rapid acceleration. With an acceleration of better than 1200 in/s², and slewing speed of 30 in/s, the 7004A and 7034A record more phenomena than previously possible with an X-Y Recorder.

The recorders are designed with the most advanced technology and integrated circuits available. They use all silicon circuitry and the proven Autogrip electrostatic paper holddown.

In order to fully utilize the superior performance, guarded circuits are provided. Guarding eliminates the effects of unwanted ac and dc common mode voltages which can be troublesome in some types of recordings and applications. Common mode voltages are particularly troublesome when recording from thermocouples, strain gages and any similar low voltage sources.

The availability of plug-in modules provides a versatile X-Y Recorder for a variety of applications. If your application changes, in many cases measurement capability is available by the simple addition of an inexpensive plug-in. In addition to the plug-in advantages, the high dynamic performance allows the recorder to be used in practically any X-Y Recorder application with complete satisfaction.

7004A (11" x 17")



7034A (8½" x 11")

Specifications

Number of plug-ins: frame will accept the equivalent of four single width plug-ins, two per axis.

Type of input: floating and guarded signal pair. Available at the front panel or at the rear connector. Input may be operated up to ±500 V dc with respect to chassis ground.

Standardization: Zener reference with temperature stability better than 0.002%/°C.

Zero set: zero may be placed up to 1 full scale from zero index.

Zero check switches: a push button zero check switch in each axis allows verification of recorder's zero position without removal or shorting of the input signal.

Range vernier: lockable sensitivity control for up to 2.5 times range setting.

Slewing speed: greater than 30"/s (75 cm/s) independent of line voltage and frequency.

Peak acceleration: greater than 1200"/s² (3000 cm/s²).

Stability: better than 0.003%/°C.

Terminal linearity: ±0.1% of full scale.

Resettability: ±0.05% of full scale.

Paper holddown: Autogrip paper holddown electrically grips charts of any size up to maximum size of platen.

Pen lift: local and remote control.

Dimensions

7004A: 17½" (445 mm) wide, 17½" (445 mm) high, 4¾" (121 mm) deep;

7034A: 17½" (445 mm) wide, 10½" (267 mm) high, 4¾" (121 mm) deep.

Weight

7004A: 24 lbs (10,9 kg) net, 32 lbs (14,5 kg) gross;

7034A: 16 lbs (7,3 kg) net, 22 lbs (10 kg) gross.

Power: 115 or 230 volts ac ±10%, 50 to 400 Hz, approximately 85 VA depending on the plug-ins used.

Price

Model 7004A—11" x 17" Chart Size	$1295
Model 7034A—8½" x 11" Chart Size	$1195

Options

01:	Metrically scaled and calibrated (7004A only)	N/C
02:	X-axis retransmitting potentiometer, 5 k ohms, ±0.1% linearity (7004A only)	$ 75
04:	Power Supply for 17005A-04 Incremental Chart Advance (7004A only)	$ 50
001:	Metrically scaled and calibrated (7034A only)	N/C

PLUG-IN MODULES
For recorder Models 7004 and 7034A

DC Coupler Model 17170A

The DC Coupler provides direct coupling of the input signal to the recorder main frame. The input signal range of 100 mV/in (50 mV/cm) may be adjusted to 250 mV/in (125 mV/cm) with a vernier control on the recorder front panel.

Specifications

Input range: a single fixed calibrated range of 100 mV/in (50 mV/cm).

Input resistance: constant 1 megohm.

Common mode rejection: 120 dB at dc and 70 dB at 50 Hz and above with 100 ohms between low side and point where the guard is connected. Applies to 10K or less source impedance.

Price: Model 17170A $50.

DC Pre-amplifier Model 17171A

The DC Pre-amplifier is a stable, low noise, dc amplifier. The 14 calibrated input ranges are supplemented by a vernier control on the recorder front panel to provide a continuously variable range from 0.5 mV/in (0.25 mV/cm) to 25 V/in (12.5 V/cm).

Specifications

Input ranges

English—0.5, 1, 2, 5, 10, 20, 50 mV/in, 0.1, 0.2, 0.5, 1, 2, 5, 10 V/in.

Metric—0.25, 0.5, 1, 2.5, 5, 10, 25, mV/cm 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5 V/cm.

Input resistance: 1 megohm.

Maximum allowable source impedance:

Range	Maximum Source Resistance
0.5 mV/in (0.25 mV/cm)	10 K ohm
1 mV/in (0.5 mV/cm)	20 K ohm
2 mV/in (1.0 mV/cm)	40 K ohm
5 mV/in (2.5 mV/cm)	100 K ohm
10 mV/in (5.0 mV/cm)	200 K ohm
20 mV/in (10.0 mV/cm)	400 K ohm
50 mV/in (25 mV/cm) and up	1 megohm

Warmup: approximately 5 minutes.

Price: Model 17171A $250

Option: 01 metrically scaled N/C

Time Base Model 17172A

The Time Base plug-in makes X-T or Y-T recordings possible. It employs all silicon solid state construction including the latest integrated circuits. Standard features include eight speeds, automatic reset and pen lift at completion of sweep, and remote start control. A vernier control on the recorder front panel extends the sweep speed thru 250 s/in (125 s/cm).

Specifications

Sweep speeds: English—0.5, 1, 2, 5, 10, 20, 50, 100 s/in; Metric—0.25, 0.5, 1, 2.5, 5, 10, 25, 50 s/cm.

System accuracy: ±1% of full scale on the six fastest ranges, ±2.5% on the remaining two ranges.

Terminal based linearity: ±0.5% of full scale.

Price: Model 17172A $200.

Option: 01 metrically scaled N/C

Null Detector Model 17173A

The Null Detector plug-in provides closed loop plotting of data in point form, at up to 50 pps. Plotting is accomplished with the Model 17012B Point Plotter. The 17012B cable plugs into a jack on the 17173A panel and the plotting head is substituted for the recorder pen. (See page 145.)

Upon receipt of a seek signal and after the recorder reaches balance the Null Detector commands the 17012B Point Plotter to plot and initiates a plot complete pulse.

The Null Detector may also be free run, independent of a seek signal, to allow point plotting of slowly varying signals.

Specifications*

Plot rate: up to 50 plots/s.

Enable-disable: required disable voltage +3 volts minimum to +20 volts maximum. Required enable voltage: 0 V dc or no connection. Other voltage combinations available upon request.

Muting: local or remote.

Plotting accuracy: ±0.25% of full scale minimum.

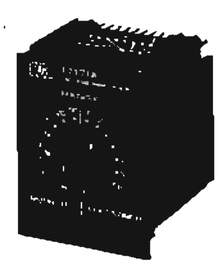
Input: all inputs, except analog inputs, are available through rear input connectors in the module. Analog inputs are applied to the input terminals of the main frame. Mating connector supplied.

Price: Model 17173A $200.

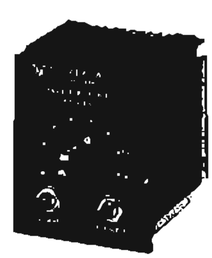
Options: 01: +3 to +20 V enable, 0 V disable $ 25.
02: −3 to −20 V disable, 0 V enable $ 25.
03: −3 to −20 V enable, 0 V disable $ 25.

*For use only with 7004A.

DC Coupler
17170A



DC Preamplifier
17171A



Time Base
17172A

Null Detector
17173A

PLUG-IN MODULES
For recorder Models 7004A and 7034A

DC Offset Model 17174A

The DC Offset plug-in provides the recorder with the capabilities of recording small signals superimposed on a steady state dc voltage. The offset plug-in suppresses the steady state dc voltage allowing the recorder sensitivity to be increased.

Specifications

Offset: 1 mV to 1 volt.

Controls: two lockable ten-turn high resolution controls (less than 1 mV to approximately 10 mV and less than 1 mV to approximately 1 V). An offset polarity switch allows upscale or downscale zero offset.

Offset voltage stability: greater than 0.005%/°C.

Insertion loss: less than 0.05%.

Price: Model 17174A $100

Filter Model 17175A

The Filter plug-in rejects ac input signal components above 50 Hz. Insertion of the 17175A prior to any signal conditioning input module will improve normal mode rejection.

Specifications

Input voltage range: −5 to +50 V dc, 10 V ac maximum peak-to-peak.

Maximum source impedance: 1 k ohm, higher impedance decreases filter response.

Rejection: greater than 55 dB at 50 Hz and higher (¼ s rise time) or greater than 70 dB at 50 Hz and higher (1 s rise time). Front panel selectable.

Insertion loss: 1%, filter may be switched out with no change in insertion loss.

Price: Model 17175A $75

Scanner Model 17176A

The Scanner plug-in electrically scans between two inputs, similar to the chopped mode on an oscilloscope, and provides the capability of plotting two dependent variables vs. one independent variable. The Scanner plug-in, utilizing the Model 17012B high speed point plotter, can scan two selectable inputs (module or main frame) in two scan modes (multiplexing both inputs or singularly). The scan rate is adjustable from 0.1 s/scan to 10 s/scan.

Specifications*

Input: module input; front panel BNC connector isolated from ground (high and low only). Main frame input; utilizes existing input connectors on main frame.

Attenuator: fixed attenuator in decade steps from X1 to X.001. Variable attenuator provides continuous coverage. Maximum input 100 V.

Input impedance: 100 k.

Accuracy: 0.2% of full scale.

Scan rate: adjustable from 0.1 to 10 s/scan.

Price: Model 17176A $300

DC Attenuator Model 17178A

The DC Attenuator, offers a stable, passive attenuator with eight ranges. A vernier control on the recorder control panel allows continuously variable settings between fixed ranges of the 17178A.

Specifications

Input ranges: English—0.1, 0.2, 0.5, 1, 2, 5, 10, 20 V/in; Metric—0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10 V/cm.

Input resistance: 1 megohm.

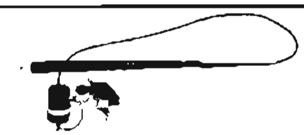
Common mode rejection: 120 dB at dc and 70 dB at 50 Hz and above with 100 ohms between low side and point where the guard is connected (at 100 mV/in or 50 mV/cm). On other ranges CMR decreases 20 dB per decade step in attenuation.

System accuracy: ±0.2% of full scale.

Price: Model 17178A $100

Option: 01 metrically scaled N/C

Point Plotter Model 17012B



17012B

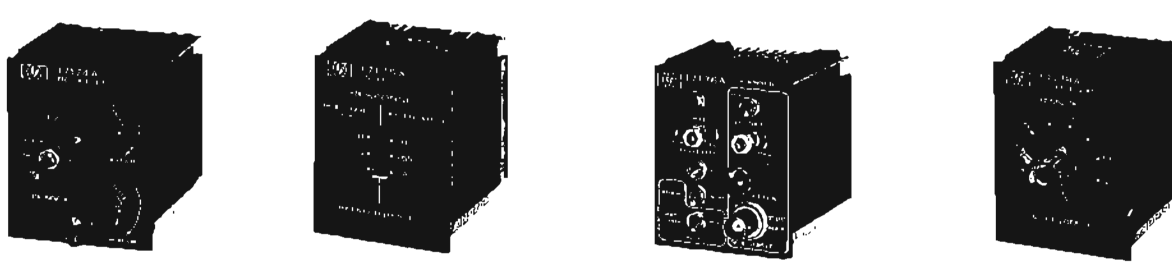
The 7004A when equipped with the 17173A Null Detector plug-in and 17012B Point Plotter, is capable of high speed plotting up to 50 points/second. High dynamic response and rapid point plotting are necessary for applications such as a high speed readout for a multichannel pulse height analyzer. Plotting is controlled by the null detector.

Specifications*

Plotting rate is up to 50 points per second; power is supplied from the recorder.

Price: Model 17012B $95

*For use with 7004A only.



DC Offset 17174A | Filter 17175A | Scanner 17176A | DC Attenuator 17178A

LOGARITHMIC CONVERTERS

Convert ac or dc signals to logarithmic scaling

Models 7560A and 7561A

Models 7560A (two channel) and 7561A (one channel) are self-contained instruments, designed to produce dc output voltages in logarithmic relationship to dc input voltages or to the peak or average amplitude of ac input voltages over a 1000 to 1 amplitude range. Standard or metric calibration is available.

The output signal of one channel may be applied to one axis of an X-Y recorder to produce curves representing logarithmic values as a function of an independent variable applied to the second axis. Since the logarithmic scale compresses the high amplitudes with respect to the lower ones, the presentation has the advantage of plotting over wide amplitude ranges with constant accuracy of reading at all levels. The dual channel model 7560A may be used for log-log plotting with one channel for each axis of the recorder.

Typical applications are: plotting the frequency characteristics of filters, transformers, amplifiers, networks, and similar devices; vibration testing; pulse height analyzer readouts; computers; and any application requiring wide dynamic range or logarithmic relationships.

7560A 7561A

Specifications, 7560A and 7561A

Input ranges:

Input attenuation	AC input range (sine wave, rms)	DC input range
0	0.001 to 1.0 V	0.00316 to 3.16 V
−10	0.00316 to 3.16	0.01 to 10.0
−20	0.01 to 10.0	0.0316 to 31.6
−30	0.0316 to 31.6	0.10 to 100.0
−40	0.10 to 100.0	0.316 to 316.0

Frequency range: 20 to 100,000 Hz.

Dynamic range: 60 dB (1000 to 1), ac or dc.

Output range: 5, 10, or 20 dB/in into 20,000 ohm load; metric unit: 2, 5, 10 dB/cm into 10,000 ohm load.

Ambient temperature range: 10° to 35°C.

Response speed: 1 second or less for input change of 20 dB.

Calibration stability: ±0.5 dB (better than ±0.2 dB over any 24 hour period).

Input impedance: approximately 2 megohms, 35 pF.

Accuracy: ±0.5 dB up to 50 kHz; and ±1.0 dB up to 100 kHz.

Power: 115 or 230 V, 50 to 60 Hz, 7560A—approximately 40 VA; 7561A—approximately 25 VA.

Dimensions: 16¾" (425 mm) wide, 13¼" (336 mm) deep, 3-27/32" (98 mm) high.

Weight: 13 lbs (5,9 kg) net; 20 lbs (9,1 kg) shipping.

Price

Dual channel: 7560A (English) 7560AM (metric) $975.

Single channel: 7561A (English) 7561AM (metric) $595.

Impedance Matching Networks

The 7560A and 7561A Logarithmic Converters and the 40D Keyboard must work into a known load impedance to maintain calibration. Impedance Matching Networks are available for most recorder models. The chart below indicates compatibility and specifies the proper network.

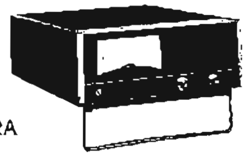
Price: $25.

ACCESSORY MODELS	RECORDER MODELS					
	2D2A 2FA* 136A* 135A* 7000A 7001A 7030A* 17171A*	2D2AM 2FAM* 136AM* 135AM*	7000AM 7001AM 7030AM* 17171A-01*	7005B 7035B	7005B-01 7035B-01	17501A 17500A
40D Keyboard	17102A (@ 0.5 mV/in)	—	—	—	—	—
40DM Metric Keyboard	—	17102A (@ 0.2 mV/cm)	17103A (@ 0.1 mV/cm)	—	—	—
7560A 7561A Log Converters	17100A (@ 10 mV/in)	—	—	17109A (@ 10 mV/in)	—	17100A (@ 100 mV)
7560A 7561A Metric Log Converter	—	17104A (@ 2 mV/cm)	17105A (@ 1 mV/cm)	—	17110A (@ 0.4 mV/cm)	17104A (@ 50 mV)

*Keyboard (Model 40D/40DM) not compatible

—— Dashes indicate not compatible

LOGARITHMIC CONVERTERS
Convert ac or dc signals to logarithmic scaling
Models 7562A and 7563A



7562A

Model 7562A

The Model 7562A is a wide range, single channel logarithmic converter designed to produce dc output voltages in a logarithmic relationship to dc input voltages or the true RMS value of an ac input voltage. With a 10,000 to 1 (80 dB) amplitude range it is extremely useful for applications requiring the logarithmic compression of a voltage range. The 7562A contains a true RMS detector which inherently is not dependent on pure sinusoidal signals to achieve measurement accuracy. A self-contained meter is calibrated in volts and dB giving the 7562A added capability as an accurate voltmeter. A constant amplitude oscilloscope output, available at the rear panel, independent of voltage changes at the input, makes the converter compatible with a variety of oscilloscope readout and phase meter applications.

Specifications

AC and dc modes

Input:

Dynamic range: 80 dB.

Voltage range: 1 mV to 10 V or 10 mV to 100 V selectable by front panel switch. Accepts either ac or positive dc signals.

Output:

Voltage: 0 to 800 mV dc corresponding to 10 mV/dB.

Output impedance: 100 ohms.

DC mode

Accuracy: ±0.25 dB at 25°C.

Input impedance: 100k ohms. Shunted by less than 100 pF. Single ended.

Temperature coefficient: ±0.02 dB/°C maximum.

Zero stability: ±0.25 dB.

AC mode

Input impedance: 1 megohm. Shunted by less than 100 pF. Single ended.

Accuracy and frequency response: (at 25°C).

Range setting	0.5 Hz–2	2–5	5–20	20–50	50–200 Hz	200 Hz–50 KHz	50 KHz–100 KHz
0.5 Hz	±1 dB	±0.5 dB					±1 dB
5 Hz			±1 dB	±0.5 dB			±1 dB
50 Hz					±1 dB	±0.5 dB	±1 dB

Temperature coefficient: ±0.04 dB/°C maximum.

Slewing speed:

Range setting	Minimum slewing speed
0.5 Hz	1 dB/s
5 Hz	10 dB/s
50 Hz	60 dB/s

Oscilloscope output: approximately 0.5 V RMS regardless of input.

Crest factor: 5 to 1 except where limited by maximum input voltage.

General

Maximum peak input voltage: ±25 V on 1 mV to 10 V range; ±240 V on 10 mV to 100 V range.

Operating temperature: 10°C to 40°C.

Warm-up time: 20 minutes nominal.

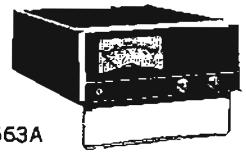
Connection facilities: front and rear-input and output-BNC connectors.

Power requirements: 115/230 V ac, 50 to 400 Hz, 40 VA.

Physical dimensions: 3-7/16" (88 mm) high, 7¾" (197 mm) wide, 11½" (292 mm) deep.

Weight: 8 lbs (3,6 kg) net; 12 lbs (5,4 kg) gross.

Price: Model 7562A $995.



7563A

Model 7563A

The Model 7563A logarithmic amplifier is a low cost, single channel, dc logarithmic amplifier with a very high dynamic range (110 dB or 316,228 to one) designed to produce a logarithmic related dc output voltage for a very wide range of dc or slowly varying input voltages. A single input range of 316 µV to 100 V is coupled with an input polarity switch for ease and versatility of operation. A high (100K ohm) input impedance and low (100 ohm) output impedance allows the 7563A to be used in systems or on the bench. A front panel meter calibrated in dB and mV is included for an instantaneous visual indication of operating levels. Applications include: the log scaling of recorder axes, pulse height analyzers, scope displays, and almost any circumstance where log scaling and compression of varying dc voltage ranges are required. Utilizing the calibrated meter (dB and volts) the 7563A has added versatility as an accurate voltmeter. Dual or single rack mounting capability is afforded by a field installable rack mounting adapter, utilizing a minimum of rack space.

Specifications

Input

Dynamic range: 110 dB.

Voltage range: 316 µV to 100 V. Accepts either positive or negative signals, selectable by front panel switch.

Output

Voltage: 0 to 1.1 V dc corresponding to 10 mV/dB.

Output impedance: 100 ohms.

Meter accuracy: reading accurate to ±1.5 dB, referred to output.

Input impedance: 100K ohms. Shunted by less than 100 pF. Single ended.

Accuracy: at 25°C.

316 µV – 1 mV	1 mV – 10 V	10 V – 100 V
±1.5 dB	±0.25 dB	±1.5 dB

Temperature coefficient: ±0.02 dB/°C maximum and ±3 µV/°C referred to input.

Zero stability: ±0.25 dB at constant temperature.

Rise time:

Signal Level	Maximum Rise Time 1 mV-10 V Range
316 µV– 1 mV	2000 µs
1 mV– 10 mV	400 µs
10 mV-100 mV	40 µs
100 mV– 1 V	4 µs
1V-100 V	2 µs

Operating temperature: 10°C to 40°C.

Warm-up time: 20 minutes nominal.

Power requirements: 115/230 V ac, 50 to 400 Hz, 40 VA.

Physical dimensions: 3-7/16" (88 mm) high, 7¾" (197 mm) wide, 11½" (292 mm) deep.

Connection facilities: front and rear-input and output-BNC connectors.

Weight: 8 lbs (3,6 kg) net; 12 lbs (5,4 kg) gross.

Price: Model 7563A $595.

RECORDER ACCESSORIES
Expanded X-Y recording capability

17005A Incremental Chart Advance

Model 17005A is an extremely versatile accessory compatible with most Hewlett-Packard 11" x 17" bench recorders. It has basically two modes of operation, incremental chart advance and continuous chart advance. The 17005A converts compatible recorders to operation as a strip chart recorder.

Specifications

Compatible recorders: 7000A, 7001A, 7004A-04 and the HO6-7005B.
Incremental advance mode
Plot density/rate:
Plot density: 200, 100, 50, 20, 10 plots/in. Metric: 80, 40, 20, 8, 4 plots/cm.
Max. advance rate: 100, 90, 50, 20, 10 plots/s.
Time base mode
Speeds: 1, 5, 10, 50, 100 s/in. Metric: 0.4, 2, 4, 20, 40 s/cm.
Accuracy: ±2%.
Frame advance mode
Advance distance: 24" (60 cm).
Accuracy: ±0.005" (0,0125 cm) noncumulative.
Advance time: less than 20 s.
Major division advance
Advance distance: selectable major divisions are in 3" (7,5 cm) increments.
Accuracy: ±0.005" (0,0125 cm) noncumulative.
Advance time: (maximum) 2.5 s.
Weight: 11 lbs (5 kg) net 16 lbs (7,3 kg) gross.
Price: Model 17005A — $895
Options:

01:	Fan Fold adapter	$125
02:	Metric calibration	N/C
03:	Cable connector compatible with 7590A(C) units prior to serial prefix 729 requires modification.	N/C
04:	Compatibility with 7004A-04	N/C

17006A Manual Chart Advance

Model 17006A permits manual chart advance by operating a hand crank. A crank handle also is provided on the supply reel for rewinding chart. Tear-off wire is included for chart "pull-through, tear-off."
Price: Model 17006 — $125

G-2B Null Detector

The G-2B Null Detector is an accessory device designed for use with the 7000A and 7001A X-Y recorders. It controls the operation of the recorder in any one of five modes during the plotting of continuous, discontinuous or point function data. The source may be any analog signal producing system or digital system with conversion accessories. The G-2B is housed in a modular cabinet with a cable and plug for external connection to the recorder.

Specifications

Plot rate
Point mode: 6 plots/s, maximum, using the Model 17009B Character Printer.
Line mode: 7 points/s, maximum, when points are displaced an average of 0.05 in. and using a regular recorder pen.
Sensitivity: better than 0.4% of full scale.
Price: Model G-2B — $325

17009B Character Printer

The Model 17009B Character Printer is specially designed to replace the pen on the 7000A and 7001A to identify points or curves when plotting families of digital information.

The points are identified with a character. Ten different characters are available, six of which are supplied with the 17009B.

Specifications

Plot rate: up to 6 plots per second (with G-2 Null Detector).
Compatible recorders: 7000A and 7001A.
Power source: supplied from the recorder.
Actuating source: external contact closure, or manually operated penlift control of recorder.
Price: Model 17009B — $95
Option 01: extra symbols (see data sheet) — $1 each

F-3B Line Follower System

The F-3B Line Follower, available for the 7000A and 7001A X-Y Recorders, regenerates original data directly from previously recorded curves. Any line prepared with pencil or pigment-type ink will be followed automatically by means of an optical photo-electric sensing element.

Specifications

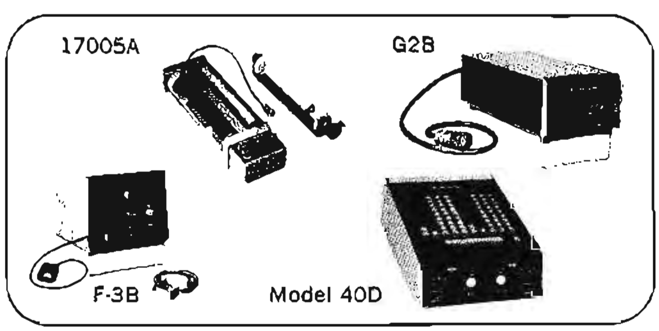
Displacement analog output: an external voltage may be applied to an existing slidewire.
Straight-line accuracy: ±0.03", 0° to 45° and time sweeps through 0.5 s/in; angular ranges from 0° up to 85° up to 5 s/in; square waves or spike functions of 0.1" maximum amplitude will remain within the scanned area at time sweeps up to 10 s/in.
Scanned area: 0.1" on either side of its center line and 0.05" along its center line.
Power: 115 or 230 volts, 50 to 60 Hz, single phase; approximately 5 VA.
Price: Model F-3B — $895

40D Keyboard

The Model 40D is a full keyboard-type accessory for use with compatible Hewlett-Packard X-Y Recorders to plot tabular data in point-graph form. Keyboard includes polarity, hold, clear and calibrate keys. Panel selectors control circuits for zero suppression, points/in or cm calibration and logarithmic plotting.

Specifications

Compatible recorders: 7000A, 7001A, 2FA and the 7004A (on special order at time of ordering the keyboard).
Keyboard: two 3-column, nine-row arrays and unit "1000" keys. Numbers from 0 to ±1999 on each axis; function keys provide X hold, Y hold, calibrate, clear and main clear.
Output attenuator (linear mode): 5 fixed steps at 10, 20, 50, 100, 200 pts/in (5, 10, 25, 50, 100 pts/cm on metric model); provision for variable attenuation between steps up to 500 pts/in (200 pts/cm on metric model).
Impedance match: refer to impedance adaptors on page 146.
Accuracy: ±0.1% of digital to analog conversion.
Power: 115 or 230 V, 50 to 60 Hz, single phase, approximately 12 VA (derived from associated recorder).
Dimensions: 9⅝" (244 mm) wide, 5-3/16" (132 mm) high, 13-11/16" (348 mm) deep.
Weight: net 16 lbs (7,2 kg); shipping 30 lbs (13,5 kg).
Price: Model 40D or 40DM (metric) — $1275
Specify model and serial number of existing recorder.



Strip-chart recorders

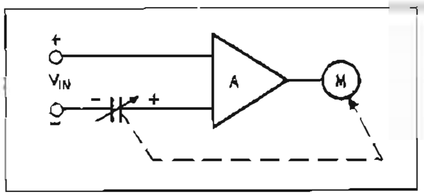
Much of the instrumentation which extends, refines or supplements human perception produces information in the form of electrical analog signals. Records of such data are, of course, necessary. Electrical data acquired in serial fashion, comprising a chain of meaningful changes in a signal, record naturally on continuous instruments such as strip-chart recorders. The character of the signal will determine the appropriate recording instrument. Permanent records of slowly changing analog values are conveniently made by Hewlett-Packard servo driven strip-chart recorders.

Laboratory and industrial type recorders are available and produce records in rectilinear coordinates with considerable accuracy—typically 0.2%. Two-pen models permit both channels to realize the full resolution of the chart width simultaneously, since the pens can overlap on the same chart without interference. Active development of strip-chart recorders has yielded high reliability, improved writing systems and other advances. Important features are: solid-state circuitry, electric writing, optical slidewires, modular construction, and versatile multi-range performance for laboratory applications.

Basic operation

Each Hewlett-Packard servo driven strip-chart recorder uses an individual electrical servo system for each channel employed. All servos are similar. Each consists of a basic balancing circuit, plus auxiliary elements for instrument versatility.

A basic potentiometric servo recorder is shown in Figure 1. The illustration shows a single range recorder in its simplest form. V_{in} is the input signal voltage to the recorder and is applied to the input of the amplifier causing the motor to be driven. The motor rotates, causing an electrical tap at V_b to be adjusted to a point where V_b equals V_{in}. At this point, the input voltage to the amplifier is zero, and the motor stops. This is considered a balanced condition and the degree of balance attained is largely a function of the amplifier's gain. If the input voltage (V_{in}) changes, the balancing action is repeated.



Common controls and circuits used to provide versatility are:

1. Stepped attenuator for each axis so that input voltages from the microvolt range to 500 volts may be handled directly.
2. Variable attenuator provides continuous adjustment to allow a transducer's output to directly correspond to the paper's coordinates in the desired units of measurement (psi, °C, etc.).
3. Zero control allows the plotting origin to be placed anywhere on the paper or suppressed electrically off the paper.

Types of writing systems

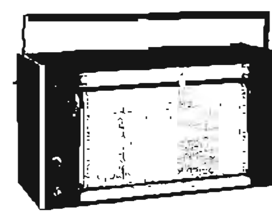
Hewlett-Packard strip-chart recorders provide two types of writing systems: ink and electric writing.

Ink recording is standard. Hewlett-Packard recorders employ the capillary ink feed system in which the ink supply is a cartridge. Uniform flow is maintained by the capillary process. Disposable pen tips are also available to minimize maintenance problems and to optimize the writing characteristics These disposable pen tips consist of two basic types, high speed and low speed.

The low speed tip operates basically the same as the standard pen. Its advantage is the capability of changing pen tips when the application changes and allowing quick and inexpensive replacement of worn or clogged pen tips.

The high speed pen tip is designed for high speed recording. It is composed of nylon fibers, which create many ink passages to insure a sufficient ink flow for high speed writing.

Electric writing is also available on strip-chart recorders. With the elimination of ink refilling, long term unattended recording with maximum reliability is possible. Electric writing features crisp, clean, permanent records with the advantage of instant start-up. It is not sensitive to light or pressure, eliminating special handling; it is permanent, without processing.



7100B

Options and accessories

A variety of options and accessories is available to customize the recorder for individual applications. Options include event markers, retransmitting potentiometers, remote electric pen lift, remote chart drive switch, disc integrator, limit switches, etc.

Also optionally available for the Model 680 is the photo slidewire. This unique balance slidewire employs optical coupling to eliminate mechanical contacts, thus reducing wear and noise and increasing reliability.

Available accessories include input filters, logarithmic converters, BNC adapters, etc.

Hewlett-Packard Strip Chart Recorders

Model	Use	Writing Width	Page	Max. Sensitivity mV Full Span	Chart Speeds	Number of Pens	Plug-ins	Price (Less Plug-ins)
680	Laboratory and system	5"	152	5.0 ①	8	One		$ 750
7100B	Laboratory	10"	150	1.0 ②	12	Two	X	$1300
7101B	Laboratory	10"	150	1.0 ②	12	One	X	$1000
7127A	Laboratory and system	10"	150	1.0 ②	4	One	X	$ 850
7128A	Laboratory and system	10"	150	1.0 ②	4	Two	X	$1150

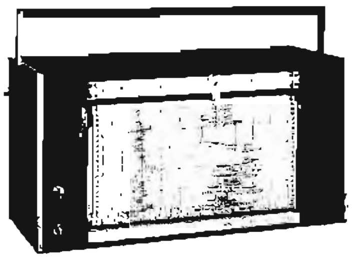
① Higher sensitivity optionally available
② Depends on plug-in selected

STRIP CHART RECORDERS

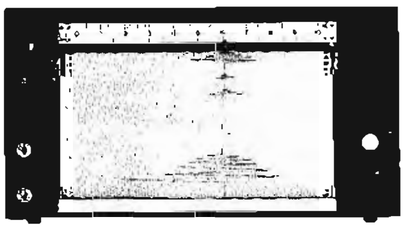
10" PLUG-IN RECORDERS

Ink or electric writing

Models 7100B, 7101B, 7127A, 7128A



7100B



7127A

The 10" strip chart recorders can be used in a wide range of laboratory and industrial applications. They feature high performance, low cost, and solid state construction for reliability, compactness, and light weight. Models 7100B and 7128A have two independent servo pen drives and require two input modules. The 7101B and 7127A are single pen units and take one input module. Ordering information should specify basic frame and exact input module or modules required.

Each main frame is equipped with instantly selected chart speeds (4 for 7127A, 7128A; 12 for 7100B, 7101B) and a modular chart magazine. The chart magazine will swing out at a 10° or 30° angle for convenient note writing. An optional integrator for simultaneously and accurately computing the area under the chart curve is also available.

Specifications

Recording mechanism

Ink: servo actuated ink pen drive.

Electric: similar to ink mechanism except a stylus, electrosensitive paper and the associated electronics are furnished in place of the ink pen.

Response time: maximum 0.5 s (50 Hz operation 0.6 s).

Chart capacity: (ink writing) 120' chart rolls, 11" wide with 10" (250 mm) calibrated writing width. (Electric writing) 100' chart rolls, 11" wide with 10" (250 mm) calibrated writing width.

Chart speeds

7100B/7101B (English)—1, 2 in/hr; 0.1, 0.2, 0.5, 1, 2 in/min; 0.1, 0.2, 0.5, 1, 2 in/s.

7100BM/7101BM (Metric)—2.5, 5, 15, 30 cm/hr; 1.25, 2.5, 5, 15, 30 cm/min; 1.25, 2.5, 5 cm/s.

7127A/7128A (English)—¼, ½, 1, 2 in/min.

HO1-7127A/HO1-7128A—6, 12, 24, 48 in/hr.

HO2-7127A/HO2-7128A—1½, 3, 6, 12 in/hr.

Power: 115 or 230 V ±10%, 60 Hz, 65 VA for 7100B and 7128A. 42 VA for Models 7101B and 7127A. 115 or 230 V, 50 Hz models available as an option.

Dimensions

7100B/7101B series (cabinet): 11-31/32" (304 mm) high, 17½" (445 mm) wide, 8¼" (210 mm) deep.

7100BR/7101BR (rack): 8-23/32" (222 mm) high, 19" (483 mm) wide, 8¼" (210 mm) deep.

7127A/7128A series: (cabinet) 9-3/32" (231 mm) high, 16¾" (425 mm) wide, 8¼" (210 mm) deep; (rack; brackets supplied) 8-23/32" (222 mm) high, 19" (483 mm wide, 8¼" (210 mm) deep.

Weight

7100B series: net 28 lbs (12,7 kg); shipping 39 lbs (17.7 kg).
7101B series: net 28 lbs (12,7 kg); shipping 33 lbs (17,3 kg).
7127A series: net 25 lbs (11,4 kg); shipping 35 lbs (15,9 kg).
7128A series: net 28 lbs (12,7 kg); shipping 38 lbs (17,3 kg).

Prices

Dual channel:

7100B/BR (English), 7100BM/BMR (metric)	$1300
7128A/HO1-7128A/HO2-7128A (English only)	$1150

Single channel:

7101B/BR (English), 7101BM/BMR (metric)	$1000
7127A/HO1-7127A/HO2-7128A (English only)	$ 850

Options:

7100B 7101B	7127A 7128A	Description	Additional Price 7100B 7101B	Additional Price 7127A 7128A
02	–	10 to 1 remote speed reducer	$85	–
04	14	5k retransmitting potentiometer (channel 1)	50	$50
05	01	High-low limit switches (channel 1)	50	50
06	08	Remote control of electric pen lift	50	50
07	02	Remote on-off chart control	25	25
10	03	50 Hz operation	N/C	N/C
11	13	Locking glass door	50	50
12	04	Event marker (ink) left side	35	35
14	06	Event markers (ink) both sides	70	70
15	07	Integrator (7127A, 7101B series or channel 2 of 7128A, 7100B series)	685	685
16	15	5k retransmitting potentiometer (channel 2)	50	50
17	09	High-low limit switches (channel 2)	50	50
18	10	High-low limit switches (both channels)	100	100
19	17	Electric writing	75	75
20	20	Scale with "0" right side	N/C	N/C
21	21	Gray control panel	N/C	N/C
22	22	Event marker (elec) left side	35	35
23	23	Event markers (elec) both sides	70	70
24	24	Disposable pen tips (servo pens only)	N/C	N/C
25	25	Soft zero right side	N/C	N/C
–	11	Carrying handle	supplied	25
–	16	Retransmitting potentiometer (both channels)	–	100

NOTE: 7100B, 7101B

Option 15 is not compatible with options 14, 16, 19, 22, or 23.

Options 15, 19, and 25 require special paper.

7127A, 7128A

Options 06, 15, 16, 17, 22, or 23 cannot be installed when instrument is equipped with Option 07.

Options 07, 17, and 25 require special paper.

Electric and ink writing systems are not compatible. Event markers must be of same type as the main writing system.

PLUG-IN MODULES
For the Model 7100B, 7101B, 7127A, and 7128A

17500A/17501A Multiple Span Input Modules

The Models 17500A (5 mV full scale) and 17501A (1 mV full scale) Multiple Span plug-ins offer high input resistance and a continuously variable span control. The inputs are floating up to 500 V above ground, have high common mode rejection and an input impedance of one megohm at null on all calibrated spans.

Specifications

Voltage spans: 17500A: 5, 10, 50, 100, 500 mV; 1, 5, 10, 50, 100 V full scale. 17501A: 1, 2, 5, 10, 20, 50, 100, 200 mV; 0.5, 1, 2, 5, 10, 20, 50, 100 V full scale.
Accuracy: ±0.2% of full scale.
Linearity: terminal based: 0.1% of full scale.
Resettability: 0.1% of full scale.
Input resistance: 1 megohm at null on all fixed calibrated and variable spans except 100,000 ohms in the variable mode on the four most sensitive spans on the 17500A only. Potentiometric operation is available to the 17500A on the four most sensitive spans and to the 17501A on the six most sensitive spans by the removal of an internal buss wire.
Interference rejection: dc common mode; 120 dB on the four most sensitive spans of the 17500A and the three most sensitive spans of the 17501A; line frequency, 100 dB on the four most sensitive spans of the 17500A and the three most sensitive spans of the 17501A.
Zero-set: adjustable full scale, plus one full scale of suppression.
Maximum source impedance: up to 10 k ohm source impedance will not alter the recorder's performance on the four most sensitive spans of the 17500A and the six most sensitive of the 17501A. No source impedance restrictions on spans above 100 mV full scale.
Reference supply: Zener diode controlled.
Weight: 2 lbs (0,9 kg) net, 5 lbs (2,2 kg) gross.
Price
Model 17500A — $250
Model 17501A — $350
Options
01: Five scale zero suppression (17501A only) — $ 50
02: Calibrated for 8" travel (full scale) — N/C
04: Gray control panel — N/C

17502A Temperature Input Module

The Model 17502A Temperature Measuring Input Module has a single span selectable to match almost any commonly used thermocouple. A wide variety of ranges are available. Thermocouple reference corrections for changes in ambient temperature are made within the module thus eliminating requirements for a remote compensation junction. The non-linear thermocouple output is converted within the module to a linear function of temperature which allows the use of standard ruled graph paper.

Specifications

Voltage spans: single span to match cold-junction thermocouples of types and ranges as listed on the data sheet.
Accuracy: ±0.5% or ±1°C (whichever is greater), refer to NBS CIR 561, dated 1955.
Input resistance: potentiometric.
Reference supply: Zener diode controlled.
Interference rejection: dc common mode, 120 dB; line frequency, 100 dB.
Weight: 4 lbs (1,8 kg) net, 7 lbs (3,2 kg) gross.
Price: Model 17502A — $250.
Option 04: gray control panel — N/C

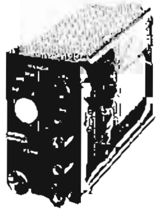
17503A/17504A Single Span Input Modules

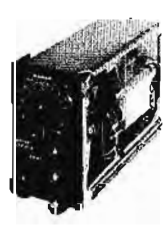
The Model 17503A plug-in, designed specifically for use with gas chromatography systems, is equipped with a single span of one millivolt full scale and potentiometric input. The Model 17504 plug-in may be ordered with any single span from a range of 5 mV to 100 V full scale. Potentiometric input is available, on the four most sensitive range cards, by removing an internal buss wire in the 17504A. The inputs of the 17503A/17504A can be floated up to 500 volts above ground and have a high common mode rejection. The zero may be positioned full scale or suppressed up to one full scale.

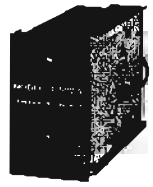
Specifications

Voltage spans: 17503A: 1 mV full scale. 17504A: 10 range cards available, which allow any span from 5 mV to 100 V full scale. (See data sheet.)
Accuracy: ±0.2% of full scale.
Linearity: terminal based: 0.1% of full scale.
Dead band: 0.1% of full scale.
Input resistance: 17503A: potentiometric. 17504A: one megohm at null.
Interference rejection: (17503A) dc common mode, 120 dB, line frequency common mode, 100 dB. Normal mode, greater than 60 dB at line frequency. (17504A) dc common mode, 120 dB on four most sensitive range cards; ac (line freq.) common mode, 100 dB on four most sensitive range cards. Normal mode greater than 60 dB at line frequency.
Zero-set: continuously adjustable over full scale, plus one full scale of zero suppression.
Maximum source impedance: up to 5 k ohm with the 17503A and 10 k ohm on the 17504A will not alert the recorder's performance.
Frequency: 60 Hz (line frequency) 50 Hz operation optional.
Weight: 2 lbs (0,9 kg) net, 5 lbs (2,2 kg) gross.
Price
Model 17503A — $250
Model 17504 (with one specified range card) — $200
Additional range cards — $ 25
Option:

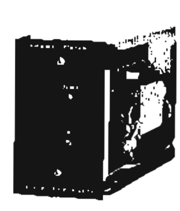
17503A	17504A	Description	
01	—	Detector selector switch	N/C
02	01	50 Hz operation	N/C
03		1 mV (for 8" travel) for use with integrator	N/C
04	04	Gray control panel	N/C


17500A

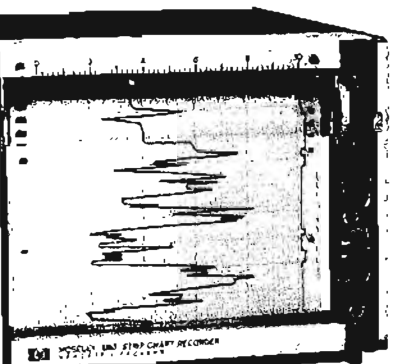

17501A


17502A


17503A


17504A

5" COMPACT RECORDER
Ink or electric writing
Model 680



680

The Models 680 and 680M, 5" strip-chart recorders provide a wide range of performance for general or specialized use. The 680 is equipped with multi-range input, multi-speed chart transport, full-range zero set, and electric pen lift: features essential for general purpose applications. The instrument is available with standard (English) or metric scaling (680M) and extra cost options such as electric writing, retransmitting potentiometer, event marker, limit switches, and dual rack adapter for rack mounting. It is useful as a monitor for instrumentation with dc outputs and for digital devices utilizing D-A converters such as the HP 581A.

The recorder features modular construction with all transistor circuitry, high accuracy, fast response, synchronous motor chart drive, and full view tilting chart magazine. Standard facilities include instant chart speed transfer, local and remote pen lift control, tear-off or chart roll storage, and cartridge-fed ink pen. Optional electric writing provides crisp, clean, permanent records for long-term unattended recording capability.

Specifications

Recording mechanism:

Ink: servo actuated ink pen drive.

Electro sensitive: similar to ink mechanism except a stylus for electrosensitive paper and the associated electronics are furnished in place of the ink pen.

Chart requirements:

Ink: 6" by 100' roll charts, 5" (12 cm) writing width. Approximately 4" by 6" visible chart area during operation.

Electrosensitive: 6" by 80' roll charts, 5" (12 cm) writing width.

Response time: one-half second or less for full scale.

Chart speeds: eight-synchronous motor controlled speeds at 1, 2, 4, 8 in/min; 1, 2, 4, 8 in/h. Metric model: 2.5, 5, 10, 20 cm/min; 2.5, 5, 10, 20 cm/h. Speeds in a ratio of 16 to 1 may be supplied at additional cost.

Spans: ten calibrated spans of 5, 10, 50, 100, and 500 mV; 1, 5, 10, 50, and 100 V full scale. Metric model has spans of 6, 12, 60, 120, and 600 mV; 1.2, 6, 12, 60, and 120 V. An extra span of 1 mV, full scale, is available at extra cost (1.2 mV on metric model).

Input: floating with respect to ground up to a maximum of 500 volts. Input resistance is 200,000 ohms per volt (166,666 ohms/volt on metric models) full scale, through 10 volt span; 2 megohms on all others. Potentiometric input on most sensitive span permits operation with essentially zero current drain at null. Constant 100,000 ohm input resistance on all spans available at extra cost on both models.

Standardization: continuous electronic reference from zener diode controlled power supply.

Zero set: continuously adjustable over full recorder span.

Accuracy: better than 0.2% of full scale.

Resettability: 0.1% of full scale.

Interference rejection: dc common mode rejection better than 100,000 to 1 on the most sensitive range.

Pen lift: local and remote.

Power requirements: 115/230 V, 60 Hz, 22 VA. 50 Hz models available at no extra cost, (Option 10).

Physical dimensions: 6½" (165 mm) high, 8⅝" (219 mm) deep, 7¾" (197 mm) wide. Rack mounting requires 7" (178 mm) of vertical space.

Weight: net approximately 11 lbs. (5 kg); shipping 17 lbs. (7,6 kg).

Accessory kit supplied: spare pen, ink filling syringe, remote pen lift mating connector, pen cleaning wire, slidewire cleaner and lubricant, 8 ink cartridges (4 red and 4 blue), and a roll of appropriate chart paper.

Prices:

Models 680 (standard) or 680M (metric):	$750
Model H01-680 or H01-680M (with added span of 1 mV on H01-680 or 1.2 mV on H01-680M):	$800
Model H02-680 or H02-680M (with 100,000 ohms input resistance on all spans):	$825

Options:

—01	With installed 5k, 0.1% linearity retransmitting potentiometer:	add $ 50
—02	With installed event marker (ink)	add $ 25
—03	With installed high-low limit switches:	add $ 90
—08	With 16 to 1 instead of 60 to 1 speed reducer:	add $ 25
—09	With remote chart drive switch:	add $ 25
—10	For 50 Hz operation:	n/c
—11	With special scale markings (specify):	add $ 10
—13	For operation with Logarithmic Converter:	add $ 25
—14	Glass door with lock:	add $ 45
—15	Electric Writing (special paper required)	add $ 75
—16	Electric writing event marker:	add $ 35
—17	Photoslidewire (not available for Models H01-680 and H01-680M)	add $100
—18	Disposable pen tips	n/c

Note: Ink and electric systems are not compatible. Event markers must be the same type as the main writing system. Option 12 replaced by Option 15.

TREND RECORDERS
Reliable long term unattended recording

7597A

The Model 7597A Trend Recorder is an analog sampling Y-T recorder with 8-channel capacity, allowing up to eight different physical or physiological variables to be plotted on an 8½" x 11" chart. The variables are plotted along the Y-axis against time on the X-axis. The 7597A is supplied with a nine hour full scale time axis; however, optional time axis durations are available of 5 hours, 13 hours, or 25 hours full scale. The scanning rate of the 7597A is nine channels per minute except on the optional 25 hour time axis where it is nine channels every three minutes. The eight variable Y-axis inputs are available through a ribbon connector located on the rear of the recorder. Besides the eight channels of information presentation on the chart, a ninth or "check" position is provided to give visual assurance of the recorder's performance and calibration.

The plotting system utilizes electro-sensitive paper and the exclusive Autogrip electrostatic paper hold-down. It provides permanent, smudge-free records that may be easily stored in notebook form for fast retrieval.

Specifications

Input impedance: 102 K ohms ±3%.

Sensitivity: adjustable from 0.5 v/inch to 3 v/inch.

Baseline adjustment: ±0.7 inches from the nominal base line zero position for each channel.

Channels: 8 input channels. Single-ended floating circuit command. Rear input connectors.

Scanning: sequential scanning through each channel. Any one or combination of channels can be programmed to be by-passed in the scanning sequence.

Scanning rate: (time for complete scan cycle, 9 channels) 1 minute for 5, 9, and 13 hour recorder. Three minutes for 25 hour recorder.

Writing system: electric writing on 8½" x 11" electrosensitive paper, 7" x 9⅝" recording area.

Y-axis accuracy: ±0.014 inch at 0-55°C.

Time axis rate: standard: 9 hours full scale, Option 003: 5 hours full scale, Option 004: 13 hours full scale, Option 005: 25 hours full scale.

Price: HP Model 7597A (black paint), $1125.
- Option 001: white paint, no additional charge.
- Option 002: gray paint, no additional charge.
- Option 003: 5 hour time base, no additional charge.
- Option 004: 13 hour time base, no additional charge.
- Option 005: 25 hour time base, no additional charge.
- Option 006: miniature phone jack rear input connectors; 1 per channel, no additional charge.
- Option 007: 5 hour time base, 50 Hz, no additional charge.
- Option 008: 9 hour time base, 50 Hz, no additional charge.
- Option 009: 13 hour time base, 50 Hz, no additional charge.
- Option 010: 25 hour time base, 50 Hz, no additional charge.

7825A

The 7825A Trend Recorder is a compact, light weight instrument capable of recording up to four slowly changing physical or physiological variables, 24 hours a day, for 63 days (50 foot roll). With an input sensitivity of ±2.5 volts, it is electrically compatible with HP 8800 Series Signal Conditioners.

A single time shared electrostatic stylus and a galvanometer-mounted feedback system provide analog or bar graph recording with 1% linearity in each of the four independent channels. Each channel is recorded in sequential order. Repetition rate is based on the number of channels in operation and the type of recording. With all four channels turned on, the scanning rate for bar graph recording is 30 seconds for a complete scan cycle (4 channels). For analog recording, the rate is 15 seconds for a complete scan cycle.

Standard chart speed is 1 cm/hr (approx 9½ inches in 24 hours). The chart paper has a full scale width of 12 cm and is marked in hours along each centimeter of length. The record is permanent, smudge free, easily reproduced, and well suited for mounting or filing.

Specifications

Input impedance: 15 K to 20 K depending on sensitivity setting.

Linearity: 1% of full scale.

Sensitivity: adjustable from no reaction to an input signal to full scale for either ±2.5 volts.

Input signal: 0 to 50 volts maximum. Positive signal corresponds to right-hand scale deflection.

Pen position: anywhere on the paper for any sensitivity adjustment. All eight positions (4 input and 4 bar graph base lines) are independent.

Pen repetition rate: all eight positions, less than 30 seconds.

Chart speed: standard 1 cm/hr. Other speeds available on special order up to 8 cm/min for single channel operation.

Input: 14-pin micro ribbon connectors or phone plugs.

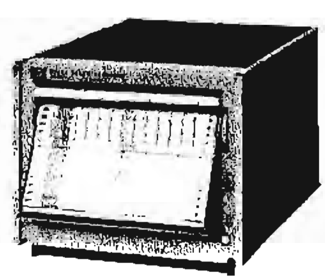
Paper: electrosensitive type, 12 cm (60 div) wide chart, margins perforated. Hours indicated at each centimeter mark.

Weight: 13 pounds (5,9 kg).

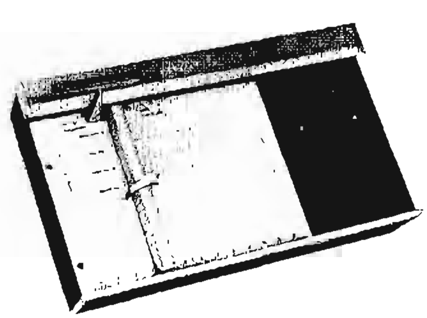
Dimensions: 6½" high x 7¾" wide x 11" deep (165 x 197 x 279 mm).

Power: 115 or 230 volts (±10%), 60 Hz, 50 watts. Option 08 Recorders: 115 or 230 volts (±10%), 50 Hz, 50 watts.

Price: HP Model 7825A Trend Recorder (white paint), $925.
- Option 01: Gray paint — no additional charge.
- Option 08: 50 Hz operation, add $25.



7825A



7597A

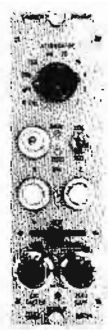
THERMAL & INK RECORDERS

Summary of HP systems for permanent, graphic records of measurements


8801A

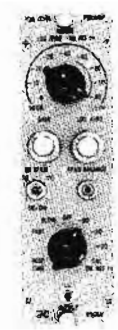

8802A


8803A


8805A


8806A

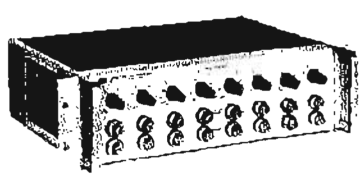

8807A

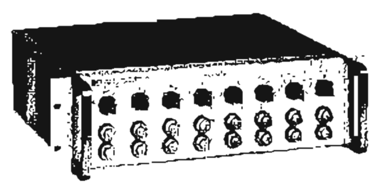

8808A


8809A

Individual plug-in preamplifiers

The 8800 Series Plug-in Preamplifiers are used as signal conditioners for the 7700 Thermal Series and the 7800 Ink Series of HP oscillographic recording systems. Preamplifiers include low gain dc, medium gain dc, ac/dc converter, phase sensitive demodulator, carrier, general purpose dc and logarithmic units. See pages 165-168 for thermal systems and pages 170-171 for ink systems using these preamplifiers.

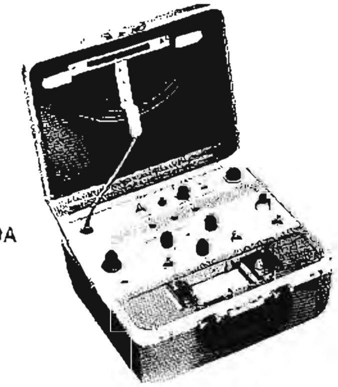

8820A


8821A

Identical-channel amplifiers

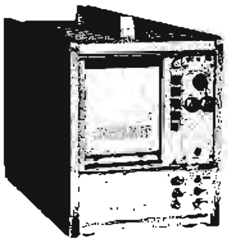
The Model 8820A Low Gain and Model 8821A Medium Gain dc amplifiers combine eight independent channels of amplification into one front panel unit for maximum operating convenience and economy. Identical sets of controls for all channels simplify operation. Rated sensitivities are 50 mV/div (8820A) and 1.0 mV/div (8821A). Both amplifier units are widely used in HP systems applications in telemetry, computer readout, multi-variable analysis, etc. See page 164 for amplifier information. See page 169 for thermal systems using these amplifiers; pages 170-171 for ink systems.

299A



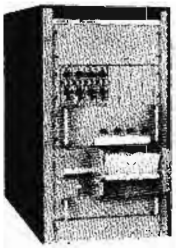
1-channel, general purpose portable recorders

The 299A and 301 are briefcase-sized, single-channel recorders, ideal for field and laboratory tests. Each weighs about 22 lbs and occupies less than ½ cubic foot. The units operate in any position and are available as 10 mV/div or universal carrier systems.

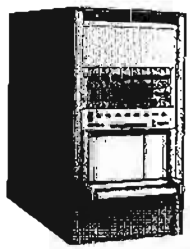


7701B

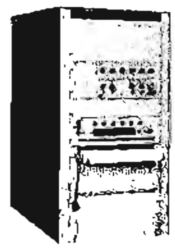
7702B



7704B



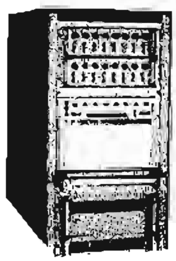
7706B
7708B



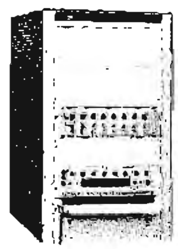
7736A
7738A

The 770 Series of thermal recorders includes 1-, 2-, 4-, 6- and 8-channel systems. The 6- and 8-channel recorders are available in horizontal and vertical models. All units use any combination of the versatile 8800 Series Preamplifiers.

7727A
7729A

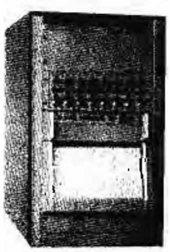


7731A



7737A
7739A

The 7727A/29A, 7731A (vertical recorders) and the 7737A/39A (horizontal recorders) are 6-, 8- and 16-channel thermal recording systems using either of the 8820A/21A multichannel amplifiers. All five systems have 18 electrically controlled chart speeds.



7858B

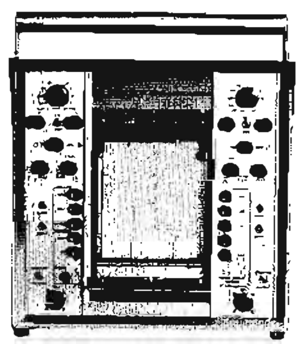
The 7858B is an 8-channel ink recorder using the versatile 8800 Series Plug-in Preamplifiers. Records are made on Z-fold packs or paper rolls. Fourteen chart speeds are provided.

7878A

The 7878A is an 8-channel ink recorder using either the 8820A Low Gain or the 8821A Medium Gain dc multichannel amplifier.

2-channel portable, dc and carrier recorders

These three portable, 2-channel recording systems operate in any position and record two variables permanently and simultaneously. Sensitivies of 0.5 mV/div (dc), 10 mV/div (dc) and 10 μV/div (on 2400 Hz carrier wave) are available.



321

Thermal writing oscillographic recorders and systems

A wide need exists in data recording for continuous, highly visible records of analog signals with maximum reliability and instant record availability. These requirements are well filled by Hewlett-Packard thermal writing oscillographic recorders, which use the heated stylus technique to produce truly rectilinear chart traces on heat sensitive Permapaper®. Significant advantages include: an absolutely reliable writing method, a resolution of 4 cycles per mm of paper travel even at small amplitudes and unattended operation for greatly extended time periods with an optional 1000-foot paper supply.

Hewlett-Packard Thermal Recorders are available with 1, 2, 4, 6, 8 and 16 channels and are compatible with standard Hewlett-Packard recording preamplifiers. All recorders and preamplifiers are available as systems in upright cabinets, less cabinet for mounting in standard RETMA equipment enclosures or in portable cases for field or laboratory use.

Ink writing oscillographic recorders and systems

The ink writing oscillographic recorder used in the 7858B and 7878A systems is a compact, all solid state, 8-channel recorder that produces rectilinear traces on either Hewlett-Packard Z-fold or roll chart paper. The Z-fold chart paper permits instant access to any part of the recording. The recording fluid, a permanent blue ink that dries rapidly on contact with the paper, permits high resolution copying of recorded data, with the capability of photographically including or deleting the chart coordinates. Position feedback from a contactless, capacitive pickup near the pen tip means long-lived recording accuracy. An ink supply system using a modulated, low pressure technique ensures uniform traces at all chart speeds, and over all points of the waveform. This technique controls the ink at the pen tip at all times, prevents spattering, and permits use of a Z-fold chart paper for instant data retrieval. The plug-in, disposable ink cartridge is cleanly replaced from the front of the system in less than 10 seconds, without stopping the recorder. The ink recorder provides a ratio of 8000:1 from the lowest chart speed of 0.025 mm/sec to the highest, 200 mm/sec, to give the best possible data resolution by matching the chart speed with the recorded waveform. All mechanical subassemblies are modular for fast "on-line" maintenance.

Hewlett-Packard ink recording systems feature a frequency response of dc to 150 Hz (−3 dB) at 10 divisions pp deflection and dc to 58 Hz (max) for full scale deflection. Linearity is 0.5% at full scale.

Ink recording systems such as the 7858B and 7878A are ideal for scientific and industrial research, production and environmental testing, quality control, telemetry, process control and analog computer monitoring. In the medical field, ink systems such as the 7868A are used in cardio-pulmonary and catheterization laboratories, and in a wide range of research, clinical and teaching applications.

Optical oscillographic recorders and systems

Hewlett-Packard optical oscillographic recorders are capable of recording up to 25 channels of high frequency transients, coded pulses or other data from dc to 5 kHz (−3 dB) at 4 inches pp. The ultraviolet optical recording systems 4508B and 4535B write with high intensity ultraviolet light to produce visible traces that require no chemical development. HP 4500 Series optical systems, which use the 658 Series amplifiers, are typically used to monitor: computer and high frequency power supply outputs, fast-changing nuclear reactions, high rates of change in pressure or temperature (particularly in fluids or metals), vibration, production testing and control applications. They are also used in high frequency telemetry and oceanographic studies.

Trend recorder

The HP 7825A Trend Recorder is a compact, light weight, time sharing instrument capable of recording up to four slowly changing physical or physiological variables on a 12 cm wide chart channel. With an input sensitivity of ±2.5 volts, the instrument is electrically compatible with HP 8800 Series Preamplifiers.

A single, time shared electric writing pen and a galvanometer-mounted feedback system provide analog or bar graph recording with 1% linearity in each of four independent channels. When physical variables are under study, the bar graph reference point can be set for a normal value and the deviation from normal can be plotted. Standard chart speed is one centimeter per hour (about 9.5 inches in 24 hours). The recorder produces crisp, clear, permanent records with the advantages of instant start up and maximum reliability for long term, unattended recording—over two months with the standard 50-foot chart.

Amplifiers and signal conditioners

Hewlett-Packard amplifiers and signal conditioners (see pages 154-155) cover an extremely wide range of measurement applications, matching the recording system to the signal source. The source can be an electrical signal from an external circuit or from a transducer that measures a physical variable such as pressure, force, flow, velocity or temperature. A wide choice of amplifiers and signal conditioners is provided for the thermal and ink systems and the 7825A Trend Recorder, including the interchangeable, single-channel 8800 Series Plug-in Preamplifiers and the multichannel 8820A and 8821A Amplifiers, which provide up to eight identical channels of amplification on a common front panel. The 658 Series multichannel amplifiers are used exclusively with the 4500 Series ultraviolet optical systems.

Analog-to-digital converter

The Model 5610A Analog-to-Digital Converter is a general purpose ADC that offers the following features: a 100 kHz throughput rate for a 10-bit word (including sign), a sample-and-hold amplifier with 50 nanoseconds aperture time, a multiplexer with 16 channel capacity, and low level, ±1 volt full scale input with optional ±2.5 volt and ±10 volt full scale input ranges available.

An interface kit that is available as an accessory includes a printed circuit card that electrically matches the converter to Hewlett-Packard computers, an interconnecting cable, and a Basic Control System (BCS) driver program and verification test software. The Model 5610A comes complete with selfcontained power supply and case.

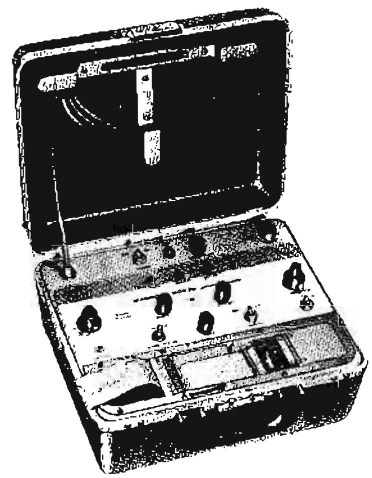
Recording chart papers

Recording chart papers are available for all Hewlett-Packard recording systems. Excellent recording characteristics are assured by matching the paper to the recorder and by rigid quality control. Paper comes in Z-fold packs for the ink recorder and in standard roll lengths for all recorders, with green grid for medical use, black for industrial use, translucent orange for diazo duplication, and brown for the ink recorder.

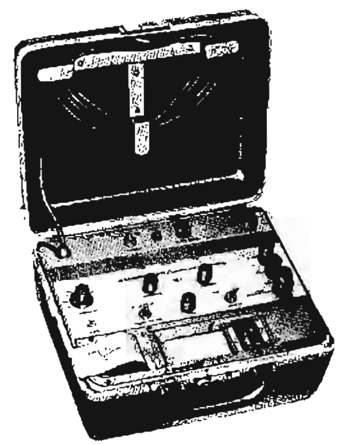
PORTABLE RECORDERS
1-, 2-channel portables
Models 299A, 301, 320 Series

1-Channel portables*

The 299A and 301 are single-channel, all solid-state, 22 lb. recorders, useful for field and laboratory equipment check-out and servicing. The 299A is a general purpose recorder, designed for broad dc coverage. Model 301 with built-in 2400 Hz carrier wave (carrier voltage 4.5 to 5.5 V rms, not adjustable), is designed for carrier inputs from inductive transducers, strain gages, resistance bridges and other ac transducers. Both units produce high resolution traces on a 3.2 cm (40 div) wide channel and possess most of the features found in larger systems. Four inches of chart are displayed at all times for study and marking. Each unit occupies less than ½ cubic foot and operates in any position.



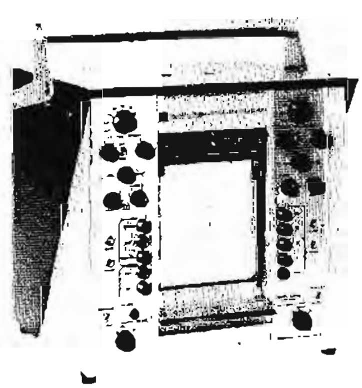
299A



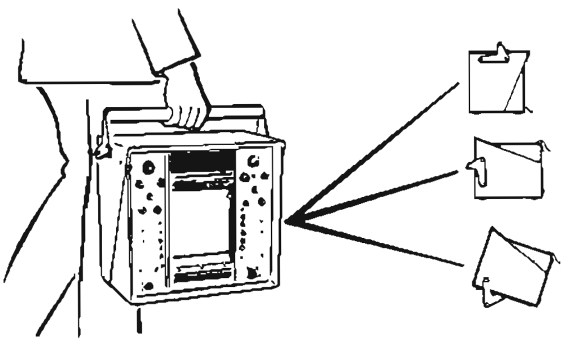
301

2-Channel portables*

Models 320, 321 and 322A are complete recording systems widely used in the field when two similar variables must be simultaneously analyzed and permanently recorded. They operate in any position, record signals on two 5 cm (50 div) channels, have electrical limiting to protect recorder styli and current feedback circuits to reduce drift. Model 320 has guarded and floating inputs designed for broad dc and ac signals even with excess ground loop noise. Model 322A has two general purpose direct-coupled amplifier channels for single-ended or balanced inputs. Calibrated zero suppression is available as Option 02. Model 321, with built-in 2400 Hz carrier excitation source, is designed to measure signals from resistance bridges, variable reluctance devices, differential transformers and other ac transducers.



321



*For additional information, see pages 158 and 159.

1-, 2-channel portables
Models 299A, 301, 320 Series

Specifications, Single-channel Portables*

Recorder Model	Model 299A	Model 301
Maximum sensitivity	10 mVrms/div (each div = 1/32")	10 μVrms/div (each div = 1/32")
Sensitivity range (attenuation)	10, 20, 50, 100, 200, 500 mV/div; 1, 2, 5, 10 V/div; attenuator accuracy ±2%	X1, 2, 5, 10, 20, 50, 100, 200 attenuation factors; attenuator accuracy ±2% max
Input circuit	5 MΩ each side, balanced to ground	6 KΩ min resistance, 13 K min reactance, measured with full zero suppression and R & C bal; 7 K resistance, 13 K reactance, with R & C bal control centered and zero suppression out; transducer impedance, 100Ω min.
Common mode rejection	50:1 on most sensitive ranges; 25:1 on other ranges	quadrature rejection ratio is greater than 100:1
Common mode tolerance	±2.5 V max on most sensitive range, higher on other ranges to ±500 V max	quadrature rejection is within specification if input amplitude does not exceed 2X inphase signal which causes stylus deflection from chart center to edge
Zero suppression	±2 V max in series with output of input attenuator; used for single-ended and balanced inputs	5-step switch, center out, two positions (for positive and negative signal)
Frequency response (−3 dB max at 10 div pp) (−3 dB max at full scale)	 dc to 100 Hz dc to 50 Hz	 dc to 100 Hz dc to 50 Hz
Zero drift Temperature, 0 to 50°C Line voltage, 103 to 127 V Time	 0.5 div/10°C 0.25 div 0.5 div/hr, 2 div/24 hrs, max	 0.25 div/10°C 0.1 div —
Noise (pp max)	0.1 div	0.25 div
Internal calibration	0.2 V, ±1%	40 μV/excitation volt, ±1% (200 μV/20 div deflection)

Specifications, Dual-channel Portables*

Recorder model	Model 320	Model 322A	Model 321
Max sensitivity	0.5 mV/div (each div = 1 mm)	10 mV/div (each div = 1 mm)	10 μV/div (each div = 1 mm)
Attenuation range	0.5, 1, 2, 5, 10, 20 mV/div and V/10 div; attenuator accuracy ±2% max	10, 20, 50, 100, 200, 500 mV/div; 1, 2, 5, 10 V/div; attenuator accuracy ±2% max	X1, 2, 5, 10, 20, 50, 100, 200 attenuation factors; attenuator accuracy ±2% max
Input circuit	0.5 MΩ on mV/div; 1 MΩ on V/10 div; floating and guarded	5 MΩ each side, balanced to ground	6 KΩ min resistance, 13 K min reactance, measured with full zero suppression and R & C bal; 7 K resistance, 13 K reactance with R & C bal control centered and zero suppression out; transducer impedance, 100Ω min
Common mode rejection	140 dB max dc; 120 dB min, 60 Hz with no input unbal; 100 dB min, 60 Hz with 5 K	50:1 on most sensitive range, 25:1 on other ranges	Quadrature rejection ratio is greater than 100:1
Common mode tolerance	±500 V max	±2.5 V max on most sensitive ranges; higher on other ranges to ±500 V max	Quadrature rejection is in specification if input amplitude does not exceed 2X inphase signal which causes stylus deflection from chart center to edge
Zero suppression	None	Order option 02:5-step switch, center out, positions for positive and negative signals	5-step switch, center out, two positions (for positive and negative signals)
Zero drift 0 to 50°C 103 to 127 V Time	 0.25 div/10°C 0.1 div —	 0.5 div/10°C 1.0 div 0.5 div/hr, 2 div/24 hrs, max	 0.25 div/10°C 0.1 div —
Noise (pp max)	0.25 div	0.1 div	0.25 div
Internal cal	10 mV, ±2%	0.2 V, ±1%	40 μV/excitation volt, ±1% (200 μV/20 div deflection)

*See pages 157 and 159 for additional information.

Specifications (1- 2-channel portables)

Gain stability: better than 1% up to 50°C on all models: better than 1% for line voltage variation from 103 to 127 V ac, all models.

Non-linearity: 0.25 div max with respect to straight line through centerline and calibration point 20 div from chart center, all models.

Frequency response: 299A, 301: dc to 100 Hz, −3 dB at 10 div pp, dc to 50 Hz, −3 dB at full scale; 320, 321, 322A: dc to 125 Hz, −3 dB at 10 div pp, dc to 50 Hz, −3 dB at full scale.

Response time: 5 msec, 10% to 90% with 4% or less overshoot, over center 10 div.

Paper speeds: 299A, 301: two speeds (5 and 50 mm/sec); 320, 321, 322A: four speeds (1, 5, 20 and 100 mm/sec); other speeds available on any model by option.

Channel width: 299A, 301: 3.2 cm (40 div); 320, 321, 322A: 5 cm (50 div).

Timer-marker: single-channel models have separate stylus for edge marking (60 Hz excitation); dual-channel models have 1 sec timers internal and extra event marker can be added on special order; jacks are provided on all models for remote operation of marker coil by contact closure.

Input connectors: single-channel, 3-pin contact male connector on front panel; dual-channel models in portable cases have 3-pin contact male front panel connectors, rear connectors when rack mounted (optional binding post adapters available).

Monitor output connectors: miniature phone jack on front panels provides approx 40 mV/div across min external load of 100 K ohms.

Electrical limiting: single-channel, approx 125% of full scale; dual-channel, approx 115% of full scale.

Power requirements: single-channel, 115 V ±10%, 60 Hz, 45 watts; dual-channel, 115 V ±10%, 60 Hz, 100 watts; 115/230 V, 50 Hz available in all models as options.

Dimensions: single channel models: 7" high, 12" wide, 10½" deep (178 x 305 x 267 mm); dual-channel models in portable cases: 13¾" high, 14¼" wide, 9½" deep (349 x 361 x 241 mm); rack mounts: 14" high, 19" wide, 16" deep (356 x 483 x 406 mm); paper take-up 320-300 for dual-channel portables: 4¾" high, 14½" wide, 9½" deep (121 x 370 x 241 mm); paper take-up rack mounted adds 5¼" (133 mm) to recorder height.

Weight: (approx): single-channel models, net 22 lbs (10 kg), shipping 25 lbs (11,3 kg); dual-channel models: net 55 lbs (24 kg), shipping 66 lbs (29,7 kg).

Accessories: (consult local HP sales office for quantity prices): single-channel: 651-202 Permapaper®, 3.2 cm wide (40 div), 125 ft. roll, $4.60; 403A Analog Stylus, $6.65; 411-1 Marker Stylus, $6.65; dual-channel: 651-52 Permapaper®, 5 cm (50 div) 200 ft roll, $12.50; 398 Analog Stylus, $7.15; 411-10 Marker Stylus, $6.65.

Optional accessory equipment: paper take-up 299-300 for single-channel models, $60; paper take-up 320-300 for dual-channel models (in portable cases), $150; 320R-300 for dual-channel models (rack mounted), $175; binding post adapter (to aid in connection of banana plugs, spade lugs, clip leads, bare wires, etc.): 299-200-C10 for 299A and 322A: $10; 301-200-C11 for 301 and 321, $9; 1251-1888 for 320, $11; extra marker (center margin for dual-channel models), $76.

Prices: 299A Single-channel dc recorder, $800.
301 Single-channel carrier recorder, $850.

Options:

02:	(301 only), add harmonic filter kit, required with 267 and 268 Series transducers,	no charge
08:	115/230 V switch, 50 Hz,	add $ 25.
12:	60 Hz speeds, 2.5, 25 mm/sec,	add $ 50.
13:	50 Hz speeds, 2.5, 25 mm/sec,	add $ 50.
16:	60 Hz speed kit 1:2 increase, 10, 100 mm/sec,	add $150.
17:	50 Hz speed kit 1:2 increase, 10, 100 mm/sec,	add $150.
18:	60 Hz speed kit 5:1 reduction, 1, 10 mm/sec,	add $135.
19:	50 Hz speed kit 5:1 reduction, 1, 10 mm/sec,	add $135.
20:	60 Hz speed kit 10:1 reduction, 0.5, 5 mm/sec,	add $135.
21:	50 Hz speed kit 10:1 reduction, 0.5, 5 mm/sec,	add $135.
22:	60 Hz speed kit 60:1 reduction, 5-50 mm/min,	add $150.

Prices: 320 Two-channel dc amplifier-recorder, $1950.
321 Two-channel carrier amplifier-recorder, $1950.
322A Two-channel dc coupling recorder, $1750.

Options:

01:	(321 only) add harmonic filter kit, required with 267 and 268 Series transducers,	no charge
02:	(322A only) zero suppression,	add $100.
03:	rack mount,	add $150.
08:	115/230 V switch, 50 Hz,	add $ 25.
12:	60 Hz medical speeds, 2.5, 5, 25, 60 mm/sec,	no charge
13:	50 Hz medical speeds, 2.5, 5, 25, 50 mm/sec,	no charge
15:	462-189 extra marker,	add $ 76.
16:	60 Hz speed kit 1:2 increase, 2, 10, 40, 200 mm/sec,	add $125.
17:	50 Hz speed kit 1:2 increase, 2, 10, 40, 200 mm/sec,	add $175.
18:	60 Hz speed kit 2:1 reduction, 0.5, 2.5, 10, 50 mm/sec,	add $175.
19:	50 Hz speed kit 2:1 reduction, 0.5, 2.5, 10, 50 mm/sec,	add $175.
20:	60 Hz speed kit 10:1 reduction 0.1, 0.5, 2, 10 mm/sec,	add $195.
21:	50 Hz speed kit 10:1 reduction, 0.1, 0.5, 2, 10 mm/sec,	add $195.
22:	60 Hz speed kit 60:1 reduction, 1, 5, 20, 100 mm/sec,	add $175.
23:	50 Hz speed kit 60:1 reduction, 1, 5, 20, 100 mm/sec,	add $175.

Model 53 Battery Converter

This portable source of ac power will operate single- and dual-channel recorders in most field applications. The combination charger/converter with completely solid state circuitry, converts the 12 V dc supplied by a self-contained lead-acid battery to 128 V at 60 Hz. Continuous duty rating is 125 watts with intermittent loads to 175 permissible. With a 35 watt load, battery life between charges is seven hours; at 125 watts, the unit operates for two hours. The Model 53 is enclosed in a flameproof carrying case 9½" high, 16" wide and 6¾" deep (242 x 407 x 172 mm). Weight with batter is 30 lbs (13,6 kg).

Model 53 without battery, 115 V, 60 Hz, $225.

Option 01: with battery (acid not furnished), add $50.

PREAMPLIFIERS
Plug-in signal conditioners for recording
8800 Series

8801A low gain dc preamplifier

The 8801A features calibrated zero suppression ranges of ±10 and ±100 V with 0.1% resolution, differential inputs and an internal calibration source (100 mV, ±1%). At a maximum sensitivity of 5 mV/div, it provides stable and precise amplification at any frequency from dc to 10 kHz; if the output signal is recorded, the response may be limited by the recorder bandwidth. Typical applications include: linear velocity measurements using Hewlett-Packard LVsyn® transducers; linear displacement measurements with Hewlett-Packard DCDT transducers, analog computer output amplification.

Specifications

Sensitivity: 5, 10, 20, 50, 100, 200 mV/div; 0.5, 1, 2, 5 V/div.

Maximum full scale input: 250 V.

Common mode rejection and tolerance: 48 dB min dc to 150 Hz; ±50 V on 5, 10, 20 mV/div ranges; ±500 V max on other ranges for less than ±1% change in differential sensitivity.

Frequency response (10 div, to −3 dB): 7701B: dc to 30 Hz. 7702B, 7704B, 7706B: dc to 125 Hz. 7708B, 7858B: dc to 150 Hz.

Rise time (10 div, 10% to 90%, 4% overshoot): 7701B: 20 msce. 7702B, 7704B, 7706B: 5 msec. 7708B: 4 msec. 7858B: 3 msec.

Output linearity (less trace width): All systems: 0.25 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at center scale and +20 div.

Output noise (max, less trace width): all systems: 0.2 div p-p.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.35%/10°C; 0.6% line. All other systems: 0.2%/10°C; 0.25% line.

Zero drift (less trace width): temperature (20° to 40°C). 7706B, 7708B: 1.05 div/10°C, 0.5 div/8 hr constant ambient. All other systems: 1.25 div/10°C, 0.5 div/8 hr, constant ambient. Line voltage (103 to 127). 7701B: 0.35 div. 7702B: 0.2 div.

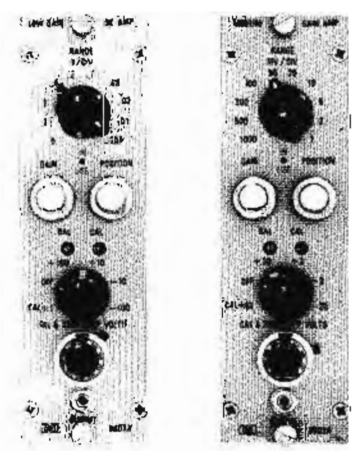
e: HP Model 8801A, $275.

on 01: bench-top unit with power ly and portable case, add $415.

8802A medium gain dc preamplifier

The 8802A has a gain five times greater than the 8801A, and zero suppression ranges of ±2 and ±20 V with 0.1% resolution. Except for the common mode tolerance, which is smaller by a factor of five on the high sensitivity positions, the choice between the 8801A and 8802A depends directly on signal input requirements.

Typical applications include: linear velocity measurements with Hewlett-Packard LVsyn® and linear displacement with Hewlett-Packard DCDT transducers, analog computer output amplification, and motor speed analysis with dc tachometers.



8801A 8802A

Specifications

Maximum sensitivity: 1 mV/div (gain 100).

Maximum full scale input: 50 V.

Sensitivity ranges: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 mV/div.

Input circuit: 180 K ohms (±1%) resistance, each side balanced to ground, shunted by approx 100 pF.

Common mode rejection and tolerance: 48 dB min dc to 60 Hz, 1000 mV/div range; 48 dB min dc to 150 Hz all other ranges; ±12.5 V on 1, 2, 5 mV/div ranges; ±125 V on 10, 20, 50 mV/div ranges; ±500 V max on other ranges.

Input frequency range: dc to 10 kHz.

Output frequency response (10 div, to −3 dB): 7701B: dc to 30 Hz. 7702B, 7704B, 7706B: dc to 125 Hz. 7708B, 7858B: dc to 150 Hz.

Rise time (10 div, to 10 to 90%, 4% overshoot): 7701B: 20 msec. 7702B, 7704B, 7706B: 5 msec. 7708B: 4 msec. 7858B: 3 msec.

Output linearity (less trace width): all systems: 0.25 div; mechanical zero of stylus within 1 div of chart center and calibrated for zero error at center scale and +20 div.

Output noise (max, less trace width): all systems: 0.2 div p-p.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.35%/10°C, 0.6% for line. 7704B, 7706B, 7708B, 7858B: 0.25%/10°C, 0.25% for line.

Zero drift (less trace width): temperature (20° to 40°C). 7706B, 7708B: 1.05 div/10°C, 0.5 div/8 hrs, constant ambient. All other systems: 1.25 div/10°C, 0.5 div/8 hrs, constant ambient. Line voltage (103 to 127 V). 7701B: 0.35 div. 7702B: 0.20 div.

Calibration: 20 mV ±1%, internal.

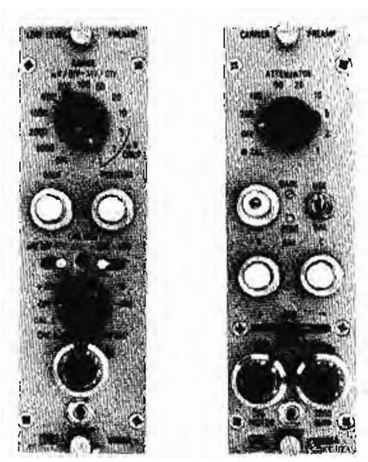
Price: HP Model 8802A, $325.

Option 01: bench-top unit with power supply and portable case, add $415.

8803A low level preamplifier

The 8803A, with a maximum sensitivity of 1 μV/div (at a gain of 100,000), accommodates a much wider range of signal amplitudes than the 8801A or 8802A. The 8803A features a fully guarded input circuit, operating in conjunction with the floating input capability for a common mode rejection as high as 100 dB at dc. In addition, the input circuit will tolerate a common mode voltage as high as ±300 V dc at any position of the range control. Twelve calibrated zero suppression ranges, each with 0.1% resolution, provide full scale suppression of ±1 ±10 and ±100 mV when attenuator is in μV ranges and volts when attenuator is in mV ranges.

Typical uses of the 8803A include: dc strain gage measurements, analysis of small variations in a large dc signal, such as the output of a regulated power supply.



8803A 8805A

Specifications

Sensitivity ranges: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000 μV/div; 10, 20, 50, 100, 200, 500, 1000, 2000, 5000 mV/div; max error ±2%.

Maximum full scale input: 250 V.

Input circuit: 1 M ohm min on μV ranges; independent of gain; 5 M ohm on mV ranges; floating and guarded.

Common mode rejection and tolerance: μV range, max source unbal of 1 K ohms; 160 dB min at dc, 120 dB min at 60 Hz; mV range, max source unbal of 500 K ohms: 100 dB min at dc, 60 dB at 60 Hz dc; 300 V peak; 60 Hz; 1 μV/div, 10 V rms; 2 μV/div, 20 V rms; 5 μV/div, 50 V rms; 10 μV/div and 10 mV/div, 100 V rms; 20 μV to 5000 μV/div and 20 mV to 5000 mV/div, 220 V rms.

Input frequency range: dc to 110 Hz.

Output frequency (10 div, dc to −3 dB): 7701B: 30 Hz. 7702B, 7704B, 7706B: 90 Hz. 7708B, 7858B: 100 Hz.

Rise time (10 div, 10% to 90%): 7701B: 20 msec (4% overshoot). 7702B, 7704B, 7706B: 7 msec (5% overshoot). 7708B: 6.4 msec (approx 6% overshoot). 7858B: approx 5.5 msec (4% overshoot).

Output linearity (less trace width): all systems: 1 μV range, 0.35 div; other ranges 0.25 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at center scale and +20 div.

Output noise (max, less trace width): all systems: 0.1 div p-p min gain.

Gain stability: temperature (20° to 40°C). 7701B, 7702B: 0.35%/10°C. All other systems: 0.2%/10°C. Line voltage (103 to 127 V). 7701B, 7702B: 0.75%, 1 to 5 mV/div; 0.55% all other ranges. All other systems: 0.4% on 1 to 5 mV/div ranges, 0.2% on all other ranges.

Zero drift (less trace width): temperature (20° to 40°C). 7701B, 7702B, 7704B: μV range: 1 μV/10°C referred to input, ±0.65 div/10°C for full scale output. 7706B, 7708B, 7858B: μV range: 1 μV/10°C referred to input, ±0.45 div/10°C for full scale output.

Calibration: 200 μV ±1% internal on μV/div range; 200 mV ±1% on mV/div range; referred to input.

Price: HP Model 8803A, $695.

Option 01: bench top unit with power supply and portable case, add $505.

8805A carrier preamplifier

The 8805A measures any physical variable that can be coupled to suitable carrier excited transducers, i.e., strain gage bridges, differential transformer transducers, and resistance or reactance transducers. Typical applications include measuring linear displacement with Hewlett-Packard Linearsyn® transducers, force with Hewlett-Packard FTA transducers, temperature with thermistors, or pressures in liquids or gases (HP 267, 268, 270, 1280 and 1281 Series Transducers). An oscillator in the recording system provides an excitation voltage for the external transducer, eliminating the need for external excitation circuitry. Calibrated zero suppression permits analyzing small signals when large static loads are present on the transducer. An internal switch is provided for full or half bridge use.

Specifications

Maximum sensitivity: 10 μV rms/div (gain, 10,000 rms ac to dc).

Maximum full scale input: 100 mV rms.

Sensitivity range: X1, 2, 5, 10, 20, 50, 100 and 200; accuracy ±2%.

Input circuit: approx 10 K ohms; transducer load impedance connected to excitation terminals 100 ohms min; transducer impedance connected to signal input terminals 5 K ohms max.

Quadrature rejection and tolerance: greater than 40 dB; tolerance: error less than ±2% full scale when quadrature voltage is equal to twice inphase signal required for full scale output.

Zero suppression: 0 to 100% of transducer full load rating.

Excitation frequency: 2400 Hz carrier is standard; frequencies from 440 to 4800 Hz available on request.

Output frequency response (10 div, to −3 dB): 7701B: dc to 30 Hz. 7702B, 7704B, 7706B: dc to 110 Hz. 7708B: dc to 120 Hz. 7858B: dc to greater than 110 Hz.

Rise time (10 div, 10-90%, 4% overshoot): 7701B: 20 msec. 7702B, 7704B, 7706B: 5.6 msec. 7708B: 4.75 msec. 7858B: approx 4 msec.

Output linearity (less trace width): all systems: 0.4 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at center scale and +20 div.

Output noise (max, less trace width): all systems: approx 0.25 div.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.45%/10°C; 0.75% line. All other systems: 0.3%/10°C; 0.4% line.

Zero drift (less trace width): 7701B, 7702B: 0.45 div/10°C; 0.35 div. 7704B: 0.45 div/10°C; 0.25 div.

Calibration: 2% ±0.02% of transducer full scale output.

Price: HP Model 8805A, $400.

Option 01: bench-top unit with power supply and portable case, add $485.

Option 02: harmonic filter kit (required with 267 or 268 transducers), add $30.

8806B phase sensitive demodulator

The 8806B provides a dc output proportional to the rms value of the input signal that is in phase or 180° out of phase with respect to a reference voltage. For maximum flexibility, the phase of the reference voltage is varied by calibrated plug-in phase shift networks for 60 Hz, 400 Hz, or 5000 Hz operation. An additional plug-in covers 6 frequency bands from 50 Hz to 40 kHz with continuous uncalibrated 0° to 360° phase shift. Other features include transformer isolation of both signal and reference voltage input circuits, and a maximum calibrated sensitivity of 0.5 mV rms/div, corresponding to a gain of 200 rms ac to dc.

Typical applications include: error signal measurements; servo, synchro, gyro and resolver system response; and amplitude and phase response.

Specifications

Sensitivity ranges: 0.5, 1, 2, 5, 10, 20, 50, 100, 200 and 500 mV rms/div. Reference voltage: 3-133 V rms in two overlapping ranges, internal range switch.

Maximum full scale input: 25 V rms.

Input circuits: signal input: transformer isolated, floating and guarded, resistance approx 1 M ohm. Reference input: differential, transformer coupled; resistance approx 500 K ohms each side to ground: may be used single-ended.

Common mode rejection and tolerance: greater than 40 dB up to 10 kHz; 500 V rms, max. Quadrature tolerance: equal to amplitude of a full scale inphase signal.

Reference frequency range: 50 Hz to 40 kHz in six bands with variable frequency plug-in; fixed frequency calibrated plug-ins 60 Hz, 400 Hz, 5 kHz.

Output frequency response and rise time (10 div, to −3 dB; 10 to 80%, 4% overshoot with fixed frequency plug-ins):

7701B: f_c = 60 Hz, −3 dB at 10 Hz, 54 msec; f_c = 400 Hz, 27 Hz, 23 msec; f_c = 5 kHz, 30 Hz, 20 msec.

7702B, 7704B, 7706B: f_c = 60 Hz, −3 dB at 12 Hz, 50 msec; f_c = 400 Hz, 65 Hz, 9 msec; f_c = 5 kHz, 125 Hz, 5 msec.

7708B: f_c = 60 Hz, −3 dB at 12 Hz, 50 msec; f_c = 400 Hz, 70 Hz, 8.5 msec; f_c = 5 kHz, 150 Hz, 4 msec.

7858B: f_c = 60 Hz, −3 dB at 12 Hz, 50 msec; f_c = 400 Hz, 71 Hz, 8 msec; f_c = 5 kHz, 160 Hz, 3 msec.

Output linearity (less trace width): all systems: 0.4 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at center scale and +20 div.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.5%/10°C; 0.6% line volts. All other systems: 0.3%/10°C; 0.25% line volts.

Zero drift (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.5 div/10 C; 0.3 div. 7704B: 0.5 div/10°C, 0.25 div. All other systems: 0.3 div/10°C; 0.25 div.

Calibration: 1 V rms internal at carrier frequency, referred to input; ±1%, 50 Hz to 10 kHz; ±2%, 10 to 20 kHz; ±3%, 20 to 40 kHz.

Price: HP Model 8806B, $495.

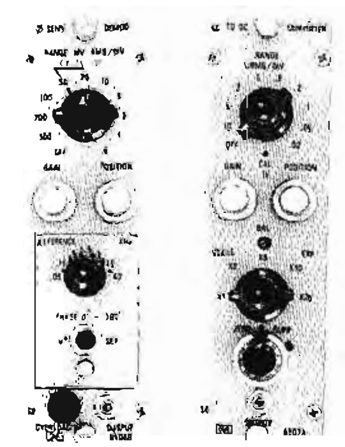
Option 01: bench-top unit with power supply and portable case, add $415.

Option 02: uncalibrated phase shifter plug-in, 50 Hz to 40 kHz, add $175.

Option 03: calibrated phase shifter plug-in, 60 Hz, add $125.

Option 04: calibrated phase shifter, plug-in, 400 Hz, add $125.

Option 05: calibrated phase shifter, 5 kHz, add $125.



8806A 8807A

8807A ac-dc converter

The 8807A provides a dc voltage output proportional to the average value of a full wave rectified ac input signal. Range sensitivity is calibrated in terms of rms for sinusoidal waveforms. The input circuit is transformer coupled, floating and guarded for high common mode rejection, allowing measurements over a wide range of input signal conditions. Calibrated zero suppression and variable scale expansion permit clear analysis of small excursions in large input signals.

Typical applications include: single and polyphase line voltage and current monitoring, motor starting current analysis, and fading analysis on short wave communication links using heterodyne frequency converters.

Specifications

Maximum calibrated sensitivity: 1 mV rms/div with X20 scale expansion; corresponds to rms ac-to-dc gain of 100.

Sensitivity ranges: 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 V rms/div.

Maximum full scale input: 500 V rms.

Input circuit: approx 1 M ohm resistance shunted by 10 pF and stray cable capacitance; floating and guarded.

Common mode rejection and tolerance: 60 dB min at 60 Hz; 40 dB min at 400 Hz, up to 10 K source unbalance; ±500 V peak.

Zero suppression: up to 100% of full scale on any range.

Input frequency range: standard model: 330 Hz to 100 kHz; Option 01: 50 Hz to 100 kHz.

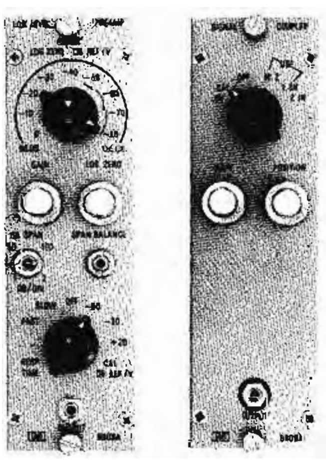
Output frequency response (10 div, to −3 dB): 7701B: 27 Hz; Option 01: 9

Hz. All other systems: 54 Hz; Option 01: 9 Hz.

Rise time (10 div to 90%, approx 10% with overshoot): 7701B: 22 msec. 7702B, 7704B, 7706B, 7858B: 11.2 msec. 7708B: 10.8 msec.

Output linearity (less trace width): all systems: 0.55 div +0.05 div x scale expansion 60 Hz to 5 kHz, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at lower and upper ends of printed coordinates.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.2%/10°C x scale expansion +0.45%/10°C; line volts 0.24% x scale expansion +0.75%. All other systems: 0.2%/10°C x scale expansion +0.3%/10°C; line volts 0.24% x scale expansion +0.4%.



8808A 8809A

Zero drift (less trace width): temperature (20° to 40°C). 7701B, 7702B, 7704B: 0.3 div/10°C x scale expansion +0.15 div/10°C. All other systems: 0.03 div/10°C x scale expansion +0.15 div/10°C. Line volts (103 to 127 V). 7701B, 7702B: 0.005 div x scale expansion +0.3 div. All other systems: 0.005 div x scale expansion +0.1 div.

Price: HP Model 8807A, $700.

- **Option 01:** 60 Hz filter for 50 Hz to 100 kHz signal frequencies, no charge when substituted.
- **Option 02:** dc plug-in, no charge when substituted.
- **Option 03:** bench-top unit with power supply and portable case, add $415.

8808A log level preamplifier

The 8808A compression and full wave detection circuits express the amplitude of an ac input signal in terms of decibels, with zero dB taken as a 1 V rms sine wave input voltage. Features a 100 dB span range, also a 50 dB span for greater signal resolution. Full span preamplifier output is either ±2.5 V or 0 to +5 V.

Typical applications include: analysis of wide ranges of signal amplitude on 100 dB linear scale (5 Hz to 100 kHz), analysis of RF and sonar radiation patterns, and use with wide band vibration and acoustic transducers.

Specifications

Maximum calibrated sensitivity: 100 μV rms sine wave corresponds to bottom scale output; −80 dB below 1 V.

Maximum full scale input: 320 V rms.

Sensitivity ranges: 50 dB span: bottom scale at −80, −70, −60, −50, −40, −30, −20, −10, and 0 dB below 1 V. 100 dB span: bottom scale at −80, −70, −60, and −50 dB below 1 V.

Input circuit: single-ended, 1 M ohm min resistance.

Input frequency range: 5 Hz to 100 kHz for less than −3 dB from midband level on slow response range; 500 Hz to 100 kHz on fast range.

Output: departure from log characteristics (less trace width): 7701B: 50 dB: 1.25 div; 100 dB: 1.0 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at lower and upper ends of printed coordinates. 7702B, 7704B: 50 dB: 1.2 div; 100 dB: same as 7701B. All other systems: 50 dB: 1.5 div; 100 dB: same as 7701B.

Rise time (10 div, 10 to 90%, 4% overshoot): 7701B: fast: 28 msec; slow: 2 sec. All other systems: fast: 20.5 msec; slow: 2 sec.

Gain stability (20° to 40°C, 103 to 127 V): 7701B, 7702B: 50 dB: 2.13 dB/10°C, 0.75 dB; 100 dB: 2.25 dB/10°C, 1.0 dB. All other systems: 50 dB: 2.05 dB/10°C, 0.58 dB from 103 to 127 V; 100 dB: 2.1 dB/10°C, 0.65 dB from 103 to 127 V.

Calibration: internal −80, −30 and +20 dB V; referred to 1 V.

Price: HP Model 8808A, $625.

- **Option 01:** bench-top unit with power supply and portable case, add $415.

8809A signal coupler

The 8809A is a solid state preamplifier with switch-selected high or low input impedance and variable gain for signal coupling to the driver amplifier input of Hewlett-Packard direct writing (thermal or ink) recorders in single or multichannel systems.

Specifications

Maximum calibrated sensitivity: 30 mV/div (gain, 3.33).

Sensitivity ranges: continuously adjustable from 20 to 50 mV/div.

Maximum full scale input: 0 to ±2.5 V.

Input circuit: switch selected 1.5 K ohms ±2% or 100 K ohms min, incremental; single-ended (floating in 7701B only).

Common mode rejection and tolerance: 50,000:1 at dc; +50 V max (7701B only).

Input frequency range: dc to 5 kHz.

Output linearity (less trace width): all systems: 0.4 div, mechanical zero of stylus within ±1 div of chart center and calibrated for zero error at center scale and +20 div.

Rise time (10 div, 10-90%, 4% overshoot): 7701B: 20 msec. 7702B, 7704B, 7706B: 5 msec. 7708B: 4 msec. 7858B: 5 msec.

Gain stability (20°C to 40°C, 103 to 127 V): 7701B, 7702B: 0.75%/10°C; line volts 1%. All other systems: 0.6/10°C; line volts 0.65%.

Zero drift (20° to 40°C, 103 to 127 V): 7701B, 7702B: 0.4 div/10°C at 30 mV/div; 0.5 div. 7704B: 0.4 div/10°C at 30 mV/div; 0.5 div. All other systems: 0.2 div/10°C at 30 mV/div; 0.3 div.

Calibration: 600 mV ±2%, internal, referred to input.

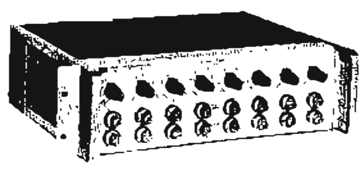
Price: HP Model 8809A, $110.

- **Option 01:** bench-top unit with power supply and portable case, add $415.

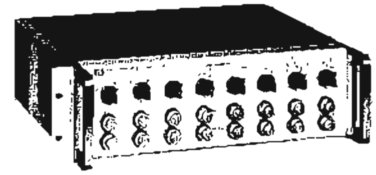
MULTICHANNEL AMPLIFIERS

Economical, variable gain for data recording

Models 8820A, 8821A



8820A



8821A

Low gain 8-channel DC amplifier

The excellent gain stability and low drift of the 8820A permit a wide range of dc measurements. The eight independent channels of amplification on one common front panel add convenience and economy.

The amplifier accepts single-ended inputs only (a common input ground may be isolated from the chassis when the recorder does not provide chassis return).

Each amplifier channel contains a nine position attenuator switch with: seven sensitivity range positions, an OFF position to check the base line while an input signal is connected and a CAL position to provide individual channel calibration test voltages. (A common CAL switch provides a base line test and a calibration test voltage for all channels simultaneously.)

Each channel also has: a polarity reversal switch for upscale deflection with an input signal of either polarity, a sensitivity control (varies sensitivity from approximately 0.5 to 1.5 times value marked on panel) and a position control to place the baseline at any location on the recording channel.

Price: HP Model 8820A, $1150.

Option 02: Unit channel reduction, deduct $15.

Medium gain 8-channel DC amplifier

The Model 8821A is a direct coupled, differential amplifier using active guarding techniques to yield excellent common mode rejection. No external dc path between the ground reference of the input signal and the 8821A output is required. This is an advantage normally associated only with amplifiers having a truly floating input.

Matched dual FET transistors in the input stage provide low thermal drift and permit use with signal sources having very high internal impedance. The input circuit is protected against overloads of up to 250 volts even on the most sensitive range.

Price: HP Model 8821A, $2500.

Option 02: Unit channel reduction, deduct $100.

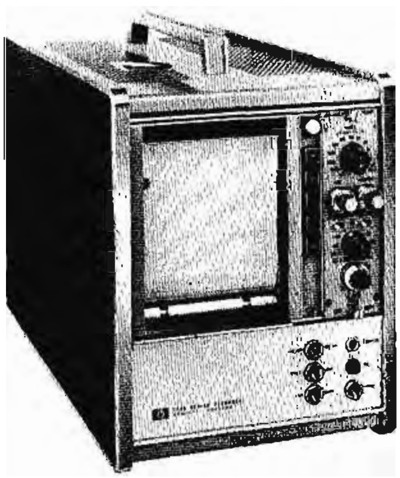
Recording system specifications using 8820A, 8821A Multichannel Amplifiers

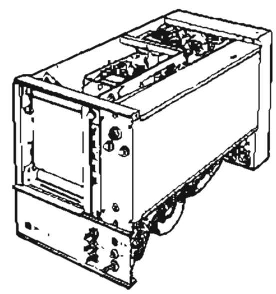
	8820A Low gain multichannel amplifier		8821A Medium gain multichannel amplifier	
System	**7727A, 7729A, 7878A**	**7731A**	**7727A, 7729A, 7878A**	**7731A**
Sensitivity	0.05 V/div (8820A gain 2)	0.1 V/div (8820A gain approx 2)	1 mV/div (8821A gain 100)	2 mV/div (8821A gain approx 100)
Sensitivity ranges	.05, 0.1, 0.2, 0.5, 1, 2, 5 volts/div	0.1, 0.2, 0.4, 1, 2, 4, 10 volts/div	1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000 mV/div	.002, .004, .01, .02, .04, 0.1, 0.2, 0.4, 1, 2, 4, 10 volts/div
Zero drift (max) Temp (20°-40°C) Line voltage (115 volts ±10%, 60 Hz)	Less than 0.5%/10°C Less than ±0.2 div (103 to 127V)	Less than 0.25 div/10°C (0 to 40°C) Less than 0.1 div (103 to 127 V)	Less than 0.5%/10°C Less than ±0.2 div (103 to 127 V)	Less than 0.25 div/10°C (0 to 40°C) Less than 0.1 div (103 to 127 V)
Gain stability Temp (20°-40°C) Line voltage (115 volts ±10%, 60 Hz)	Less than 0.5%/10°C Less than ±0.15% (103 to 127 V)	Less than 0.5%/10°C (0 to 40°C) Less than 0.25% (103 to 127 V)	Less than 0.5%/10°C Less than ±0.15% (103 to 127 V)	Less than 0.5%/10°C (0 to 40°C) Less than 0.25% (103 to 127 V)
Output Linearity	±0.25 div after calibrating at chart center and +20 div	±0.2 div typically ±1 div after calibrating at chart center and +10 div	±0.25 div after calibrating at chart center and +20 div	±0.2 div; typically ±0.1 div, after calibrating at chart center and +10 div
Internal calibration circuit	dual calibration, 1 V reference in each channel, plus a 1 V common reference for all channels. Cal accuracy ±1%	dual calibration; 1 V reference in each channel, plus a 1 V common reference for all channels. Cal accuracy ±1%.	±0.02 V ±1% on six most sensitive ranges, +2.0 V ±2% on six least sensitive ranges	±0.02 V ±1% on six most sensitive ranges, +2.0 V ±2% on six least sensitive ranges
Frequency response (10 div pp, dc to —3 dB)	7727A: 125 Hz 7729A: 150 Hz 7878A: 150 Hz	125 Hz	7727A: 125 Hz 7729A: 150 Hz 7878A: 150 Hz	125 Hz
Rise time (10 div, 10% to 90%) 4% overshoot	7727A, 5 msec 7729A: 4 msec 7878A: 3 msec	4 msec	7727A: 5 msec 7729A: 4 msec 7878A: 3 msec	4 msec
Input circuit	Single ended to ground, 1 M ohm ±5% all ranges shunted by approx 150 pF	Single ended to ground, 1 M ohm ±5% all ranges shunted by approx 150 pF	9 M ohms floated and guarded, 1 to 50 mV/div ranges; 4.5 M ohms each side to ground (differential), 100 to 5000 mV/div ranges; may be used single-ended on all ranges	9 M ohms floated and guarded 1 to 50 mV/div ranges; 4.5 M ohms each side to ground (differential), 100 to 5000 mV/div ranges; may be used single-ended on all ranges
Common mode rejection ratio			100 dB at 60 Hz, 1 mV/div sensitivity, 1 K ohm source unbalance; 66 dB at 60 Hz, 50 to 5000 mV/div, 1 K ohm source unbalance	100 dB at 60 Hz, 1 mV/div sensitivity, 1 K ohm source unbalance; 66 dB at 60 Hz, 50 to 5000 mV/div, 1 K ohm source unbalance

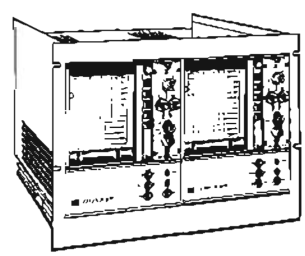
1-CHANNEL RECORDER
Wide channel for greater resolution
Model 7701B

Model 7701B is a single-channel, all solid-state, portable recorder that accepts any one of the versatile, interchangeable 8800 Series Plug-in Preamplifiers. Frequency response is dc to less than 3 dB down at 30 Hz, independent of amplitude. Featuring a 100 mm wide recording channel, the 7701B provides over twice the resolution offered by standard 50 mm wide channel recorders.

A high torque, low impedance galvanometer with velocity feedback moves the stylus over a knife-edge platen producing true rectilinear traces which can be correlated with timing marks in the chart margin. Trace accuracy is achieved by electrical galvanometer damping; thermal drift is minimized by current feedback. Adjustable electrical limiting protects the stylus and prevents overload. Over 2000 hours of continuous recording at 0.5 mm/min is possible without changing the chart roll.


7701B In Portable Case


Less Cabinet


Dual Rack Mount

Specifications

(See pages 160-163 for available 8800 Series Plug-in Preamplifiers.)

Chart speeds: four speeds standard (0.5, 2.5, 10 and 50 mm/sec), mechanically shifted and selected by front panel pushbuttons; four additional speeds (0.5, 2.5, 10 and 50 mm/min) can be added as Option 03 for a total of 8 speeds.

Event marker: right margin, manually operated from front panel; 1 sec or 1 min plug-in timer and one additional event marker optional.

Front panel controls: stylus heat adjust, pushbutton speed selectors, local-remote switch, timer-off-marker switch, mm/sec-mm/min switch, power switch and galvanometer damping (screwdriver adjust).

Paper: 200 ft roll of 10 cm wide Permapaper® (651-217); time lines every 5 mm, amplitude lines every 2 mm (50 div full scale).

Paper take-up: automatic paper take-up standard (concealed in recorder).

Power: 115 V ±10%, 60 Hz, 105 watts; 115/230 V ±10%, 50 Hz, 100 watts; (Option 08).

Dimensions: 7701B, in carrying case: 13¾" high, 9¾" wide, 18½" deep (349 x 247 x 460 mm); without case: 10½" high, $8\frac{11}{16}$" wide, 17½" deep (269 x 221 x 445 mm); rack mounting adapter (mounts 2 recorders): 14" high, 19" wide, 17½" deep (356 x 483 x 445 mm).

Weight: 7701B in carrying case, including typical 8800 Series Preamplifier weight: net 32½ lbs (14,5 kg), shipping 42 lbs (18,9 kg); rack mounting adapter: net 20 lbs (9,1 kg), shipping 30 lbs (13,5 kg).

Accessories: consult local Hewlett-Packard sales office for quantity prices; 1-channel, 10 cm (50 div) 200 ft roll Permapaper® (651-217), $14; 412-4 Analog Stylus, $15; 411-9 Marker Stylus, $9.

Prices: Model 7701B, less preamplifier, $1490; Option 01: 440 Hz oscillator card required with 8803A Preamplifier, (allows use of any 8800 Series Preamplifier except 8805A), add $60; Option 02: 2400 Hz oscillator card required with 8805A, (allows use of any 8800 Series Preamplifier except 8803A), add $60; (Note: Options 01 and 02 cannot be taken on same instrument.) Option 03: mm/min Speed Reduction Kit (60:1, 60 Hz), add $110; Option 04: Left Event Marker, add $45; Option 05: one minute timer, add $30; Option 06: one second timer, add $20; Option 07: less Portable Case, deduct $90; Option 08: 115/230 V switch, 50 Hz operation, add $50; Option 15: one minute timer, 50 Hz unit, add $30; Option 16: one second timer, 50 Hz unit, add $25.

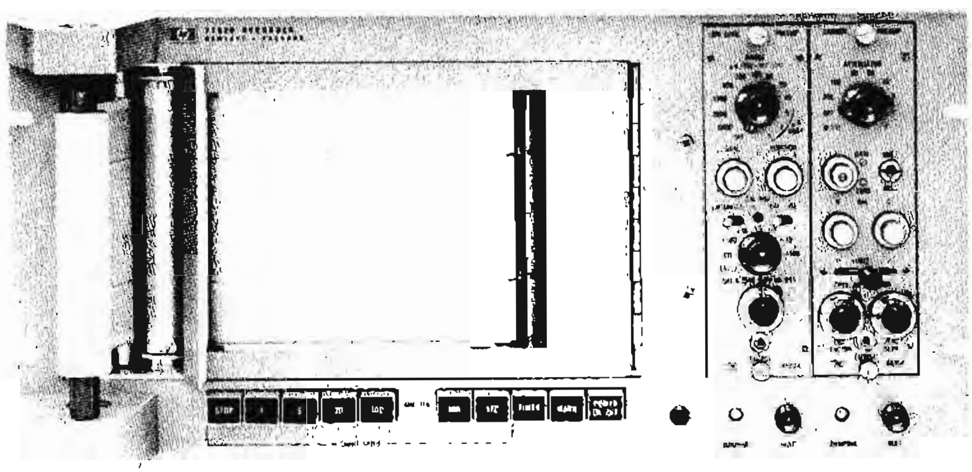
Note: add price of preamplifier to the above basic assembly prices for complete system cost. See pages 160-163 for specifications and prices.

DUAL-CHANNEL RECORDER

Mount in cart, cabinet or portable case

Model 7702B

Model 7702B is a 2-channel thermal recorder using any pair of the eight versatile 8800 Preamplifiers as signal conditioners. Preamplifier units include: low, medium and high gain dc; ac-dc converter; phase sensitive demodulator; carrier; general purpose dc; and a logarithmic unit. For accurate chart time correlation, a marker for one second is standard with a one minute timer added as an option. Remote marking, which may be used for information coding, is standard. The reliable heated stylus recording technique provides sharp, high resolution images that will not fade or smudge on plastic-coated Permapaper®. Frequency response is dc to less than 3 dB down at 125 Hz for a 10 div pp chart deflection. Response time (damping set for 4% overshoot) is less than 5 msec for 10% to 90% of a 10 div pp square wave. The power amplifier features adjustable electrical limiting over a span from ±12 div to beyond the edge of the chart coordinates to prevent overload and to protect the styli.



7702B

Specifications

(See pages 160-163 for performance specifications with 8800 Series Plug-in Preamplifiers.)

Chart speeds: four speeds standard (1, 5, 20 and 100 mm/sec) mechanically shifted and selected by front panel pushbuttons; other speed combinations available as options; provision is made for optional remote control of chart drive from suitable 115 V ac source.

Timer-off-marker: separate stylus marks edge of chart with 1 sec pulses in TIME position or with line frequency pulses in MARK position; remote marking provision at rear connector by simple contact closure (115 V ac).

Front panel controls: individual stylus heat controls; pushbuttons for power, timer, marker and speed selection; individual galvanometer damping adjustments (screwdriver adjust).

Paper: standard 200 ft rolls of 5 cm wide, 2-channel Permapaper® (651-52), easily loaded from the recorder front panel; 1-channel Permapaper® (651-51), may be used if only one channel is operated; orange, translucent Permapaper® (651-182), is available for making multiple copies of recording on contact copier (ozalid).

Paper take-up: automatic paper take-up standard equipment.

Power: 115/230 V ±10%, 60 Hz, approx. 200 W; 115/230 V ±10%, 50 Hz, available in Option 08.

Dimensions: rack mounted: 8¾" high, 19" wide, 17" deep (222 x 483 x 432 mm); portable case (Option 02): 10 7/16" high, 20⅞" wide, 21 13/16" deep (265 x 530 x 576 mm); mobile cart (Option 05): 39¼" high, 26¾" wide, 20½" deep (997 x 680 x 521 mm).

Weight (approx): typical with 2 preamplifiers, rack mounted: net, 60 lbs (27,2 kg), shipping 89 lbs (40,4 kg); portable case (Option 02): net, 89 lbs (40,4 kg), shipping 135 lbs (60,8 kg); mobile cart (Option 05): net, 130 lbs (59 kg), shipping 172 lbs (77,4 kg).

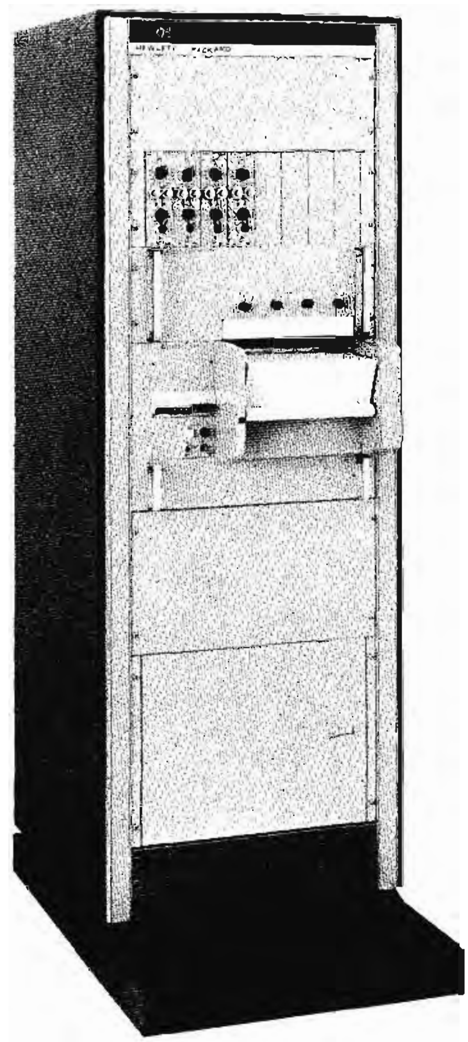
Accessories: (consult local Hewlett-Packard sales office for quantity prices); 2-channel, each 5 cm wide (50 div), 200 ft Permapaper® roll (651-52), green coordinates on white, $12.50; 1-channel, 5 cm (50 div), 200 ft Permapaper® roll (651-51), green lines on white, $6.90; 398, analog stylus, $7.15; 411-10, marker stylus, $6.65 ea.

Prices: Model 7702B, less preamplifiers, $1675; Option 02: in portable case, add $195; Option 03: single channel operation, deduct $75; Option 05: in mobile cart, add $195; Option 08: 50 Hz operation, add $50; Option 10: chart speeds of 2.5, 5, 25 and 50 mm/sec (specify 50 or 60 Hz), no extra charge; Option 11: 60:1 speed reduction, 60 Hz, add $1.50; Option 12: 60:1 speed reduction, 50 Hz, add $150; Option 13: one minute timer, 60 Hz (available only when Option 11 is taken), add $34; Option 14: one minute timer, 50 Hz (available only when Option 12 is taken), add $34; Option 15: extra marker, add $76; Option 16: 60 Hz speed kit (1:2 increase), speeds of 2, 10, 40 and 200 mm/sec, add $125; Option 17: 50 Hz speed kit (1:2 increase), speeds of 2, 10, 40 and 200 mm/sec, add $125; Option 18: 60 Hz speed kit (2:1 reduction), speeds of 0.5, 2.5, 10 and 50 mm/sec, add $175; Option 19: 50 Hz speed kit (2:1 reduction), speeds of 0.5, 2.5, 10 and 50 mm/sec, add $175.

Note 1: add price of preamplifiers to the above basic assembly prices for complete system cost; see pages 160-163 for specification and prices.

4-CHANNEL RECORDER
Pullout tabletop facilitates chart noting
Model 7704B

The Model 7704B is a 4-channel thermal recording system featuring nine paper speeds, horizontal paper flow for marking ease and a marker (either one sec pulses or external event contact closure) for accurate time correlation. Any combination (up to four) of the eight versatile 8800 Series Preamplifiers may be used as signal conditioners. The knife-edge recording technique provides recordings on true rectangular coordinates and gives a sharp, high resolution trace on Permapaper®. Frequency response is dc to less than 3 dB down at 125 Hz for chart deflection of 10 div pp, damping set for 4% overshoot on a 10 div square wave. Individual power amplifiers have adjustable electrical limiting over span from ±12 div (referenced from channel centerline) to beyond edge of chart coordinates to protect the galvanometer and stylus.



7704B

Specifications

Chart speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec standard, mechanically shifted. Remote operation of chart drive and start-stop functions.

Markers: right side marker standard; second marker mounted between channels 1 and 2 (Option 15). In MARK position, marker pulses at line frequency. In TIME position, marker pulses at line frequency for a few cycles every second.

Front panel controls: individual stylus heat controls, speed selector handle, motor starting switch, timer-off-marker switch, remote control connector for motor and marker.

Paper type: 4-channel green (or orange for copy making) Permapaper®, 10 in. (25.4 cm) wide, 5 cm (50 div) per channel, amplitude lines every 1 mm, time lines every 1 mm. Front panel paper loading and take-up. Two-channel paper may be used for economy when recording either one or two variables.

Paper footage indicator: indicates paper footage remaining on the supply roll; located on right side of recorder.

Power: 115 V ±10%, 60 Hz, approx 180 watts (less preamplifiers); 115 V ±10%, 50 Hz, specify Option 08; 230 V ±10%, 50 Hz, specify Option 09.

Cooling: convection, cabinet vented top and bottom. External ambient temperature should not exceed 40°C.

Dimensions: mobile cabinet: 72½" high, 24" wide, 26" deep excluding base (1841 x 610 x 660 mm), 36½" deep with base (927 mm); rack mount (Option 01): 28" high, 19" wide, 20¾" deep max (711 x 483 x 527 mm). Option 02 (portable cases): consult field office.

Weight (approx): 4-channel recorder with four amplifiers, less preamplifiers, in cabinet: net 408 lbs (185 kg), shipping 504 lbs (228 kg); rack mount (Option 01): net 200 lbs (91 kg), shipping 275 lbs (125 kg).

Accessories: consult local Hewlett-Packard sales office for quantity prices; 4-channel, 5 cm per channel (50 div), green coordinates on white, 200 ft Permapaper® roll (651-54), $18.20; 4-channel orange translucent for contact reproductions, 200 ft roll (651-184), $29.10; 398 Analog Stylus, $7.15; 411-10 Marker Stylus, $6.65.

Optional accessory equipment: 608-100-C11 extra Event Marker, $70; 14040A Marker Amplifier (produces over 1 mm marker deflection with ±1.5 V, 0.5 mA signal input), $110.

Prices: Model 7704B, less preamplifiers, $4020. Option 01: less cabinet, deduct $375; Option 02: portable cases, consult field office; Option 08: 115 V, 50 Hz operation, add $50; Option 09: 230 V operation, add $100; Option 12: unit channel activity decrease, deduct $75 per channel; Option 15: extra marker placed between channels 1 and 2 (specify other location), add $70.

Note 1: add price of preamplifiers to the above assembly prices for complete system cost; see pages 160-163 for specifications and prices.

6- AND 8-CHANNEL SYSTEMS

Record 6 or 8 variables simultaneously

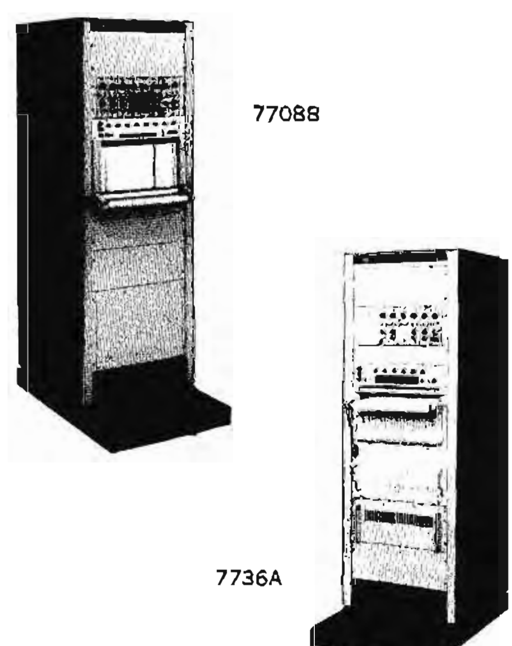
7706B/7708B/7736A/7738A

The Models 7706B, 7736A and 7708B, 7738A are 6- and 8-channel thermal systems that offer the measurement versatility of the 8800 Series interchangeable, individual channel preamplifiers. All four systems are identical except for recorder type: the 7706B and 7708B use space saving vertical recorders; the 7736A and 7738A feature horizontal type recorders that facilitate chart notation.

Transistorized power amplifiers incorporate galvanometer damping circuits to ensure recorder accuracy, current feedback to reduce drift and adjustable electrical limiting to prevent overloading and to protect the styli. Frequency response is dc to 125 Hz for the 6-channel system; dc to 150 Hz for the 8-channel system.

Four and six channel paper may be used for economy when recording less than the maximum number of channels. Permapaper® in opaque or translucent (for copying) forms is available.

Systems are available in RETMA standard mobile cabinets, less cabinet for mounting in RETMA standard equipment racks or in portable cases (7706B, 7708B only).



Specifications

(See pages 160 to 163 for 8800 Series Preamplifier specifications and prices.)

Paper speeds: standard recorders are supplied with 9 speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50, and 100 mm/sec, electrically shifted and selected by front panel pushbuttons; optional "D" version recorders have 9 additional speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/min; provision is made for remote operation of paper speeds and paper drive.

Event marker: right margin; built-in timer provides 1 sec timing marks; provision for manual or remote event marking from external contact closure; "D" version recorders provide 1 sec and 1 min timing markers (Option 11); one optional extra event marker (Option 15) can be installed between channels 1 and 2 and actuated by external contact closure; DC Marker Driver Amplifier 14040A is available for dc event marking (produces greater than 1 mm event marker deflection with ±1.5 volts, 0.5 mA signal input).

Front panel controls: individual stylus heat controls; pushbutton speed selectors; motor starting switch, timer-off-marker switch.

Paper footage indicator: front panel indicator shows number of feet remaining on the supply roll.

Paper supplies (optional): 1000 foot paper supply or horizontal writing table with concealed 200 foot paper take-up available as accessories.

Power: recorder: 115 volts ±10%, 60 Hz, 230 watts; 115 or 230 volts, 50 Hz available on special order; systems:
7706B 115 V ±10%, 60 Hz, 330 watts approx
7708B 115 V ±10%, 60 Hz, 550 watts approx
7736A 115 V ±10%, 60 Hz, 330 watts approx
7738A 115 V ±10%, 60 Hz, 550 watts approx

Weight: (less preamplifiers in cabinet mount): 7706B: net 458 lbs (214 kg), shipping 582 lbs (264 kg); 7708B: net 515 lbs (232 kg), shipping 617 lbs (280 kg); 7736A: net 412 lbs (187 kg), shipping 560 lbs (254 kg); 7738A: net 476 lbs (216 kg), shipping 600 lbs (272 kg); portable cases Option 02: 7706B: recorder in case, net 200 lbs (91 kg), shipping 228 lbs (103 kg); 7708B: recorder in case, net 232 lbs (105 kg), shipping 322 lbs (146 kg); 7706B, 7708B: power supply and preamplifiers in case (typical), net 103 lbs (46 kg), shipping 190 lbs (86 kg).

Dimensions: (all systems) mobile cabinet mount: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" deep with base (927 mm); (all systems) rack mount Option 01: (recorder) 17½" high, 19" wide, 24⅛" deep (445 x 483 x 613 mm); (typical 8800 Preamplifier) 7" high, 2-1/6" wide (178 x 52 mm); portable cases Option 02: (recorder case) 19¾" high, 21" wide, 21½" deep (502 x 533 x 546 mm), (amplifier case) 7-9/16" high, 22" wide, 21½" deep (200 x 570 x 546 mm).

Accessories: 8-channel, 4 cm (50 div), 200 ft Permapaper® roll 651-58, $23.50; 6-channel, 5 cm (50 div) 651-56, $18.90; (consult local Hewlett-Packard sales office for 1000 ft rolls and price for quantity purchases of 200 ft rolls); 399 Analog Writing Arm (8-channel), $6.65; 398 Analog Writing Arm (6-channel), $7.15; 411-3 Marker Stylus (8-channel), $6.65; 411-10 Marker Stylus (6-channel), $6.65.

Optional accessory equipment: 358-800-1 Concealed Paper Take-up, $475; 1069-05A 1000 ft Supply Adapter, $178; 608-100-C11 Extra Event Marker, $70; 14040A Marker Driver Amplifier (±1.5 V dc input), $110; 358-1400 Recorder Carrying Case, $450; Preamplifier Carrying Case 858-1400, $250.

Prices: (see Note 1): Model 7706B (6-channel cabinet assembly, less preamplifiers) $4820; Model 7708B (8-channel cabinet assembly, less preamplifiers) $5495; Model 7736A (6-channel cabinet assembly, less preamplifiers) $5800; Model 7738A (8-channel cabinet assembly, less preamplifiers) $6475.
Option 01: (all models) less cabinet: 7706B Option 01, $4425; 7708B Option 01, $5100; Model 7736A Option 01, $5375; Model 7738A Option 01, $6050.
Option 02: less cabinet, mounted in portable cases: 7706B Option 02, $4970; 7708B Option 02, $5645.
Option 08: (all models): 50 Hz operation, add $50.
Option 09: (all models): 230 V operation, add $100.
Option 11: (7706B, 7708B): mm/min speeds, add $250.
Option 12: (all models): unit channel decrease, deduct $75.
Option 15: (all models): extra marker between channels 1 and 2, specify other location, add $70.

Note 1: Add price of preamplifiers to above prices for total system cost; see pages 160 to 163 for specifications and prices.

6-, 8- AND 16-CHANNEL SYSTEMS

Record 6, 8, or 16 variables simultaneously

7727A, 7729A, 7731A, 7737A, 7739A

Hewlett-Packard 6, 8 and 16-channel basic assemblies offer complete versatility for making accurate, permanent records of multiple variables. These basic assemblies accept multichannel 8820A and 8821A Amplifiers designed to condition and control simple or complex signals. Variables appear as sharp, clean, permanent traces on Permapaper® charts opaque or translucent (for copying). Traces from dc to 150 Hz, 3 dB down, 10 div pp can be recorded with exceptional clarity on the 8-channel systems and dc to 125 Hz, 10 div pp on 6 and 16-channel systems. The following table summarizes the differences between the 6, 8 and 16-channel thermal recording systems.

System	Channels	Recorder Type	Amplifier
7727A	6	vertical	8820A/8821A
7729A	8	vertical	8820A/8821A
7731A	16	vertical	8820*/8821A*
7737A	6	horizontal	8820A/8821A
7739A	8	horizontal	8820A/8821A

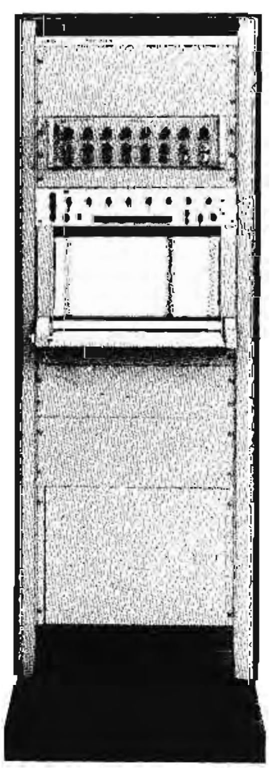
*Two required.

Specifications

(See page 164 for 8820A/8821A Amplifier specifications and prices.)

Paper speeds: standard recorders are supplied with 9 speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec, electrically shifted and selected by front panel bushbuttons; optional "D" version recorders have 9 additional speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/min; provision is made for remote operation of paper speeds and paper drive.

Event marker: right margin; built-in timer provides 1 sec timing marks; provision for manual or remote event marking from ex- marker (Option 15) can be installed between channels 1 and 2 and actuated by external contact closure; DC Marker Driver Amplifier 14040A is available for dc event marking (produces greater than 1 mm event marker deflection with ±1.5 volts, 0.5 mA signal input).



7729A

Front panel controls: individual stylus heat controls; pushbutton speed selectors; motor starting switch, timer-off-marker switch.

Paper footage indicator: front panel indicator shows number of feet remaining on the supply roll.

Paper supplies (optional): 1000 foot paper supply or horizontal writing table with concealed 200 foot paper take-up available as accessories.

Power: recorder: 115 volts ±10%, 60 Hz, 230 watts; 115 or 230 volts, 50 Hz available on special order; systems:
7727A 115 V ±10%, 60 Hz, 330 watts approx
7729A 115 V ±10%, 60 Hz, 330 watts approx
7731A 115 V ±10%, 60 Hz, 550 watts approx
7737A 115 V ±10%, 60 Hz, 350 watts approx
7739A 115 V ±10%, 60 Hz, 350 watts approx

Weight: (less preamplifiers in cabinet mount): 7727A: net 432 lbs (196 kg), shipping 530 lbs (229 kg); 7729A: net 436 lbs (188 kg), shipping 538 lbs (232 kg); 7731A: net 517 lbs (223 kg), shipping 680 lbs (294 kg); 7737A: net 390 lbs (168 kg), shipping 500 lbs (216 kg); 7739A: net 450 lbs (174 kg), shipping 575 lbs (248 kg); portable cases Option 02: 7727A: recorder in case, net 200 lbs (86 kg), shipping 228 lbs (103 kg); 7729A: recorder in case, net 232 lbs (105 kg), shipping 322 lbs (146 kg): 8820A/21A Amplifiers: net 17 lbs (8 kg), shipping 20 lbs (9 kg).

Dimensions: (all systems) mobile cabinet mount: 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" deep with base (927 mm); (all systems) rack mount Option 01: (recorder) 17½" high, 19" wide, 24⅛" deep (445 x 483 x 613 mm); (amplifier) 5-7/32" high, 19" wide, 13¼" deep (133 x 483 x 337 mm); (7727A, 7729A) portable case Option 02: (recorder) 19¾" high, 20" wide, 20½" deep (502 x 508 x 521 mm), (amplifier) 5-7/32" high, 16¾" wide, 13¼" deep (133 x 425 x 337 mm).

Accessories: 8-channel, 4 cm (50 div), 200 ft Permapaper® roll 651-58, $23.50; 6-channel, 5 cm (50 div) 651-56, $18.90; (consult local Hewlett-Packard sales office for 1000 ft rolls and price for quantity purchases of 200 ft rolls); 399 Analog Writing Arm (8-channel), $6.65; 398 Analog Writing Arm (6-channel), $7.15; 411-3 Marker Stylus (8-channel), $6.65; 411-10 Marker Stylus (6-channel), $6.65.

Optional accessory equipment: 358-800-1 Concealed Paper Take-up, $475; 1069-05A 1000 ft Supply Adapter, $178; 608-100-C11 Extra Event Marker, $70; 14040A Marker Driver Amplifier (±1.5 V dc input), $110; 358-1400 Recorder Carrying Case, $450.

Prices: (See Note 1): Model 7727A (6-channel cabinet assembly, less amplifiers), $4030; Model 7729A (8-channel cabinet assembly, less amplifiers), $4705; Model 7731A (16-channel cabinet assembly, less amplifiers), $8000; Model 7737A (6-channel cabinet assembly, less amplifiers), $4750; Model 7739A (8-channel cabinet assembly, less amplifiers), $5425.

Option 01: (all models) less cabinet: 7727A Option 01, $3605; 7729A Option 01, $4280; 7731A Option 01, $7575; 7737A Option 01 $4325; 7739A Option 01, $5,000.

Option 02: less cabinet, mounted in portable cases: 7727A Option 02, consult local Hewlett-Packard office, 7729A Option 02, consult local Hewlett-Packard office.

Option 08: (all models): 50 Hz operation, add $50.

Option 09: (all models): 230 V operation, add $100.

Option 11: (7727A, 7729A): adds nine mm/min speeds, add $250.

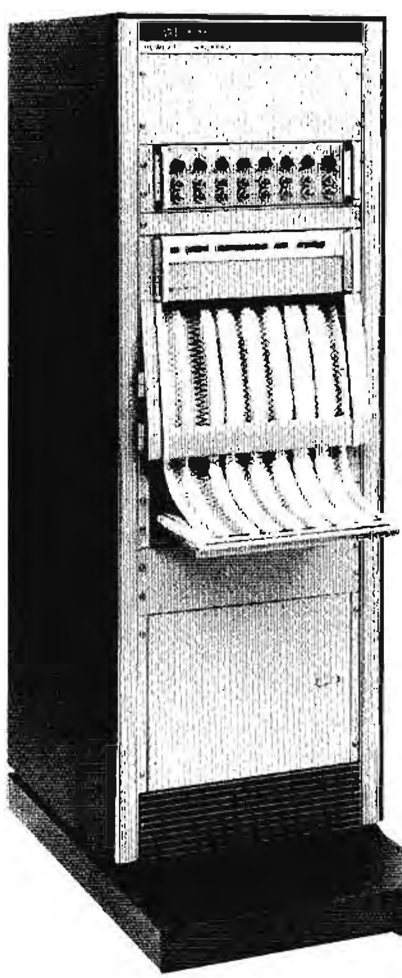
Option 15: (all systems except 7731A): extra marker between channels 1 and 2, specify other location, add $70.

Note 1: Add price of amplifiers to above prices for total system cost; see page 164 for specifications and prices.

INK RECORDER

New system records on Z-fold paper or rolls

Models 7858B, 7878A



7878A

Features:

- 8 channels using plug-in signal conditioners
- Sharp, high resolution, consistent width trace from dc to 150 Hz
- Easily reproduced by inexpensive means
- Recorded on numbered Z-fold chart or paper rolls
- Disposable plug-in recording ink supply

Uses:

- Computer readout
- Quality control records
- Multiple design test measurements
- Telemetry recording
- Multi-station observations

The 7858B and 7878A are 8-channel rectilinear ink recording systems featuring position feedback from a contactless capacitive pickup near the pen tip. The recorder used in both systems has a self-contained power supply and modular-type solid state driver amplifiers. The chart viewing area is 15⅝" wide and 10" high. The chart moves from top to bottom from an internal Z-fold paper supply to a take-up drawer, or from an internal supply roll to a take-up roll. The system is mounted in a standard mobile cabinet, rack mount (Option 01) or portable carrying cases (Option 02).

The 7858B uses any combination of the eight 8800 Series Preamplifiers: compact, solid state modules which plug into the system from the front to mate with the preamplifier power supply, which is an integral part of the 7858B system. AC excitation voltages are supplied, as needed, from plug-in oscillator circuit cards in the power supply. Preamplifiers include: low gain dc, medium gain dc, high gain dc, ac/dc converter, phase sensitive demodulator, carrier, general purpose dc and logarithmic units. Characteristics and prices for the preamplifiers are given on pages 160-163.

The 7878A uses either the 8820A Low Gain or the 8821A Medium Gain Multichannel Amplifier. Each combines eight independent channels of amplification into one front-panel unit, with all operating power, including ac excitation voltages, generated within the amplifier. Amplifier specifications are given on page 164.

System characteristics

Power: 115 V ±10%, 60 Hz, approx 600 watts. 50 Hz available as Option 08; 230 V operation on Option 12.

Weight (approx): 7858B in cabinet with preamplifiers, 550 lbs (249 kg); 7878A in cabinet with amplifier, 495 lbs (225 kg); recorder only, 170 lbs (77,2 kg).

Dimensions: in cabinet, 72½" high, 24" wide, 26" deep excluding base (1842 x 610 x 660 mm), 36½" deep with base (927 mm); recorder: 17" high, 19" wide, 23" deep (444 x 482 x 585 mm).

Cooling: cabinet vented top and bottom for natural convection cooling. Maximum external ambient temperature, 40°C.

Remote operation: connector provided for remote operation of chart drive, chart speed selector and timer/marker. Provides a voltage to indicate remote readiness.

Recorder description

The recorder features include: 14 electrically controlled chart speeds selected by front panel pushbuttons; built-in roll paper take-up; plug-in ink supply cartridge that may be replaced while recorder is operating; and simple paper loading from front. The take-up drawer for Z-fold paper is standard. The recorder also has enclosed, individual, moving coil pen motors with adjustable electrical damping and limiting; contactless pen tip position feedback; a connector is provided for remote control of paper drive, paper speeds and markers; low ink supply indicated on front panel and at remote location.

Recorder Specifications

Frequency response: dc to 150 Hz for 10 div pp deflection; 58 Hz maximum for full scale deflection.

Response time: from 10% to 90% amplitude—

Total Deflection	Response Time
10 div	3 msec
25 div	4 msec
50 div	6 msec

Drift: (driver input shorted, and after one hour warmup):

Temperature: less than 0.1 div, 20°C to 40°C.

Line voltage: less than 0.1 div, 115 V ±10%, 60 Hz.

Paper drift: less than 0.5 div.

Gain stability: (after one hour warmup):

Temperature: less than 0.1%/10°C, 20°C to 40°C.

Line voltage: less than ±0.1%, 115 V ±10%, 60 Hz.

Sensitivity: ±2.5 V nominal, for full recording chart width deflection (4 cm).

Linearity

Method 1: after calibrating for zero error at center scale and +20 div, less than ±0.25 div, including hysteresis.

Method 2: after calibrating for zero error at lower and upper end of printed coordinates, less than ±0.5 div, including hysteresis.

Limiting: electrical limiting from ±12 div (referenced from channel centerline) to beyond channel edge.

Noise: less than 0.1 div pp with driver input shorted.

Ink system: low pressure, permanent blue ink, modulated to match recording pen velocity and chart speed. Dries rapidly on contact with paper. Disposable, plug-in cartridge can be replaced while operating system; ½ hour reserve.

Chart: 15⅝" wide (4 cm, 50 div channels), rectilinear coordinates on 500 ft roll or 500 sheet folded, numbered pack 11-9/10" x 15⅝".

Chart speed: 14 speeds selected by seven speed pushbuttons plus 1X and 100X multiplier pushbuttons (0.025, 0.05, 0.1, 0.25, 0.5, 1.0, 2.0, 2.5, 5, 10, 25, 50, 100 and 200 mm/sec.)

Paper take-up: internal roll accessible by pivoting writing table down from top. Z-fold take-up is below recorder.

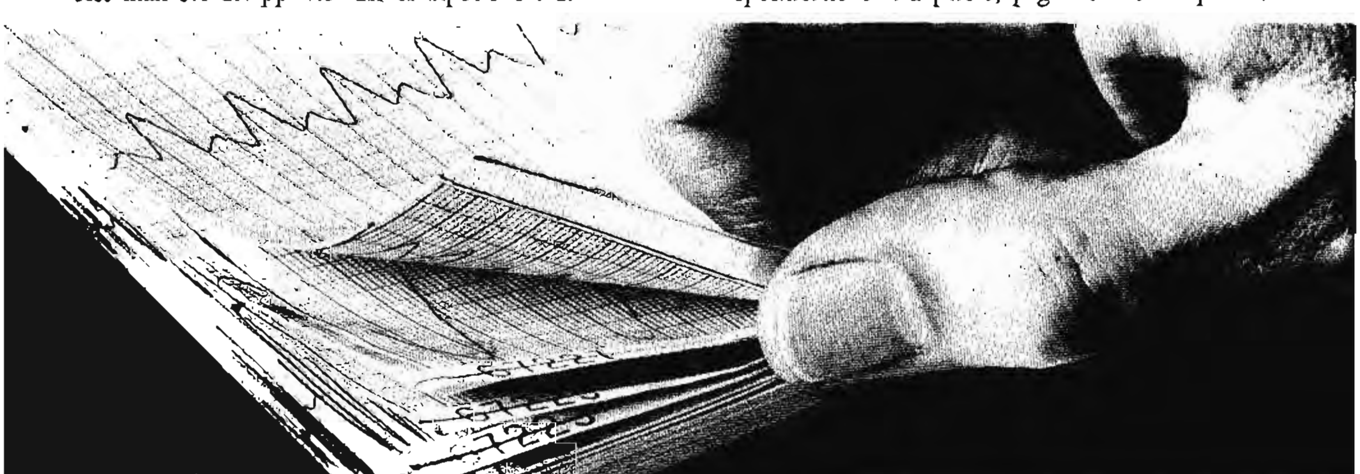
Timer/marker: left margin marker provides timing pulse every second or minute. Right side marker provides event marking by local or remote switch or simple contact closure.

Accessories: (consult your local Hewlett-Packard sales office for quantity price): 9280-0066 roll recording chart, 15⅝" x 500' (397 mm x 154 m), 8-channel translucent, $30; 9280-0067 Z-fold recording chart, 15⅝" x 11-9/10" x 500 pages, translucent, $35; 07858-67260 ink cartridge, 4 oz, $12; 07850-61400 pen kit, $26.

System prices:

Model 7858B, less preamplifiers, $9750.
Model 7878A, less amplifier, $8700.
Option 01: less cabinet, deduct $425.
Option 02: portable cabinet, no additional charge.
Option 08: 50 Hz operation, add $50.
Option 09: 230 V operation, add $100.
Option 12: unit channel activity decrease, deduct $200 per channel.

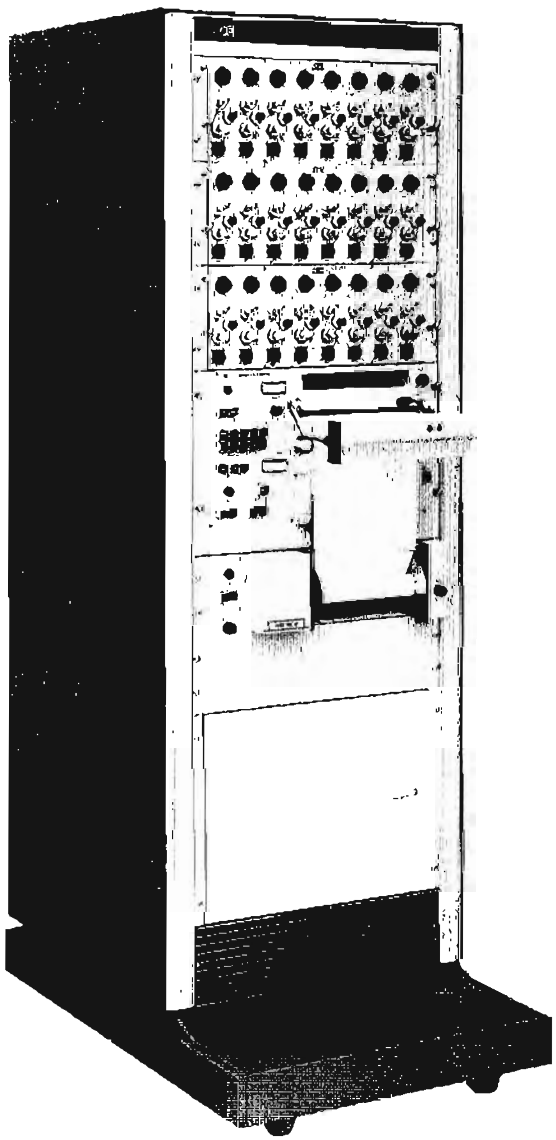
Note 1: add price of plug-in preamplifiers (for 7858B) or multichannel amplifier (for 7878A) to above prices for total system cost. See pages 160 to 163 for preamplifier specifications and prices; page 164 for amplifiers.



OPTICAL RECORDER

For high frequency, high speed applications

Models 4508B, 4524B



4524B

Advantages:

- Up to 25 channels
- One basic galvanometer for all frequencies
- Individual internal calibration
- Galvanometer protected by current limiting
- Individual multi-position attenuator in each channel
- Trace positioned electrically anywhere on chart

Uses:

- Telemetry recording
- Power measurements at 400 Hz
- Transient measurements
- Data measurements sampled at high pulse rates

The HP 4500 Optical Recorder is a completely integrated system for high speed, permanent recording of multiple variables from dc to 5 kHz. Recordings are made at any of nine speeds (0.25 to 100 in./sec) on ultraviolet sensitive paper, and promptly developed under an attached development lamp. Time and amplitude lines recorded with data provide a high order of recording accuracy and convenience. Systems may use 650 Series Amplifiers or 8800 Series Amplifiers (special order) or combinations. The 650 Series Amplifiers are available with maximum sensitivities of 2.5, 50 and 625 mV/in., with and without zero suppression. Each 650 Series Amplifier consists of eight identical modular channels of electronics, with a common power supply. Twenty-four channel systems are driven by three 8-channel amplifiers. A 25th channel galvanometer can be driven directly or by an external amplifier.

Additional features include: full width timing lines (0.01 and 0.1 sec), amplitude lines (removable over part or all of the recording), sequential light beam interruption for trace identification, event marker, lamp power control and meter, and a paper footage meter. Special frequency boost and compensation circuits extend the frequency response of the 2 kHz galvanometers to 5 kHz range (−3 dB, 4″ pp deflection). Current feedback in the matching network between amplifier and galvanometer stabilizes frequency response.

Dimensions: in mobile cabinet, 72½″ high, 24″ wide, 26″ deep, excluding base (1842 x 610 x 660 mm), 36½″ deep with base (927 mm).

Weight: 4508B in cabinet, net 554 lbs (247,5 kg), shipping 650 lbs (292,5 kg); 4524B in cabinet, net 579 lbs (262 kg), shipping 675 lbs (306 kg).

Prices:

4508B UV Recording System, 8 channels, 115 V, 60 Hz, for 650 Amplifiers; less amps., galvanometers, $4200.

4524B UV Recording System 24 channels, 115 V, 60 Hz, for 650 Series Amplifiers; less amplifiers, galvanometers, $4400.

Option 01: (both models) less cabinet, deduct $475.

Option 02: (both models) portable case, deduct $240.

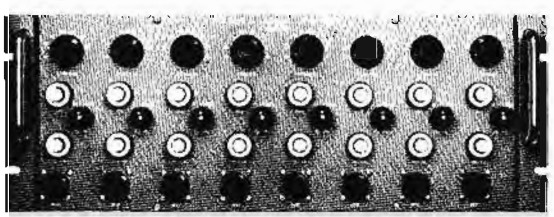
Option 08: (both models) 50 Hz operation. Available with time lines every 1 or 0.1 sec only. No charge.

Option 09: (both models) 230 V operation, add $100.

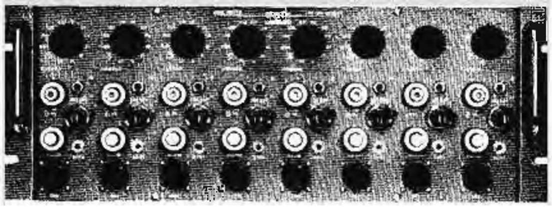
Note 1: add price of amplifiers and galvanometers (1120-1296, $126 ea.) to above prices for total system cost; see page 173 for amplifier specifications and prices.

MULTICHANNEL AMPLIFIERS
Solid state amplifier/driver
658 Series for 4500 Optical Recording Systems

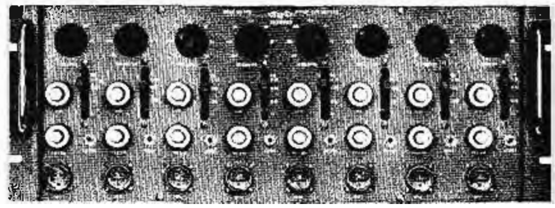
Model:	658–2000	658–2900	658–3400
Amplifier type	galvanometer driver, general purpose	low gain, general purpose	medium gain, general purpose
			2.5 mV/in. (20 mV for 8" trace)
Input circuit	single ended, 100 k	bal to gnd; 1 M ohm each side	floating and guarded, 100 k
Zero suppression	none	max suppression is 10X input signal required for 4" beam deflection for any setting of sensitivity range switch	none
Common mode rejection ratio	N/A	34 dB X1 range, 28 dB other ranges	140 dB at dc, 120 dB at 60 Hz bal 110 dB at 60 Hz, 1 k ohm unbal
Common mode voltage tolerance	N/A	±2.5 V on X1 range; multiply att range X2.5 to max of ±500 V	±500 V
Frequency response	Within 3 dB point, 0 to 5 kHz (4" pp), 0 to 3 kHz (8" pp), all models		
Response time	From 10% to 90% amplitude, 80 μsec, 4% or less overshoot, all models		
Zero drift	0.025"/10°C max, 0° to 50°C; 0.01" max, 103 to 127 V	0.1"/10°C max, 0° to 50°C; 0.04" max, 103 to 127 V; 0.1"/hr	0.025"/10°C max, 0° to 50°C; 0.01" max, 103 to 127 V
Gain stability	Better than 1%, 0° to 50°C; better than 1%, 103 to 127 V, all models		
Noise	Max pp at calibrated gain, 0.02" on all models		
Max nonlinearity		±1.5% full scale (8"), all models	
Internal calibration	2.5 V ±1%	0.2 V ±1%	10 mV ±2%
Size, weight	7" high, 19" wide, 20-1/2" deep (178 x 483 x 520 mm); Option 02 increases depth to 23-3/8" (593 mm); net weight 80 lbs (35 kg), shipping weight 90 lbs (40,5 kg)		
Prices, options*	658–2000, $2200; Option 01: 6-channel, deduct $140 Option 02: with fan, add $145	658–2900, $2895; Option 01: 6-channel, deduct $260 Option 02: with fan, add $145	658–3400, $3780; Option 01: 6-channel, deduct $240 Option 02: with fan, add $145



658-2000



658-2900



658-3400

INSTRUMENTATION MAGNETIC TAPE RECORDING

Magnetic tape recording is used in all walks of life, to record and reproduce information of various kinds. In the case of the familiar *audio* home tape recorder and business dictating machine, that information is voice and music, converted to electrical form by a microphone. Another type, the *video* tape recorder, finds daily use in today's television programming. Your bank account is most likely recorded on a *digital* tape unit, used extensively with computer systems for the mass storage of digitized data (see page 108). All of the above are considered *special purpose* in that each is designed for a specific application.

The instrumentation recorder is, on the other hand, a *general-purpose instrument*, used in any scientific field where there is a need to preserve analog data for later evaluation. The data may already be in electrical form (from dc to 1.5 MHz) or may be one of an almost unlimited variety of physical or scientific phenomena that are convertible to electrical form by a transducer.

Standards for instrumentation recording were established within the field of telemetry by the Inter-Range Instrumentation Group (IRIG). These standards are rigidly adhered to throughout the instrumentation magnetic tape recording industry. Compatibility and exchange of recorded data between various magnetic recording systems demand such standardization, regardless of the specific area of application. "IRIG Telemetry Standards," Document No. 106-66 dated March 1966, represents the latest publication of these standards and is referenced throughout the industry.
(Copies are obtained from the Defense Documentation Center for Scientific and Technical Information, Cameron Station, Alexandria, Virginia 22314.)

Three categories of instrumentation recorders were established by IRIG: low-band, intermediate-band and wide-band. Each of these provides for increasingly greater recording bandwidths, to 1.5 MHz.

Three recording methods have been specified to meet various requirements: *Direct recording, Frequency Modulation recording, and Pulse recording.* Direct and FM recording meet the needs of the majority of applications; Pulse recording is used for more specialized purposes.

Standardized tape speeds are 1⅞, 3¾, 7½, 15, 30, 60, and 120 inches per second. Naturally, the higher tape speeds are used for recording greater bandwidths; the slower tape speeds for the maximum in recording time.

Direct recording provides the greatest bandwidth available from a magnetic tape recorder, and requires only relatively simple, moderately priced electronics.

With this recording method, the intensity of magnetization on tape is made proportional to the instantaneous *amplitude* of the input signal.

In the *reproduce* process, however, a signal is induced from tape to heads *only* in response to *changes* in flux on the recorded tape; the direct record process cannot, therefore, extend down to dc.

This direct recording method is also characterized by some amplitude instability, caused primarily by random surface inhomogeneities in the tape. These variations are normally a few percent at the lower recording frequencies, and can exceed as much as 10% near upper bandwidth limits. Occasional momentary signal decreases of over 50% may occur; these are commonly referred to as "drop-outs."

Uses for direct recording, then, have a common requirement: economy, with a maximum bandwidth, in applications where amplitude variation errors are not critical. Typical applications include audio recording, where the human ear averages any amplitude variation errors, or recordings where the signal's frequency, not amplitude, is of primary importance.

Frequency modulation recording (FM) overcomes some of the basic limitations of the direct recording process, but at the expense of high frequency bandwidth; response does, however, extend down to dc. This recording technique significantly improves the signal amplitude stability, since it is now proportional to carrier deviation, rather than the intensity of magnetization on tape.

In the FM recording method, a carrier oscillator is frequency-modulated by the input signal. The oscillator's center frequency corresponds to a zero-level input, with deviation from that center frequency being proportional to the amplitude of the input signal; the polarity of the input signal determines the direction of deviation.

FM recording is used primarily when the dc component of the input signal is to be preserved, or when the amplitude variations of the direct recording method cannot be tolerated. Accuracy of the reproduced signal is another factor in favor of FM recording, being in the order of 1%, vs 5% for the direct recording process.

For more information on magnetic recording, request a copy of Hewlett-Packard Application Note No. 89, "Magnetic Tape Recording Handbook."

Advantages of magnetic recording

Recording on magnetic tape is an economical, time-saving method of preserving almost any type of information for later analysis. Once converted to electrical form and recorded, it is available indefinitely. It can be easily compared or studied alone by means of X-Y or strip-chart recorders, oscilloscopes, wave analyzers, digitizing systems, and the like. Since the information can be reliably played over and over again, it is readily analyzed in several different ways.

Time compression or expansion techniques (record at one tape speed; play back at another) offer unique opportunities for data analysis on measuring instruments of your choice. For example: slowly varying phenomena, too slow for oscilloscope viewing, may be recorded at a slow tape speed, then reproduced at tape speeds up to 32 times faster . . . now acceptable for oscilloscope viewing. Conversely, high frequency information can be recorded at high tape speeds, then reproduced at a slower tape speed with a concurrent downward frequency-translation: 200 KHz recorded at 60 ips is translated to 6,250 Hz (200 KHz ÷ 32) when reproduced at 1⅞ ips. At this lower speed, low-frequency test equipment is readily used for analysis of a relatively high frequency signal.

Continuous monitoring is another of the more important advantages of magnetic tape recording. Unexpected and/or unpredictable events are preserved; if no significant phenomenon occurs, the tape is simply erased and reused. Continuous monitoring can, threfore, record such irreplaceable data as power-line transients, seismic tremors, the effects of atomic blasts, etc.

Time relationships among several rapidly occurring events are readily evaluated, each event being simultaneously recorded on one of up to 14 data channels. Later analysis finds this capability extremely important in establishing cause and effect relationships among the recorded phenomena.

Recorded information is immediately available for reproduction; there is no delay for processing of any kind. On the other hand, tapes can be stored for long periods without degradation of the recorded material; thus, events separated widely in time can be compared easily.

Predetection recording of telemetered data exemplifies another important advantage of magnetic tape recording. As the name implies, data is preserved in its transmitted form, then the best method of detection is determined *after the fact* with a minimum possible loss of information.

Since the carrier and all its sidebands are present in the recording, repeated analyses can be made using different detection equipment to achieve the best possible signal recovery.

Applications

Instrumentation magnetic tape recording finds wide application in all fields of scientific endeavor . . . wherever there is a need to preserve data for later evaluation. The need for magnetic tape recording occurs in the fields of medicine, industrial measurement, nuclear and geological investigations, oceanography, and aerospace telemetry.

These applications are but a few; the total number is constantly expanding. The Hewlett-Packard magnetic tape recording systems described on the following pages are dependably and reliably meeting these needs.

HP magnetic tape recording systems

Instrumentation magnetic tape recording systems consist of three basic parts: (1) the tape transport, (2) the magnetic head assemblies, and (3) the record/reproduce electronics. In addition, the magnetic tape, itself, while not an integral part of the system, *is* an extremely important factor in overall system operation. In some instances, it is the tape that imposes the limitations of performance; *care* in selecting tape to match recording requirements is well justified.

The tape transport moves the tape past the head assemblies at a precise and constant speed.

HP transports do this with low wow and flutter, using a rugged, uncomplicated mechanism. By using a high degree of mechanical filtering in the form of viscous-damped flywheels, and controlled friction elements, each element along the tape path contributes toward uniform tape movement past the magnetic head assemblies.

The magnetic tape is reeled in a manner that insures no loss of valuable data from tape stretching, tearing, or other accidents. Fail-safe brake design, with optimum braking torque on each reel regardless of the direction of tape motion, assures fast, smooth starts and stops. Even during a power failure, there's no danger of tape spillage or stretching.

Any of six tape speeds are selected simply by depressing the appropriate pushbutton; no capstan or belt changes are required. *Snap-on* reel hub design allows one-handed mounting of tape reels; tape threading is quick thru the simple, uncluttered tape path.

The tape footage counter has consistently enabled users to locate specific data on tape with accuracies equivalent to 0.05%, even after repeated high-speed end-to-end shuttlings of a reel of tape.

No maintenance is required other than the normal cleaning of the heads and tape guides to remove tape oxide dust; even this is accomplished in a matter of *seconds*. The rugged cast aluminum transport frame, precision finished on numerically-controlled machine tools, assures proper alignment and interchangeability of all parts in the tape drive system; complex alignment or adjustments have been eliminated.

Magnetic head assemblies have both record and reproduce sections, one impressing the input data onto the tape as variations in magnetization, the other converting these variations back into electrical signals.

Instrumentation recorders use magnetic head assemblies with four head stacks: two for recording, two for reproducing. The tape first passes the head stack where the *odd*-numbered data channels are recorded, then past the next stack for recording the *even*-numbered channels. Likewise, the two following stacks reproduce the respective data tracks. It is this IRIG-compatible head-stack configuration that keeps interchannel crosstalk to a minimum; spacing between individual heads in each stack is maximized, while still recording 7 data channels on ½-inch tape, or 14 on 1-inch tape.

Hewlett-Packard designed and manufactured magnetic heads are uniquely coupled to current-sensing preamplifiers; it is this combination that offers users of HP tape systems an unprecedented signal-to-noise ratio at frequencies up to 1.5 MHz. All four head stacks are mounted on a single precision baseplate and prealigned for easy replacement in the field. Precision machining of all mating parts has eliminated the need for adjustments. (On the wideband, 1.5 MHz assemblies, minor azimuth adjustments of the reproduce heads assure optimum performance.)

Conversion from ½- to 1-inch tape width (to 14 channels) is straightforward and easily made at any time after original purchase. Only the head assembly, tape guides, pinch roller, and reel hubs need be changed. Kits are available for field conversion, thus, a system originally equipped for 7-channel operation is readily expanded to fourteen merely by installing the appropriate conversion kit and adding another 7 channels of record/reproduce electronics.

The record and reproduce electronics within a recording system applies the input data to the record heads and recovers the data from the reproduce heads. Direct, FM, and pulse electronics are used in present-day applications.

Record electronics presents a nominally high impedance to the data source to minimize loading; it also shapes the frequency response appropriately to assure a constant-flux recording characteristic over the required bandwidth. Record level meters are provided for data channel monitoring.

Reproduce electronics raises the microvolt-level signals from the reproduce heads to a usable output signal. Since these low-level signals are subject to noise pickup, the outstanding signal-to-noise ratio of the HP reproduce electronics becomes an even more important factor in the reliable reproduction of low level input signals.

Two types of electronics are used in Hewlett-Packard magnetic tape recording systems:

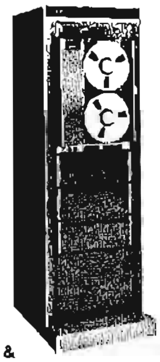
1) *Interchangeable* electronics, in the low cost 3907B, 3914B, 3917B, and 3924B systems.

2) *Manually switchable* electronics, in the more versatile, low-noise 3950 and 3955 Series systems.

For additional information on these, refer to the following pages.

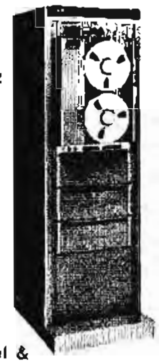
MAGNETIC TAPE SYSTEMS
IRIG-compatible instrumentation recording
Series 3900, 3950, 3955

3907B/3914B
Low-band recording
(FM—dc to 10 kHz
Direct—50 Hz to
100 kHz)



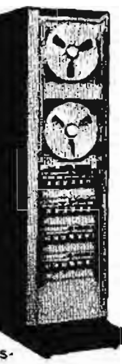
Medical, Chemical & Electronic applications

3917B/3924B
Intermediate-band
(FM—dc to 20 kHz
Direct 50 Hz to
250 kHz)



Medical, Chemical & Electronic applications

3955 Series
Intermediate-band
(dc to 300 kHz)



Sophisticated Industrial & telemetry applications

3950 Series
Wide-band recording
(dc to 1.5 MHz)

Aerospace and other complex applications

The primary features of the Hewlett-Packard line of instrumentation magnetic recording systems are briefly highlighted on this page. The table below summarizes the basic capabilities of each system, with reference to specifics on the following pages.

All IRIG-compatible bandwidths are covered by HP systems, as shown above. The 3917B and 3924B systems pages 177-178) offer low-cost intermediate-band recording for medical, chemical and industrial applications.

Features:

- Simple tape-threading, for operator convenience
- Tape-path cleaned in a matter of seconds
- A truly accurate tape-footage counter allows precise location of previously recorded data
- All operational controls are front panel accessible
- IRIG-compatible recording, for reproducing data on or from other tape systems
- Basic design concept: rugged construction for reliable operation; easy to service
- No cooling required by solid state electronics
- Field convertible from ½" to 1" tape (factory provision required); provides for future 14-channel operation
- Wide-band (1.5 MHz) direct recording with phase equalization, for optimum fidelity of reproduced signal

Two types of record/reproduce electronics are used in Hewlett-Packard magnetic tape recording systems:

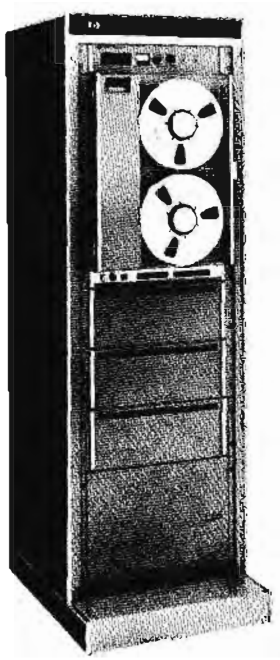
(1) Low-cost electronics, with record and reproduce circuitry for each in data channel mounted on a single Insert card. These interchangeable, printed circuit cards may be selected for Direct, FM, or Pulse recording. Speed equalization is via front panel plug-in networks. (Used in Models 3907B, 3914B, 3917B and 3924B.)

(2) The more flexible, multi-speed manually switched electronics offer greatly improved signal-to-noise ratios. The Record Amplifiers and Reproduce Amplifiers are separately packaged; this provides greater system flexibility and economy where, for example, there is need for fewer reproduce than record data channels. Amplifiers, available for Direct or FM recording, house three of the six speed-equalization networks, selectable by front panel push-bar operation. (Used with 3950 Series and 3955 Series systems.)

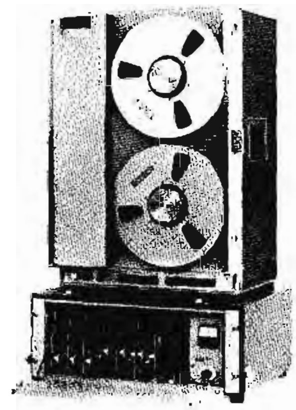
SYSTEM CAPABILITIES

IRIG band	Bandwidth: Direct recording B.W.	Direct recording S/N (dB)	FM recording B.W.	FM recording S/N (dB)	Tape speed (max)	Reel size (max)	Number of tracks	tape width	model	see page
LOW	100 Hz to 100 kHz	40*	dc-10 kHz	45	60 ips	10½"	7 + edge	½"	3907B	177-178
					60 ips	10½"	14 + edge	1"	3914B	177-178
INTERMEDIATE	300 Hz to 250 kHz	35*	dc-20 kHz	45	60 ips	10½"	7 + edge	½"	3917B	177-178
					60 ips	10½"	14 + edge	1"	3924B	177-178
	300 Hz to 300 kHz	40*	dc-20 kHz	48	60 ips	15"	14	1"	3955A	179-180
					60 ips	15"	7	½"	3955B	179-180
					60 ips	10½"	14	1"	3955C	179-180
					60 ips	10½"	7	½"	3955D	179-180
WIDE	400 Hz to 1.5 MHz	30*	dc-400 kHz	30	120 ips	15"	14	1"	3950A	179-180
					120 ips	15"	7	½"	3950B	179-180

* Measured with bandpass filter at output. Corner frequencies are those of specified bandwidth; rolloff is 18 dB/octave.



3900 Series System
in mobile cabinet
with optional
voice channel



3900 Series
Portable System
(Option 02)

IRIG-Compatible Instrumentation
Recording Systems
3907B, 3914B lowband (to 100 kHz)
3917B, 3924B intermediate band (to 250 kHz)

Hewlett-Packard Low-Band and low-cost Intermediate-Band Instrumentation Recording is provided by the models described on this and the following page (also see the Table on page 176).

Both 7- and 14-channel operation are offered, with IRIG-compatible tape-speeds and recording bandwidths.

The primary features of these systems evolve through use of low-cost, simplified electronics, making them especially suited to Medical, Chemical and Industrial applications, plus general laboratory testing. The electronics are all solid state and mounted on front panel accessible printed-circuit cards for ease in making recording mode changes.

Both the Record and the Reproduce electronics for a data channel are on a single printed-circuit Insert Card. This combination offers more compact electronics, at lower cost.

Data Channel Insert Cards are available for Direct, FM and Pulse modes of recording and can be all alike or mixed as desired to meet the requirements of data to be recorded on each of the 7 (or 14) channels.

For operation at the different tape speeds, the data channel electronics are compensated by sliding a Direct or FM Plug-in card into the appropriate Insert Card (none is required for Pulse recording). With the appropriate Plug-ins, the Insert Cards are ready for operation at any of the six standard tape speeds.

FM Flutter Compensation is provided by channel 3 in 7-channel systems and 3 and/or 10 in 14-channel systems. By placing the Compensation Switch to ON, a signal is fed to the output of each of the other channels, significantly reducing the flutter noise component and improving the signal-to-noise ratio over the bandwidth, at all tape speeds. A new feature of the FM electronics is the "record squelch" switch which allows *re*-recording on any pre-selected channels without erasing the other channels.

The Insert Rack and Transfer Chassis, located directly below the Tape Transport, contains the power supply and data channel electronics; up to eight Record/Reproduce Amplifier Inserts (one for the edge-track) are accommodated in each unit. It also provides built-in, switchable metering for aligning and monitoring FM channels; front panel test points are provided for power supply voltage testing.

Voice channel commentaries use edge-track recording, by incorporating the Model 3907-06A Voice Channel Amplifier in the system (see above photo). The magnetic heads on all models contain an edge-track which may be used for voice commentary or time-coded data.

Transport Operating Controls include pushbuttons for LINE (power), STOP, PLAY, REVERSE, FORWARD and RECORD. Also, all transport tape speeds, 1⅞ ips through 60 ips, are selected electrically by front panel pushbuttons. Both Record and Reproduce can be performed simultaneously for immediate display of the data being recorded. A connector is provided for remote control of the PLAY, STOP, REVERSE, FORWARD and RECORD functions.

The Transport can be easily converted in the field to accommodate either ½" or 1" wide tape. A factory provision is required on the original system to allow for ½" to 1" conversion. No such provision is required for conversion from 1" to ½" tape.

The 3900 Series of Magnetic Tape Recorders are ideally suited for use with the 8800 Series Single Channel Preamplifiers and the 8820A/21A Multi Channel Amplifiers. The 8875A Differential Amplifier may also be used with these systems.

Optional accessory equipment

Input signal coupler: adapts seven FM or Direct single-ended inputs for use with push-pull input signals. Attenuator network plug-ins (one per channel) required.
Price: HP Model 3907-07A, $395.

Control panel: a central signal-distribution point for up to eight data channels. Input data is from tape or preamplifiers; outputs drive single-ended inputs of recorders or monitors, such as the Optical Recorders, Thermal Recorders, Ink Recorders, Viso-Scopes, or a Magnetic Tape Recorder.
Price: HP Model 568-2000A, $1750.**

Remote control module: includes all functions except speed selection for tape recorder operation from another location. With 25 ft cable. Rack mounting on Option 01. (See photo, page 183.)
Price: HP Model 3907-11A, $385.

Voice channel amplifier: provides for edge-track recording of commentaries at same time data is being recorded. Edge-track is on all transports; only a Reproduce Preamplifier and Direct Record/Reproduce Insert must be added. Includes microphone.
Price: HP Model 3907-06A, $250.

System prices

(add appropriate Record/Reproduce Electronics)

Model 3907B, 7-track, Low-Band Systems	$6185.
Model 3914B, 14-track, Low-Band Systems	$8415.
Model 3917B, 7-track, Intermediate-Band Systems	$6435.
Model 3924B, 14-track, Intermediate-Band Systems	$8915.

System options

Less cabinet: includes all hardware for 19" rack mounting.
Option 01: (all systems) deduct $505.

Mounted in portable cabinets, (see photo, page 177).
Option 02: 7-channel systems deduct $200.
14-channel systems no charge.

Record/reproduce electronics

Direct record/reproduce insert: each direct recording channel requires one data amplifier insert, plus a reproduce equalization plug-in (listed below) for each tape speed to be used.
Price: HP Model 3900-12B, $155 ea.

Direct equalization plug-ins: these slide into direct insert (listed above) to be used. Available for all six tape speeds.
Price: HP Model (depends on tape speed), $40 ea.

FM record/reproduce insert: each FM recording channel requires one data amplifier insert, plus an FM carrier frequency plug-in (listed below) for each tape speed to be used.
Price: HP Model 3900-13C, $200 ea.

FM frequency plug-ins: these slide into FM insert (listed above), to generate the appropriate FM carrier frequency for tape speed to be used. Available for all six tape speeds.
Price: HP Model (depends on tape speed), $41 to $60.

Pulse record/reproduce insert: (no plug-ins required. Each pulse recording data channel requires one pulse insert.
Price: HP Model 3900-14A, $125 ea.

Reproduce preamplifier: for use with voice channel amplifier (Model 3907-06A).
Price: HP Model 3900-10B, $41 ea.

Power, weight and dimensions (all models)

System power: 105 to 125 V rms, 60 Hz, approx 350 watts.

System weight (approx):
3907B: 456 lb (207 kg), net
3914B: 520 lb (236 kg), net
3917B: 424 lb (192 kg), net
3924B: 424 lb (192 kg), net

System dimensions: 72⅛" high, 22-1/16" wide, 30" deep (1832 x 561 x 763 mm).

Condensed specifications

(Common to Models 3907B through 3924B)

Note: For complete specifications, request current technical data sheet. Speed-dependent specifications are shown at 60 ips.

**Does not include system cables.

Tape transport

Magnetic tape: 4600 ft of 1-mil tape on 10½" reel.
Tape speeds: 60, 30 15, 7½, 3¾ and 1⅞ ips.
Drive speed accuracy: ±0.25% of nominal capstan speed with 60 Hz ±0.03% line; speed is directly proportional to line frequency.
Maximum interchannel time displacement error: total interchannel displacement error (dynamic) ±1 μsec at 60 ips between 2 adjacent tracks on same head stack (all models).
Start time: within speed limits in approx 6 sec; flutter within specifications in approx 10 sec at 60 ips.
Stop time: 2 sec max. Power-failsafe braking.
Rewind time: approx 200 sec for 4600 ft reel.
Peak-to-peak flutter characteristics (at 60 ips):
0.2% over 0 to 200 Hz bandwidth
0.3% over 0 to 1.5 kHz bandwidth
0.6% over 0 to 10 kHz bandwidth

Direct electronics

Record amplifier input: 20 K ohms input resistance, single-ended. 0.5 to 10 V rms, adjustable.
Reproduce amplifier output: output impedance 100 ohms max, single-ended. Level adjustable from 1 V rms to 2.1 V rms at ±3 mA. DC level adjustable ±1.5 V.
Third harmonic distortion (conforms to IRIG stds):
3907B and 3914B: 1% typical at 1 kHz, 60 ips.
3917B and 3924B: 1% typical at 500 Hz, 30 ips.
Bandwidth (at 60 ips):
3907B and 3914B: ±3 dB, 100 to 100 kHz.
3917B and 3924B: ±3 dB, 300 to 250 kHz.
Signal-to-noise ratio (at 60 ips):
3907B and 3914B: 40 dB* over 100 Hz to 100 kHz bandwidth.
3917B and 3924B: 35 dB* over 250 Hz to 250 kHz bandwidth.

FM electronics

Record amplifier input: 20 K ohms input impedance, single-ended. ±2.5 V dc nominal, adjustable from ±1.2 to ±5 V.
Reproduce amplifier output: output impedance less than 100 ohms max. Single-ended output is ±2.5 V dc, nominal (at ±3 mA max); adjustable from ±1.2 to ±5 V. DC position adjustable ±2 V.
Drift: ±0.5% for 10°C change, 15°C to 35°C; ±0.25% max for 10 V line voltage change.
Linearity: max departure from a straight line, using 0% and +30% frequency deviation as reference points, will be:
3907B and 3914B: ±1%
3917B and 3924B: ±1.5%
Bandwidth (at 60 ips):
3907B and 3914B: +0, −1 dB from dc to 10 kHz.
3917B and 3924B: +0, −1 dB from dc to 20 kHz.
Signal-to-noise ratio (at 60 ips):
3907B and 3914B: 45 dB over dc to 10 kHz bandwidth.
:(48 dB with flutter compensation).
3917B and 3924B: 45 dB over dc to 20 kHz bandwidth.
Total harmonic distortion (at 60 ips):
3907B and 3914B: 1.2%
3917B and 3924B: 1.5%
FM center carrier frequency (at 60 ips):
3907B and 3914B: 54 kHz, nominal.
3917B and 3924B: 108 kHz, nominal.

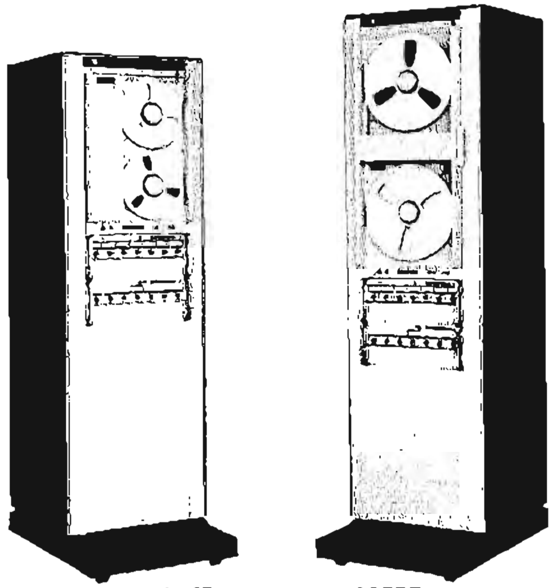
Pulse electronics

Recorder amplifier input: 10 K ohms input impedance, single-ended. Rectangular, zero-based, negative-going pulse, −7½ V to −30 V final amplitude.
Reproduce amplifier output: output impedance of 1 K ohms; may be loaded. Single-ended output of approx −11.8 V into open circuit is zero-based, rectangular pulse.
Pulse characteristics (at 60 ips): (for 3907B and 3924B; specifications for 3917B and 3924B shown in parentheses).
Maximum rise time: 4 (3) μsec.
Minimum input pulse duration:
50 (25) μsec for output pulse reproduction accuracy.
10 (2) μsec for any output pulse.
Pulse reproduction accuracy: ±5 (±10) μsec.

*S/N, as measured with external bandpass filter at output. Corner frequencies are those of specified bandwidth; rolloff is 18 dB/octave.

Intermediate band (to 300 kHz) recording
3955 Series

INTERMEDIATE BAND INSTRUMENTATION RECORDERS
40 dB signal-to-noise ratio to 300 kHz.



3955D 3955B

The HP 3955 Series Magnetic Tape Recorders provide you with highly flexible, yet easy-to-operate systems to record and/or reproduce electrical signals in their original form. Both 7- and 14-channel capacity is available; plug-in electronics (Direct and FM) can be intermixed as desired. Maximum bandwidth at 60 ips is 300 kHz for Direct recording, and 20 kHz for FM recording.

Each 3955 System includes a high-performance Tape Transport and a number of interchangeable Record and Reproduce Amplifiers, offering an extremely wide latitude in determining the exact system configuration. You can choose 7- or 14-track capability in *either* of two basic tape transports.

The smaller transport, which can handle tape reels up to $10\frac{1}{2}''$ in diameter, provides economy as well as performance. This transport is for applications requiring average recording times.

The larger transport accepts tape reels up to 15″ in diameter to provide over 19 hours of recording time at a tape speed of $1\frac{7}{8}$ ips.

The 7- and 14-track Record and Reproduce **Head Assemblies** conform to the generally accepted industry-standards for magnetic heads and tape format, as specified in IRIG (Inter-Range Instrumentation Group). In addition, for best alignment, the head stacks are mounted on a single precision baseplate. Because they are prealigned, head assemblies are easily field replaceable.

Tape reels snap on and off specially-designed hubs, and the open tape path allows quick, convenient tape threading.

All operating controls for the system are located on the transport chassis. Pushbuttons are utilized throughout to obtain the desired mode of operation. Rear connectors are provided for remote control operation, accessories, and interconnecting cabling.

The transparent cover door completely encloses the reels and tape drive path to protect these parts from dust and damage. The control buttons are left uncovered for ready access when changing operating modes.

The transports are slide-mounted. When withdrawn, they can be tilted in either direction for complete front-of-system accessibility of all parts for maintenance purposes.

The outstanding electrical and mechanical performance of the tape transports used in the 3955 Series Tape Systems is inherent in their simple, straightforward design. The rugged cast aluminum transport frame is precision-finished on automated machine tools to insure proper alignment of all parts of the tape drive system. Close tolerances in the computer-controlled machining process assure parts interchangeability without need for complex alignment, adjustments, or shims, in the transport mechanism.

Test Signals are provided by the Record Mainframe; 7 pushbuttons (see Figure 2) introduce test signals to the desired track. To apply a test signal, simply connect it to the front panel TEST INPUT jack and depress the appropriate pushbutton. This removes the normal data-signal and inserts the test-signal into the desired Record Amplifier.

In the Record mode the recorded test signal is simultaneously reproduced with a delay equal to 3.5 inches of tape length, and is available at the output of the appropriate Reproduce Amplifier. It can be monitored by depressing the channel pushbutton on the Reproduce Mainframe (see photo, page 182); this connects the reproduce monitor meter and front panel OUTPUT jack to the desired Reproduce Amplifier. Using this technique, it is easy to quickly check all channels for proper operation from the front panel.

With all their flexibility, the 3955 Systems are extremely easy to operate and maintain.

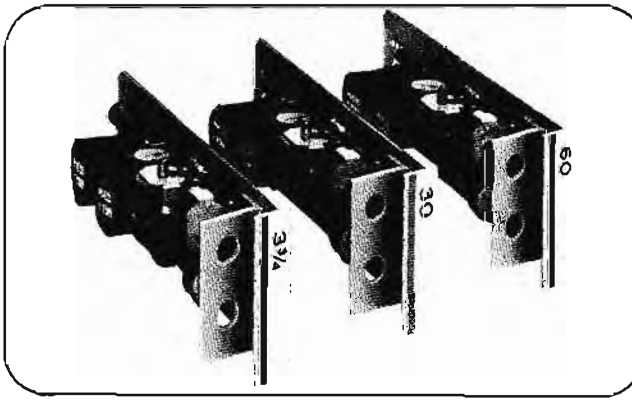


Figure 1. Tape-speed networks, changeable from front-panel.

Record and Reproduce Electronics

The solid-state Record and Reproduce Amplifiers for the 3955-Series are separately packaged, modular units, designed as front-panel plug-ins. Supply voltages, signal connections, and metering for all amplifiers are provided by the Record and Reproduce Mainframes. Two mainframes are used in 7-channel systems; four in 14 channel systems.

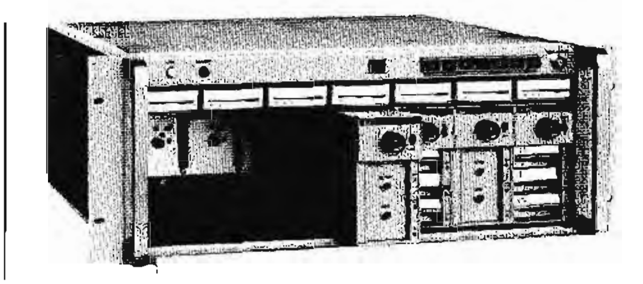


Figure 2. Recorder Mainframe, showing plug-in Record Amplifiers (Reproduce Mainframe is shown on Page 182).

A metal cover-door opens downward for Amplifier adjustment or removal (as shown in photo, above).

Direct electronics, with 300 kHz bandwidth, and **FM electronics,** with dc to 20 kHz bandwidth, is provided for the 3955-Series (see listing, below; also shown on page 181).

The Reproduce Amplifiers used in 3955 systems are especially well suited to the magnetic head characteristics. The HP preamplifier, which evolved from other areas of magnetic development in Hewlett-Packard laboratories, gives an *outstanding signal-to-noise performance.*

Different equalization is used for each tape speed. Each equalizer circuit is mounted on a convenient plug-in circuit card (Figure 1). The push-bar indicates with the tape speed numerically, as well as by a colored stripe to match the *color* of the speed pushbutton on the Tape Transport. Amplifiers accommodate equalizers for three tape speeds. The desired equalizer is selected by pushing on the equalizer push-bar. A mechanical "teeter-totter" automatically removes the previously operating equalizer from the circuit. The plug-in design of the equalizers allows reliable and rapid front-panel substitution of units for any speed, or of any entirely new set.

Prices for Record and Reproduce Electronics

Direct electronics: (to 300 kHz)

- **Direct Record Amplifier:** HP Model 3534A, $125 ea. (no equalization plug-ins required).
- **Direct Reproduce Amplifier:** HP Model 3537A, $100 ea. Direct Reproduce Equalizers**, $25 ea.

FM electronics (dc to 20 kHz)

- **FM Record Amplifier:** HP Model 3535A, $210 ea. FM Record Tuning Units**, $15 ea.
- **FM Reproduce Amplifier:** HP Model 3538A, $170 ea.
  With FM flutter compensation, Option 01, $235.
  With 0 to 5 volt p-p output, $(on request).
  FM Reproduce Filter Units **, $40 ea.

System Prices

System prices depend on number and type of record and reproduce amplifiers, plus complementary equipment included. The following include 7- or 14-channels of direct record and reproduce electronics: 3-speed equalization; no complementary equipment:

Model 3955A: 14-channel system; 15" max reel dia	$14,500
Model 3955B: 7-channel system; 15" max reel dia	$10,050
Model 3955C: 14-channel system; 10½" max reel dia	$14,000
Model 3955D: 7-channel system; 10½" max reel dia	$ 9,550

Condensed Specifications

(common to all 3955-Series models)

Note: for complete specifications, request current technical data sheet. Speed-dependent specifications are shown (at 60 ips).

Tape Transport

Magnetic tape: 3955A/B: 9200 feet of 1-mil tape on 15" reel (max). 3955C/D: 3600 feet of 1-mil tape on 10½" reel (max).
Tape speeds: 60, 30, 15, 7½, 3¾ and 1⅞ inches per second.
Drive speed accuracy: ±0.25% of nominal capstan speed with 60 Hz ±0.03% line; speed is directly proportional to line frequency.
Maximum time base error (TBE) (at 60 ips): 0.4 μs p-p jitter, max, over a 0.1 ms time interval.
Maximum interchannel time displacement error (ITDE): ±1 μs at 60 ips between two adjacent tracks on the same head stack.
Start time: within speed limits in approximately 6 seconds.
Stop time: 1 second, maximum. Power-failsafe braking.
Rewind time (approx): 4 min for 9200 feet; 2 min for 3600 ft.
Peak-to-Peak flutter characteristics (at 60 ips):
Within specs approx 10 seconds after start.
0.2%, p-p, over 0 to 200 Hz bandwidth.
0.3%, p-p, over 0 to 1.5 kHz bandwidth.
0.6%, p-p, over 0 to 10 kHz bandwidth.
Footage counter: 5 digits, ±0.05% accuracy.

Direct Electronics

Record amplifier input (3534A): *input impedance*: 20 K ohms min, shunted by 150 pF, unbalanced. *Input signal level*: 0.15 to 10 V rms, adjustable for IRIG-specified record level.
Reproduce amplifier input (3537A): *output impedance*: 50 ohms, nominal. Unbalanced output signal adjustable from zero to 1 V rms (0.5 V rms into 50Ω); IRIG-specified record level on tape.
Total harmonic distortion (with 3534A and 3537A amplifiers): 1.2% THD, or less, when recording at IRIG-specified level.
Bandwidth (at 60 ips): ±3 dB, 300 Hz to 300 kHz.
Signal-to-noise ratio (at 60 ips):
40 dB*, or better, over 300 Hz to 300 kHz bandwidth. (System noise is limited by the magnetic tape used.

FM electronics

Record amplifier input (3535A): *input impedance*: 20 K ohms min, shunted by 150 pF, unbalanced. *Input signal level*: ±0.7 to ±15 volts peak, adjustable for ±40% carrier deviation.
Reproduce amplifier output (3538A): *output impedance*: 600 ohms, nominal. Unbalanced output signal is 2.8 V p-p into matched load (5.6 V p-p, open ckt); adjustable down to 0.3 V p-p. DC position adjustable to 0 V dc at zero deviation.
Drift:
±0.4% max, for 10°F change, 32°F to 131°F.
±0.25% max, for 10 V line voltage change.
±0.5% of p-p output max, per 8 hrs (after 20 min warmup).
Linearity: ±1% max departure from a zero-based straight line.
Bandwidth (at 60 ips): +0.5, −1 dB from dc to 20 kHz, with 600 ohm load and output filter adjusted for flat amplitude response (also adjustable for best squarewave response).
Signal-to-noise ratio (at 60 ips): >48 dB over dc - 20 kHz bandwidth. (Further improved with FM flutter compensation ampl).
Total harmonic distortion (at 60 ips): 1.5%, maximum.
FM center carrier frequency (at 60 ips): 108 kHz.

Power, weight and dimensions

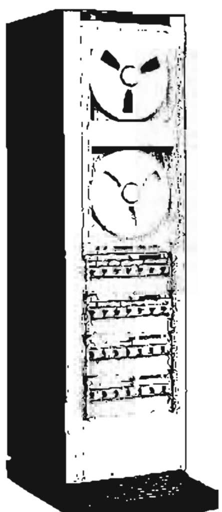
System power: 115 V ±10%, 60 Hz (230 V, 50 Hz optional). 440 to 460 watts, approx (14-track models); 330 to 350 watts, approx (7-track models).
System weight: (depends on number of channels and complementary equipment included: the following are typical): 675 lbs (304 kg), net, for in-cabinet 14-channel system.
575 lbs (257 kg), net, for in-cabinet 7-channel system.
System dimensions: (standard cabinet, with base with casters). 82⅜" h. x 23⅞" w. x 35-11/16" d. (2099 x 607 x 907 mm).

* S/N ratio measured using bandpass filter at output. Corner frequencies are of specified bandwidth; rolloff is 18 dB/octave.

** Amplifiers accept three (3) tape speed compensating plug-ins, simultaneously. Part number depends upon tape speed specified; plug-ins are available for all six tape speeds.

Wide-band (to 1.5 MHz) recording
3950 Series

WIDE-BAND INSTRUMENTATION RECORDER
30 dB signal-to-noise ratio to 1.5 MHz.



3950A

The 3950 Series Magnetic Tape Recorders are a versatile and reliable means for recording and/or reproducing large amounts of data. With up to fourteen record and reproduce channels, six electrically switchable operating speeds, and tape reel capacity up to 15 inches in diameter, these systems provide a wide choice of operating modes.

Each 3950 system includes a high-performance Tape Transport, plus Record and Reproduce Amplifiers for the number of data-channels desired.

Simple and straightforward design of both the Tape Transport and the amplifiers assures reliable operation with a minimum of routine adjustment and maintenance. System flexibility permits arrangement of its parts in any desired quantity and configuration. Systems can be expanded or rearranged quickly and easily at field locations.

Bandwidth of each Direct-recording channel is 400 Hz to 1.5 MHz, providing 17 minutes of recording time when using 15-inch reels and operating at the fastest speed of 120 ips. At its lowest standard speed of 3¾ ips, the system will record 400 Hz to 47 kHz for over 9½ hours. With FM electronics, the bandwidth is from dc to 400 kHz at 120 ips, and dc to 5 kHz at 3¾ ips.

Outstanding electrical and mechanical performance is inherent in the simple, straightforward tape transport *designed and built by Hewlett-Packard.* The rugged cast aluminum transport frame is precision finished on automated machine tools to assure proper alignment of all parts of the tape drive system. Close tolerances in the computer-controlled machining process assure parts interchangeability without need for complex alignment or adjustments in the transport mechanism.

Exceptionally good motional stability is achieved by a tape drive system that is easy to thread and requires a minimum of maintenance.

The 7 and 14-track Magnetic Head Assemblies conform to generally accepted industry-standards for magnetic heads and tape format, as specified by IRIG (Inter-Range Instrumentation Group). The head stacks are mounted on a single precision baseplate. The prealigned head assemblies are easily field replaceable, within 10 minutes.

Tape reels snap on and off specially-designed hubs for maximum operator convenience.

All operating controls for the system are located on the transport chassis. Pushbuttons are utilized throughout to obtain the desired mode of operation. Rear connectors are provided for remote control operation, accessories, and interconnecting cabling.

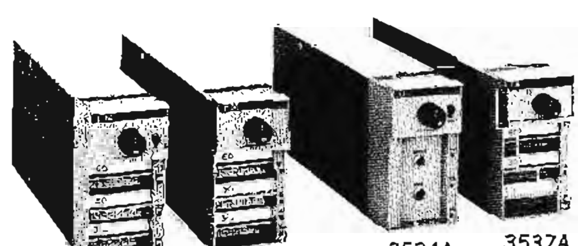
A transport cover door completely encloses the reels and tape drive path to protect these parts from dust as well as possible damage. Control buttons are left uncovered for ready access to quickly change transport operating modes.

The transport is slide-mounted. When withdrawn from the rack, it can rotate in either direction from the vertical to provide complete front-of-system accessibility of both top and bottom of the transport for maintenance purposes.

Test Signals are provided by the Record Mainframe; 7-pushbuttons (see photo, page 180) introduce test signals to the desired track. To apply a test signal, simply connect it to the Record Mainframe front-panel TEST INPUT jack, and depress the appropriate pushbutton. This removes the normal data-signal and inserts the test-signal into the desired Record Amplifier.

In the Record mode, the recorded test signal is reproduced with a delay equal to 3.5 inches of tape length and is available at the output of the appropriate Reproduce Amplifier. It can be monitored by depressing the channel pushbutton on the Reproduce Mainframe (see Figure 2); this connects the reproduce monitor meter and front panel OUTPUT jack to the desired Reproduce Amplifier. Using this technique, it is easy to quickly check all channels for proper operation from the front panel.

The flexible 3950-Series systems are extremely easy to operate and maintain.



3535A 3538A 3534A 3540A 3537A 3543A

Figure 1. Record and reproduce amplifiers.

Record and Reproduce Electronics

Solid state Record and Reproduce Amplifiers for HP 1.5 MHz Recorders are modular units designed for front-panel plug-in mounting in the system Mainframes (see Figure 2). Two Mainframes are used in 7-channel systems; four in 14-channel systems. Each seven-channel Mainframe provides power supply voltages, signal connections and metering for all amplifiers.

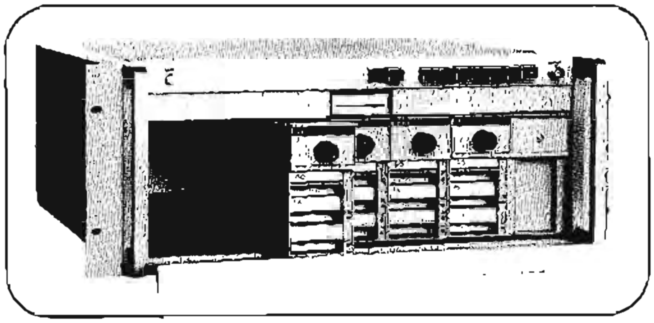


Figure 2. Reproduce Mainframe, showing plug-in Reproduce Amplifiers. (Record Mainframe is shown on page 180.)

A metal cover door opens downward (as shown in Figure 2) for access to adjustments, and easy removal of the amplifiers.

Direct electronics, with 1.5 MHz bandwidth, is provided for the 3950-Series (see listing below). FM electronics, also used with the 3955-Series Systems (pages 179-180), provides dc to 20 kHz FM recording. Wideband FM Electronics (dc to 400 kHz) is available on special order.

A radical new kind of Reproduce Amplifier, especially well suited to magnetic head characteristics is used with the 3950-Series Systems. Also, the HP preamplifier, which evolved from other areas of magnetic development in Hewlett-Packard laboratories, gives *an outstanding signal-to-noise performance.*

Different equalization is used for each tape speed. Each equalizer circuit is mounted on a convenient plug-in circuit card (shown on page 179). The push-bar indicates the tape speed numerically, as well as by a colored stripe to match the *color* of the speed pushbutton on the Tape Transport. The amplifiers accommodate equalizers for three tape speeds. The desired equalizer is selected by pushing on the equalizer push-bar. A mechanical "teeter-totter" automatically removes the previously operating equalizer from the circuit. The plug-in design of the equalizers allows reliable and rapid front-panel substitution of units for any speed, or of any entirely new set.

Prices for Record and Reproduce Electronics

Direct electronics (to 1.5 MHz)
- **Direct Record Amplifier:** HP Model 3540A, $170 ea. (no equalization plug-ins required).
- **Direct Reproduce Amplifier:** HP Model 3543A, $160 ea. Direct Reproduce Equalizers***, $40 ea.

FM electronics (dc to 20 kHz)**
- **FM Record Amplifier:** HP Model 3535A, Option 01, $210 ea. FM Record Tuning Units***, $15 ea.
- **FM Reproduce Amplifier:** HP Model 3538A, $170 ea.
  With FM flutter compensation, Option 01, $ (on request).
  With 0 to 5 volts p-p output $ (on request).
  FM reproduce filter units***, $40 ea.

System Prices

System prices depend upon the number and type of record and reproduce amplifiers, plus complementary equipment included. The following represent a full 7 or 14-channels of direct record and reproduce electronics; 3-speed equalization; no complementary equipment:

Model 3950A: 14-channel system; 15" max dia reels	$19,700
Model 3950B: 7-channel system; 15" max dia reels	$13,350

Condensed Specifications

(Common to both 3950A and 3950B)

Note: for complete specifications, request current technical data sheet. Speed-dependent specifications are shown (at 120 ips).

Tape Transport

Magnetic tape: (transports accept 10½", 14", or 15" NARTB reels).
4,600 feet of 1-mil tape (0.18 mil† oxide) on 10½" reel.
9,200 feet of 1-mil tape (0.18 mil† oxide) on 14" reel.
10,800 feet of 1-mil tape (0.18 mil† oxide) on 15" reel.

Tape speeds: 120, 60, 30, 15, 7½, and 3¾ inches per second.

Drive speed accuracy: ±0.25% of nominal capstan speed with 60 Hz ±0.03% line; speed is directly proportional to line frequency.

Maximum time base error (TBE) (at 120 ips): 3 μs p-p jitter, max, over a 0.1 ms time interval.

Maximum interchannel time displacement error (ITDE): ±0.5 μs at 120 ips (±1 μs at 60 ips) between two adjacent tracks on the same head stack.

Start time: within speed limits in approximately 6 seconds.

Stop time: 1 second, maximum. Power- failsafe braking.

Rewind time: approximately 4½ min for 9200 ft; 5 min for 10,800 ft.

Peak-to-peak flutter characteristics (at 120 ips):
0.2%, p-p, over 0 to 200 Hz bandwidth.
0.3%, p-p, over 0 to 1.5 kHz bandwidth.
0.6%, p-p, over 0 to 10 kHz bandwidth.

Footage counter: 5 digits, ±0.05% accuracy.

Direct Electronics

Record amplifier input (3540A):
- **Input impedance:** 100 ohms, shunted by 70 pF, unbalanced.
- **Input signal level:** 0.25 to 30 V rms, adjustable for IRIG-specified record level.

Reproduce amplifier output (3543A):
- **Output impedance:** 75 ohms, unbalanced.
- **Output signal level:** adjustable up to 1 V rms into 75 ohms with IRIG-specified record level on tape.

Total harmonic distortion (with 3540A and 3543A amplifiers): 1.2% THD, or less, when recording at IRIG-specified levels.

Bandwidth (at 120 ips):
±4 dB, 400 Hz to 1.5 MHz.
±3 dB, 10 kHz to 1.5 MHz.

Maximum rise time (at 120 ips): 0.4 μs with fundamental of squarewave at 150 kHz.

Signal-to-noise ratio (at 120 ips): 30 dB*, or better, over 400 Hz to 1.5 MHz bandwidth. (System noise is limited by the magnetic tape used.)

FM Electronics

The FM record and reproduce amplifiers used with the 3955 Series Magnetic Tape Systems (pages 179-180) are also plug-in compatible with the 3950 Series, offering a dc to 20 kHz bandwidth. Wideband (dc to 400 kHz) FM electronics is available on special order.

Pulse recording

The direct electronics includes an adjustable all-pass network for phase compensation of pulse response.

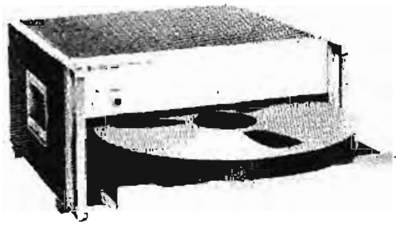
Power, weight and dimensions

System power: 115 V ±10%, 60 Hz (230 V, 50 Hz optional).
3950A: 600 watts (approx); 14-channel system.
3950B: 520 watts (approx); 7-channel system.

System weight: depends on number of channels, and complementary equipment included; the following are typical:
675 lb (302 kg), net, for 14-channel Model 3950A.
575 lbs (257 kg), net, for 7-channel Model 3950B.

System dimensions: (cabinet, including extended base with casters). 82⅝" high x 23⅞" wide x 35-11/16" deep (2099 x 607 x 907 mm).

* S/N ratio, as measured using bandpass filter (at output) with corner frequencies of specified bandwidth; rolloff is 18 dB/octave.
** Wideband FM Electronics, dc-400 kHz, available on special order.
*** Amplifiers accept three (3) tape speed plug-ins, simultaneously. Part number depends upon tape speed specified; plug-ins are available for all six tape speeds.
†* Normally used for wideband recording applications.



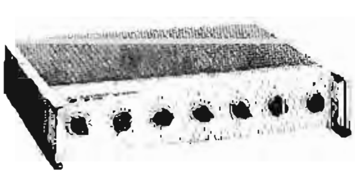
Automatic Tape Degausser Model 3603A

Voice Channel Model 3604A

AC Power Supply Model 3680A

Tape Servo Model 3681A

Remote Control Unit Model 3907-11A



Reproduce Track Selector Model 11539A

Automatic Tape Degausser, HP Model 3603A $900

Degausses magnetic tape to 90 dB below saturated recorded level. Automatic operation; complete erasure every time. Designed for continuous operation. Accepts 3″ to 15″ diameter reels; ¼″ to 1″-wide tape. Use in rack or on table top. Digital Reel Hub Adapter Model 11572 $17.00

Voice Channel, HP Model 3604A $550

Records voice commentaries along with data. Provides for edge-track or multiplex recording. Multiplex operation combines voice with data for recording on any direct-record channel. Includes loudspeaker and retractable microphone.

FM Frequency Source (not shown), **HP Model 3605A** $675

Provides precise carrier-frequency signals for alignment of Model 3538A FM Reproduce Amplifiers.

AC Power Supply, HP Model 3680A $1,100

Used to obtain crystal-controlled drive speed accuracy when system is operated from variable-frequency (47-63 Hz) power source. Eliminates minor tape speed changes resulting from abnormal frequency variations in the ac power line. Amplifier is driven from either an internal crystal or an external frequency source. Ideal for laboratory or field use, supplying up to 100 watts, 115 volts, at any frequency from 30 Hz to 1.5 kHz

Tape Servo, HP Model 3681A $1,380

Generates IRIG-specified speed-control signal for recording on tape with data. When the tape is replayed, the reproduced speed-control signal drives the 3680A AC Power Supply (above); it, in turn, controls the tape speed such that data signals are reproduced at exactly the same frequency as recorded.

Option 01 Amplitude Modulation 17 kHz $1,210

Option 02 Constant Wavelength and AM, 17 kHz $1,580

Remote Control Unit

Includes all functions for tape recorder operations from another location. With 25′ cable. Rack mounting optional.

HP Model 3907-11A (for 10½″ reel systems) $385

HP Model 3907-11A, Option 02 (for 15″ reel systems) $435

Reproduce Track Selector

Permits system economy by using less than a full complement of Reproduce Amplifiers. Each front-panel switch connects any of the 14 recorded data-tracks to the input of a single Reproduce Amplifier. With seven switches available, only one Reproduce Mainframe, and from 1 to 7 Reproduce Amplifiers may be used with a 14 channel system.

HP Model 11539A, Option 01 (for 10½″ reel systems) $340

HP Model 11539A, Option 02 (for 15″ reel systems) $340

Pack Sensor (not shown) **HP Model 11553A** $350

Senses the remaining tape-pack on both supply and take-up reels. Permits system to be stopped before tape runs off end of reel; used for recycling tape, or turning on a second tape recording system before the first one runs out of tape. For 15″ reel systems, only.

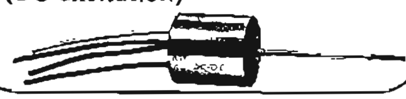
PHYSICAL PHENOMENA TRANSDUCERS

TRANSDUCERS

Sensors of linear motion, force, size and pressure

Models 7LV, 585, FTA, 1281, DCDT, 311-A

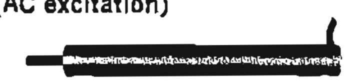
Linear Displacement (DC excitation)



The 7DCDT and the 24DCDT linear displacement transducers are extremely convenient to use for measuring, monitoring or controlling mechanical displacement. No external carrier system is required and phase shift and balancing adjustments are not necessary. Each DCDT has a built-in carrier oscillator and demodulator which produces a high-level dc output voltage proportional to the linear displacement of the core. Both series have extremely high resolution, zero hysteresis and non-linearity less than ±0.5% of the total stroke. The 24DCDT's have approximately three times the sensitivity of the 7DCDT's and an operating temperature to 120°C (7DCDT, 60°C). Excitation of 7DCDT models is 5 to 7 volts dc; for 24DCDT models, 20 to 28 volts dc.

Model	Model 7DCDT/24DCDT					
	-050	-100	-250	-500	-1000	-3000
Stroke (range) (in)	±0.05	±0.1	±0.25	±0.5	±1	±3
Output, volts f.s. 7 DCDT	1.5	2.8	1.5	3.3	4.8	5.0
Output, volts f.s. 24 DCDT	5.0	9.0	7.0	12.5	18.0	13.0
Output impedance 7 DCDT	2.2 k	3.0 k	5.0 k	5.3 k	5.5 k	5.0 k
Output impedance 24 DCDT	2.5 k	3.5 k	5.2 k	5.5 k	5.6 k	5. 6k
Dimensions, inches (mm) diameter 7 DCDT / 24 DCDT	0.75 (19.2)					
length 7 DCDT	0.81 (20.6)	1.06 (27.0)	3.00 (76.2)	3.50 (89.2)	4.50 (115)	10.50 (267)
length 24 DCDT	0.87 (22.2)	1.12 (28.5)	3.21 (81.8)	3.71 (94.2)	4.71 (120)	10.52 (286)
Weight (gm) Armature Assembly	1.6	2.1	3.4	3.8	4.3	8.1
Weight (gm) net	23	28	68	78	100	210
Weight (gm) shipping	84	84	168	168	196	308
Price: 7 DCDT	$100	$105	$120	$130	$140	$160
Price: 24 DCDT	$145	$150	$165	$175	$185	$210

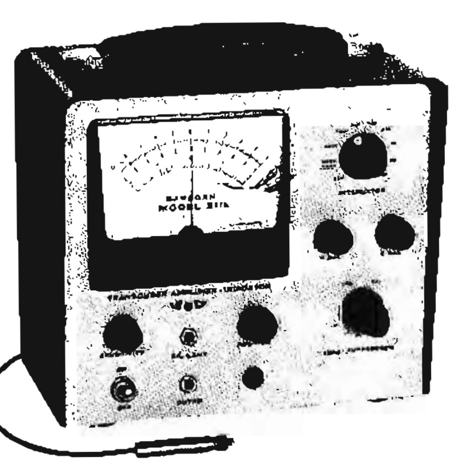
Linear Displacement (AC excitation)



Linearsyn® (585DT, 595DT) Transducers produce an electrical output proportional to any physical parameter convertible to a relative displacement between the transducer's core and coil assembly. A wide selection of transducers is available for Hewlett-Packard or equivalent carrier amplifiers (linear displacements to 0.000001" may be resolved). Non-linearity error will not exceed 1.0% of total stroke; temperature range, −46°C to +96°C. Linearsyns are shielded, immersible in non-corrosive fluids, resistant to shock and vibration, and void of mechanical hysteresis and friction. Standard carrier frequency is 2.4 kHz, with a range of 400 Hz to 10 kHz (585DT), or 20 kHz (595DT).

Model	585DT				595DT		
	-050	-250	-500	-1000	-005	-025	-100
Stroke range (inches)	0.05	0.25	0.5	1	0.005	0.025	0.1
Sensitivity* (V/in./vex)	4.8	1.7	1.1	0.79	2.2	3.4	2.7
Impedance* (ohms) primary:	163	151	332	157	93	303	330
secondary:	2140	176	370	247	154	365	365
Vex* (max)	21	17	25	30	5	11.5	13
Size—inches (mm) diameter:	0.75 (19)	0.75 (19)	0.75 (19)	0.75 (19)	0.375 (10)	0.375 (10)	0.375 (10)
length:	1.63 (41)	3.31 (84)	4.88 (124)	6.88 (155)	0.90 (23)	1.09 (28)	1.09 (28)
Weight (gm) armature assembly	5	7	12	18	0.10	0.25	0.29
Weight (gm) net	47	104	132	178	7.1	7.9	7.9
shipping	227	227	227	227	84	84	84
Price	$55	$60	$65	$70	$40	$45	$45

* At standard carrier frequency.



Transducer Amplifier-Indicator

The 311A Transducer Amplifier-Indicator is a convenient, portable unit for quickly measuring any physical variable to which a transducer requiring ac excitation may be attached. The 311A provides 2.4 kHz excitation to the transducer, and provides two indications of the variable under measurement: (1) a 4" panel meter, to follow slowly changing variables, and (2) an electrical output for an oscilloscope, recorder, or other indicator for frequencies up to 200 Hz. Internal calibration and five-position zero suppression are standard features.

Price: HP Model 311A, portable case, 115/230 V switch, 50 to 400 Hz, $475.

Option 02: Harmonic filter kit installed, no additional charge. Filter is required with 267 and 268 Series Transducers. ducers.

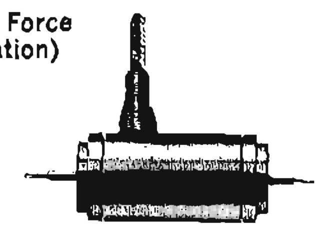
Linear Velocity (No excitation)

LVsyn® Linear Velocity Transducers are designed for sensitive measurements of relative velocity. The basic design eliminates the need for external excitation and makes the transducers easy to set up and use. DC voltages are generated by moving a high flux-density, permanent magnet in the bore of differentially wound coils. Voltage amplitude is proportional to core velocity. Resolution of an LVsyn output is nearly unlimited—sensitivity over the rated stroke range is constant within 5%—temperature range is from −46°C to 93°C. Linearity is better than 1%. LVsyn's can be operated single-ended or push-pull; while immersed in non-corrosive fluids; without end stops or displacement limits. Each transducer is supplied with a calibration record.

Model	3LVA5	3LV1	6LV1	6LV2	6LV3	6LV4	7LV9	7LV20
Sensitivity (mV/in/sec)	120 40*	90 35*	500 250*	500 250*	500 250*	500 250*	350 150*	20 7*
Resistance (k ohms)	2	2.5	13	19	25	32	17	3
Inductance (henrys)	0.085	0.065	1.6	2.9	3.2	4	2.8	0.035
Stroke inches (mm)	0.5 (13)	1 (25)	1 (25)	2 (51)	3 (76)	4 (101)	9 (229)	20 (508)
Size—inches (mm) diameter:	0.37 (10)	0.37 (10)	0.63 (16)	0.63 (16)	0.63 (16)	0.63 (16)	0.75 (19)	0.75 (19)
length:	3.16 (80)	4.22 (108)	5 (128)	7 (178)	9 (230)	11.25 (275)	22.75 (580)	30 (760)
Weight (gm) armature assembly	3.5	4.5	11	15	17	22	69	40
Weight net coil (grams) core shipping	20 3.5 84	25 4.5 84	110 11 224	150 15 252	200 17 308	250 22 336	610 69 756	800 50 900
Price	$50	$50	$50	$55	$60	$65	$100	$120

*Output with non-breakable magnet cores (-N models); to order add suffix -N to basic model number, e.g., 3LVA5-N, 3LV1-N, etc. Prices same as standard models.

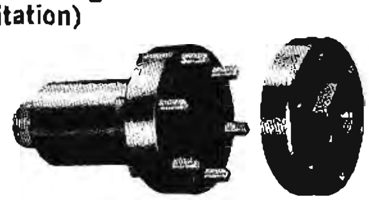
Low Level Force (AC excitation)



FTA low-level tension and compression sensing transducers (±1 to ±100 gm) are ideal for measuring buoyancy, discrete weight, small bearing torques, displacements and angles, as well as physiological motion. These small "Microforce" transducers provide an economical way to measure uni- or bi-directional forces with infinite resolution, linearity to 0.2% of full scale and hysteresis as low as 0.1% of applied force. FTA's have 400% overload capacity, low tracking force (no bearing friction) and excellent thermal stability from −18°C to 75°C.

Model	FTA-1-1	FTA-10-1	FTA-100-1
Force (range, gm)	±1	±10	±100
Displacement (full scale, in)	±0.01	±0.01	±0.01
Sensitivity (full scale, mV/vex)	8	8	8
Natural frequency (Hz)	65	130	390
Sensitivity (g) (% of f.s./g) radial:	0	0	0
axial:	21	5	0.6
Excitation	5 V at 2.4 kHz		
Zero shift (% of f.s/°C)	0.02		
Temperature range	−45° to +75°C		
Dimensions, inches (mm)	1.37 lg, 0.75 dia (35 x 19)		
Weight (gm)	net 153, shipping 760		
Price	$200		

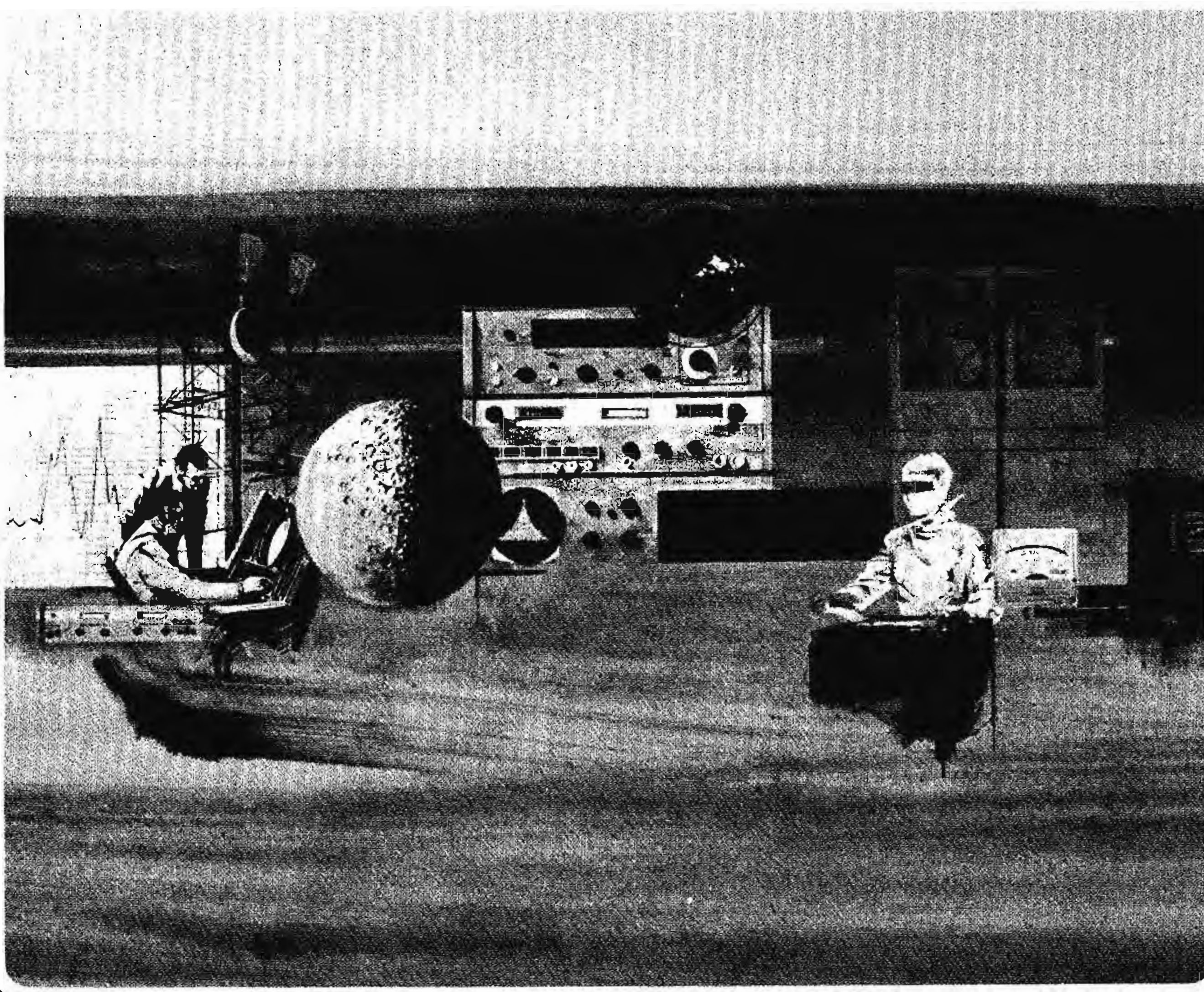
Medium and High Pressure (AC excitation)



1281 Series Pressure Transducers are heavy duty units designed for use in either gas or liquid systems at low or high viscosities (pressure ranges from 15 to 3000 psi). The units match the input requirements of Hewlett-Packard Carrier Preamplifiers such as the 8805A, 350-1100C, 301, 321, 311A; and will provide a fast response to rapidly changing pressures. The 1281 Series has many industrial and laboratory applications in fields such as hydraulics, material processing, and pressure monitoring, as well as in systems designed to control a manufacturing process. The units are designed for either tube or flush mounting.

Model	1281-01A	1281-02A	1281-03A	1281-04A	1281-05A
Range (psi)	15	100	300	1,000	3,000
Overload (psi)	50	300	900	3,000	4,500
G Sens. (%FS)	0.1	0.02	0.005	0.002	0.001
Natural Freq	Above 1 kHz				
Sensitivity	8 mV/V (nominal)				
Impedance	400 ohms input, 500 ohms output				
Non-linearity	0.5% (max)				
Hysteresis	0.1% (max)				
Volume displ	0.001 in^3 at full scale (max)				
Zero shift	0.01%/C° (max)				
Excitation	5 V at 2.4 kHz				
Temperature	−45°C to +120°C				
Price:	$250				

Precision Voltmeters and Sources



PRECISION ANALOG VOLTMETERS & SOURCES

As industrial and military electronics become more sophisticated, measurements require greater precision in normal working environments. To help alleviate today's measurement demands, Hewlett-Packard offers a broad line of precision instruments.

Traceable to NBS

The absolute accuracy of Hewlett-Packard's precision instruments and calibrators is traceable to the National Bureau of Standards, as shown in the flow chart, Figure 1. Special care has been taken to develop instruments with state-of-the-art stability so that specified accuracy and traceability can be maintained for long periods of time.

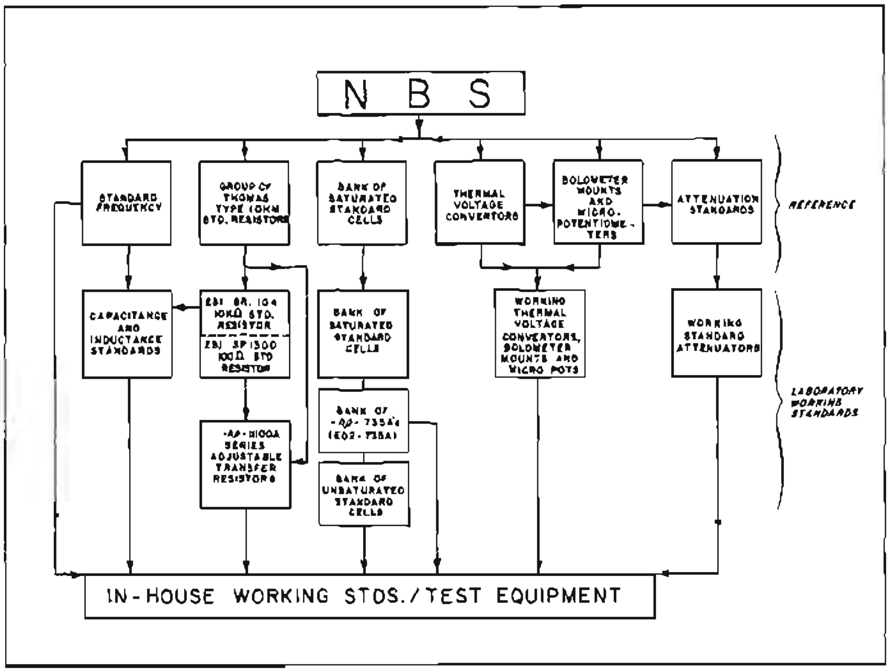


Figure 1. HP Instrument traceability to NBS.

0.02% ac signal generator

Available for the first time, ac voltages can be calibrated over a continuous wide band of frequencies with the accuracy of a dc calibration system.

The HP Model 745A AC Calibrator with a continuous frequency of 10 Hz to 110 kHz has a voltage accuracy of ±0.02% from 20 Hz to 20 kHz. Long-term stability is ±0.01% over a 6-month calibration period. Six voltage ranges from 1 mV to 100 V full scale (1 additional range reserved for future 1000 V amplifier) are available with a 6-digit readout and 10% overrange capability. The error of the instrument under test can be read directly in percent of reading without time-consuming calculations.

The 745A is programmable for both frequency and voltage ranges. Provision for local or remote sensing is obtained through a front-panel switch with separate sense-output terminals for remote sensing.

The accuracy of this ac calibrator is dependent on an ultra stable Zener diode in a temperature-controlled oven. This Zener diode is a reference for two voltages; +9.9 V and −9.9 V. These voltages are used to generate a square wave with a special circuit (patent pending) that maintains the basic accuracy of the two dc voltages in the square wave (refer to the block diagram, Figure 2). The accuracy of the rms value of the square wave thus generated is approximately 0.001%. A magnetic divider is used to obtain a 1.1 V rms square wave which is applied to the input of a 6-place magnetic divider to provide 6 digits of settability from 0.1 V to 1.1 V rms. The output of the calibrator is compared to this reference either directly or through an attenuator by the sampling amplifier. The 100 V range attenuator is a precision resistive divider manufactured by Hewlett-Packard. It has an excellent T.C. and long-term stability. All other range attenuators are inductive dividers. The output of the 1 V range is compared directly to the reference square wave. Figure 3 shows the long-term stability of a 745A reference supply. The rms value of the square wave is compared to the rms value of a portion of the sinewave output through a single thermocouple. The error signal is demodulated, amplified, and fed back to the oscillator to correct the voltage at the output.

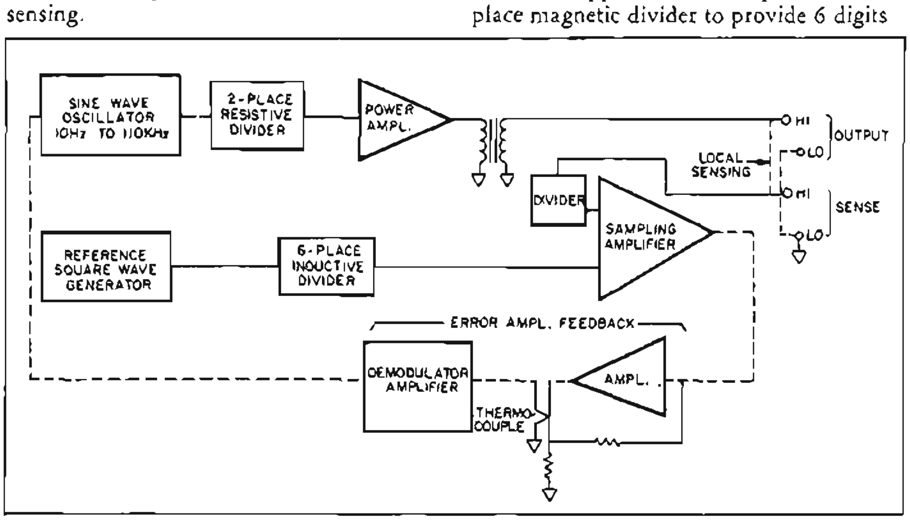


Figure 2. Simplified block diagram of 745A.

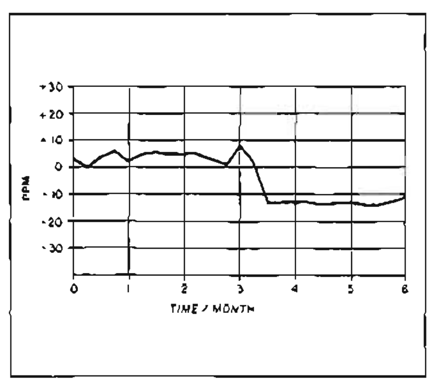


Figure 3. 6 month stability of a 745A reference supply.

The sinewave oscillator of the 745A Calibrator uses a beat-frequency technique combined with frequency dividers. The output from a 5 MHz crystal oscillator is divided by a factor of 9, resulting in an output of 555 kHz. This signal is heterodyned with a variable-frequency oscillator of 545 kHz to 445 kHz. The difference, or beat frequency, is the output frequency on the upper range (10 kHz to 110 kHz). Each successive lower range is a result of heterodyning different frequencies and using a 10:1 divider. This variable-frequency oscillator is locally tuned on the front panel by a variable air dielectric capacitor or remotely controlled by a varying dc voltage or resistance.

The output of the sinewave oscillator is amplified and transformer-coupled to the output terminals. The purity of the sine wave output at 25 kHz is shown in Figure 4 as the 745A output is swept by the 3590A Wave Analyzer. Two sense terminals make it possible to locally sense at the output terminals, or to sense remotely, merely by pressing a front-panel button switch and making the necessary remote connections.

The 745A is easily calibrated. The decade dividers and all but one of the range dividers are magnetic and need no adjustment.

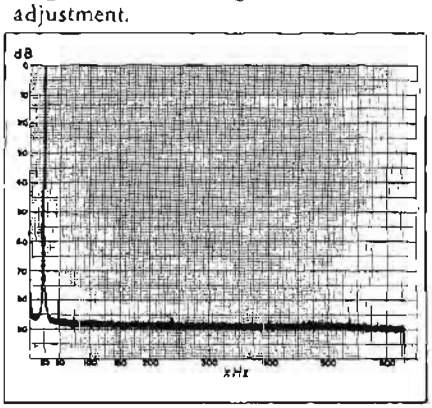


Figure 4. Recording of the 745A output, set at 25 kHz, as it is swept by the HP 3590A Wave Analyzer. The signal at zero frequency is the zero response of the 3590A.

DC precision sources

The long-term accuracy and stability of the Hewlett-Packard dc precision sources are dependent on selected Zener diodes. Three distinct steps are necessary to provide a reliable reference diode: 1) process control in its original fabrication, 2) design of a compatible circuit, and 3) a 100% thorough test of the completed circuit.

To achieve the stability and accuracy necessary for the HP precision dc sources, a selected Zener diode and its associated circuitry is housed in a temperature-controlled oven. The inner-oven temperature is held nominally at 80°C ±0.01°C during normal room variations.

The HP 735A Transfer Standard uses this reference supply to obtain accurate stable voltages of 1.000 volts, 1.018 to 1.020 volts, and 0 to 1000 μV. It is quickly calibrated by a front-panel adjustment using a standard cell (or another 735A) and a null meter.

This precision voltage source transfers standard-cell voltages to 1.000 volts with an accuracy of 10 ppm and a stability of 10 ppm per month.

Transfer accuracy between saturated standard cells or unsaturated standard cells is 2 ppm.

The E02-735A is a bank of four 735A's combined with a switch and terminals that make it possible to compare an external voltage with any one of the four 735A's or to compare an external voltage with the arithmetical mean of the four 735A outputs.

Included with each E02-735A is a graph on the 1.018 position showing that 95% of the time, the mean of the four 735A's vary from a straight line less than ±1 μV, over a period of 120 days.

The HP 740B and 741B DC Standards use the oven-reference supply for a reference voltage to generate the 0 to 1000-volt accurate, stable output. This reference voltage is applied to a precision resistive divider, which is the input to an amplifier chain, as shown in Figure 5.

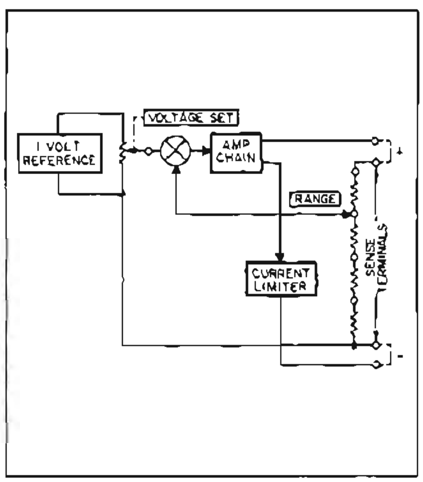


Figure 5. HP simplified dc standards diagram.

The summing point compares the input of the amplifier to an attenuated sample of the output taken from the range voltage divider. The current limit control is nominally adjusted for the protection of the output load.

Precision dc differential voltmeters

Measurements made by the differential voltmeter technique (sometimes called a potentiometric or manual voltmeter) are recognized as one of the most accurate means of relating an unknown voltage to a known reference. These measurements are made by adjusting a precision resistive divider to divide down an accurately known reference voltage. The divider is adjusted to the point where the divider output equals the unknown voltage, as shown by the null voltmeter (Figure 6).

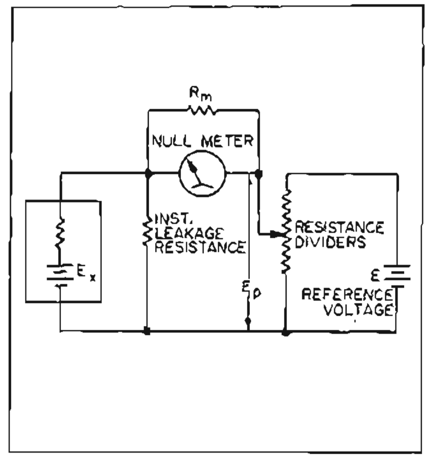


Figure 6. Classic differential voltage measurement.

The unknown voltage is determined to an accuracy limited only by the accuracies of the reference voltage and the resistive divider: the meter serves only to indicate any residual differential between the known and unknown voltage.

The differential method is highly accurate (Hewlett-Packard currently offers ±0.002% accuracy).

A high-voltage standard is required to measure high voltage. This need may be overcome by inserting a voltage divider between the source and the null-meter (Figure 7). This, however, results

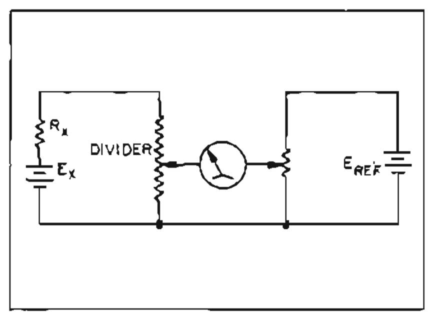


Figure 7. Potentiometric method of measuring unknown voltages.

in relatively low-input resistance for voltages higher than the reference standard. This low-input resistance is undesirable because accurate measurements may not be obtained if substantial current is drawn from the source being measured. Most differential voltmeters used today offer input resistance approaching infinity only at a null condition, and then only if an input voltage divider is not used.

To overcome these limitations, Hewlett-Packard has developed an input isolation stage which develops an input resistance exceeding 10^{10} ohms and measures voltages up to 1000 volts dc. This high resistance is maintained independent of null condition.

As shown in the block diagram of Figure 8, the HP 740B DC Standard/

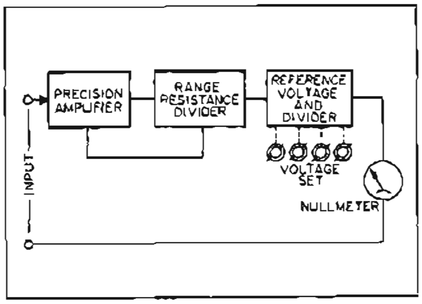


Figure 8. Simplified diagram of dc standard, differential voltmeter in differential voltmeter mode.

Differential Voltmeter has the principal parts of the conventional differential voltmeter.

In a marked departure from conventional differential voltmeter design, the circuitry also includes a high-gain feedback amplifier as an impedance converter between the measured voltage source and the measurement circuits. The amplifier insures that the high-input impedance is maintained regardless of whether the instrument is adjusted for a null reading.

A further advantage provided by the amplifier is that the resistive voltage divider which enables voltages as high as 1000 volts to be compared to a precision 1-volt reference may be placed at the output of the amplifier rather than being in series with the measured voltage source. The isolation provided by the amplifier between the input and the range "stick" thus enables the instrument to have high-input impedance on all ranges.

The range dividers, amplifier, and voltage reference supply are used in the 740B and 741B for both the precision dc source and the differential voltmeter.

Precision ac differential voltmeter

Highest accuracy in ac voltage measurements is accomplished by using an ac differential voltmeter.

The HP 741B uses a precision rectifying circuit to convert the unknown ac directly to dc (equivalent to the average value of the ac), and the resulting dc is read to 5-place resolution by a potentiometric voltmeter technique. The measurement is straightforward in that the ac remains connected to the converter at all times and can be monitored continuously. Besides being a precision ac/dc differential voltmeter, the instrument is also an ultra stable, high-resolution dc standard source. Refer to page 196 for additional information.

The accuracy of ac measurements is enhanced by the high-impedance probe attached to the instrument. The input impedance is 1 MΩ shunted by <5 pF. The low-input capacitance is important in measurements where capacitance loading is critical. Using the 741B, it is possible to measure high ac voltages without drawing large reactive currents.

A block diagram of the HP 741B in the ac differential voltmeter mode of operation is shown in Figure 9.

With compensation for both the frequency and the amplitude of the input signal, it has been possible to accomplish accurate ac-to-dc conversion that is linear over an amplitude range from 1/10 full scale to full scale throughout a broad frequency range. With proper calibration procedures, it is possible to reduce errors to less than ±0.02% end scale between 100 Hz and 100 kHz under normal laboratory conditions.

Differential voltmeter/ratiometer

Recently introduced, the HP 3420A/B carries a 0.002% accuracy specification with stability of 1 ppm per hour (of range) and 5 ppm per day. Nullmeter resolution is 0.2 ppm of range on all ranges. These specifications set new standards in the state of the art for differential voltmeters.

To make 0.002% accuracy meaningful, the HP Models 3420A/B have six ten-digit decade dividers, plus the usual last-digit meter, and ±10 μV full-scale sensitivity. A further feature is rechargeable battery operation, available in the 3420B version. A self-contained power source is important when it is necessary to measure dc voltages with common-mode noise. Because the instrument can be completely isolated from the power line, these common-mode voltages do not influence the reading.

A block diagram of the HP 3420A/B is shown in Figure 10. DC voltage measurements in the 1 and 10-volt ranges are performed by the differential voltmeter technique, comparing the input voltage to a known internal voltage. This comparison is performed by a nullmeter. On the 100 and 1000-volt ranges, the input voltage is scaled to the 1-volt level by a precision 10 MΩ resistance divider.

The outstanding accuracy of the instrument is controlled by the internal voltage reference supply and the precision resistor networks. To enable the instrument to operate on battery power, an oven was not used.

All six decades are binary-coded dividers. The first decade has a 10% over-range capability to aid in measuring standard cells and other voltages that occur slightly above full scale. This feature enables the user to determine measurements with a resolution of <1 ppm.

The combination of high stability in the voltage reference supply, high resolution and zero stability in the null detector, and six-decade divider gives a useful sensitivity of 0.2 ppm of range on all ranges.

Besides being a precision differential voltmeter, the 3420A/B is also a precision ratiometer.

When making dc voltage measurements, there are cases where the absolute value of the voltage is of little interest. Instead, the point of interest is its value in relationship to some other voltage level or the ratio of it to some other level, i.e.,

$$N = \frac{Vb}{Va} = \text{ratio}$$

This ratio appears often in engineering work. Examples are resistor dividers, po-

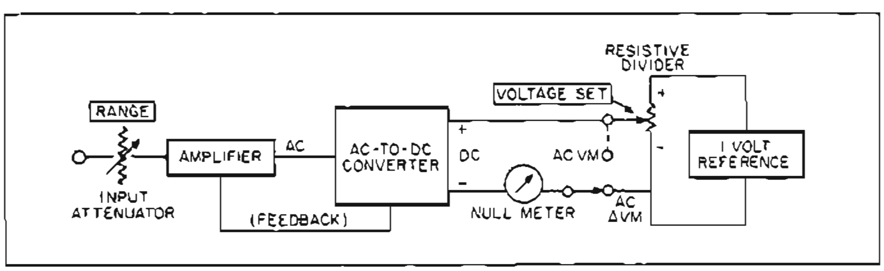


Figure 9. Simplified block diagram of an ac differential voltmeter.

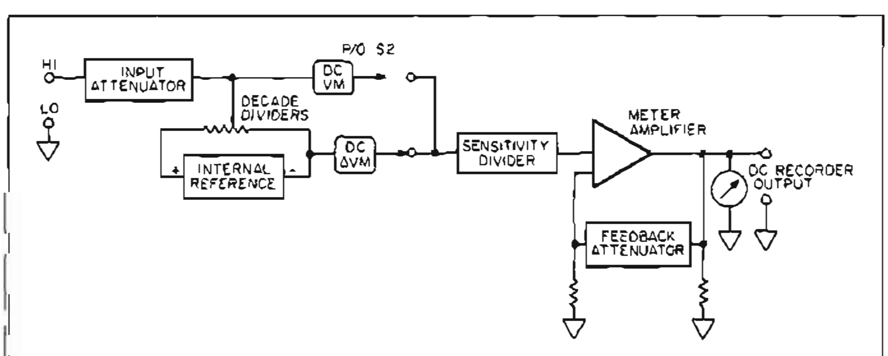


Figure 10. HP 3420A/B DC Differential Voltmeter mode.

tentiometer linearity, and power at various voltage levels.

Hewlett-Packard's precision differential voltmeters are multifunction instruments. Table 1 summarizes these instruments, giving the functions of each with the major specifications. By selecting the accuracy and stability necessary in anticipated tests and the functions most useful for specific needs, a precision instrument can be selected.

Thermal converters

Hewlett-Packard thermal converters are true rms detectors, yielding a dc output proportional to the temperature rise resulting from the ac input power. The Models 11049A, 11050A, and 11051A offer an exceptionally flat response and nearly constant impedance (50Ω) over a frequency range of 5 Hz to 10 MHz. Option 01 has a frequency range from 5 Hz to 60 MHz, and Option 02 has a frequency range from 5 Hz to 100 MHz. Each thermal converter is shipped with a calibration report with statement of uncertainty traceable to NBS. Each option has an additional individual correctional data sheet attached to the calibration report.

AC/DC meter calibration systems

The HP E02-738BR Voltmeter Calibration System includes the Model 652A Test Oscillator and the Model 738BR Voltmeter Calibrator, mounted in a convenient cabinet. This system was designed specifically for calibrating high-impedance voltmeters and oscilloscopes.

The 738BR provides a 400 Hz rms or peak-to-peak ac voltage and a dc voltage output from 300 μV to 300 volts. The accuracy is better than 0.1% dc and 0.2% ac. The 652A provides a frequency response, by using the expand position of the meter, from 10 Hz to 10 MHz with a flatness of ±0.25%.

The HP Model 6920B Meter Calibrator is an easily portable, simple device used to calibrate ac and dc meters from 0.01 volt to 1 kV, and from 0.01 mA to 5 A. The output setting of voltage or current is adjusted by means of a three-digit, ten-turn readout on any volt, milliampere, or ampere range. The dc accuracy is 0.2%, and ac accuracy is 0.4% of output.

Designed primarily for calibrating production test equipment where moving vane meters are employed, the Model 6921A offers 0.25% accuracy at moderate cost. Moreover, the basic amplifier design of the ac meter calibrator allows it to operate into fully reactive loads. It offers four voltage ranges covering from 1.4 volts to 280 volts, and five current ranges covering from 1.4 milliamperes to 5 amperes. An internal oscillator provides frequencies of 60 Hz, 400 Hz and 1 kHz An extra bandwidth is provided to accept external oscillators from 50 Hz to 2 kHz.

Table 1. HP Multifunction Precision Analog Instruments

Features	Model 740B (pg 192)	Model 741B (pg 196)	Model 3420A/B (pg 195)
DC STANDARD	Yes	Yes	No
Ranges	4 (1 V to 1000 V)	4 (1 V to 1000 V)	
Accuracy	±(0.002% setting +0.0004% range	±0.01% setting or ±0.001% range +10 μV	
Remote sensing Current limit	Yes 5 to 50 mA	Yes 4 to 20 mA	
DC Δ VOLTMETER	Yes	Yes	Yes
Ranges	7 (1 mV to 1000 V)	7 (1 mV to 1000 V)	4 (1 V to 1000 V)
Accuracy	±(0.005% reading +0.0004% range)	±0.02% reading or ±0.004% range	±(0.002% reading +0.0002% range)
AC Δ VOLTMETER	No	Yes	No
Voltage range		7 (1 mV to 1000 V)	
Frequency range		20 Hz to 100 kHz	
Accuracy		±(0.02% reading +0.01% range) 400 Hz to 5 kHz for 50 mV 100 V to ±(0.4% reading +0.01% range)	
HIGH IMPEDANCE VM	Yes	Yes	Yes
Ranges	10 (1 μV to 1000 V dc)	7 (1 mV to 1000 V) ac and dc	9 (10 μV to 1000 V) dc
Accuracy	±(2% range +0.1 μV)	±2% ac and dc, +200 μV for 1 mV - 50 mV (20 Hz - 50 kHz)	±3%
DC RATIOMETER	No	No	Yes
Ranges			4 (X1 to X.001)
Accuracy			±(0.002% reading +0.0004% range)
GENERAL			
Readout	5-digit display tubes and meter	4-digit readout and meter	6-digit readout and meter
Stability	±(15 ppm setting +2 ppm range/mo.)	dc 10 ppm setting +1 ppm range/day ac < 50 ppm/day (20 Hz to 20 kHz)	±5 ppm/day
Floating	Yes	Yes	Yes
Guarding	Yes	No	No
Recorder output	1 V dc max at 1 mA end scale	1 V dc max at 1 mA end scale	1 V dc at 1 mA end scale
Amplifier output	Yes	Yes	No
Voltage gain	60 dB max (1 V to 1000 V dc)	Unity (0 to 1 kV dc)	

Note: Refer to pages 229-251 to obtain information on Hewlett-Packard Precision Digital Instruments. Refer to page 191 for the AC Precision Calibrator.

AC CALIBRATOR
Programmable signal generator
Model 745A

745A

Description

AC voltages are now available over a continuous wide band of frequencies with Standards Lab accuracy. Calibration of ac voltmeters, amplifiers and other ac devices can be performed with high confidence using the 745A AC Calibrator. Extreme precision test equipment can be measured over a wide bandwidth. You can select the output amplitude with 6-digit resolution in a range between 0.100000 mV rms and 109.9999 V rms in 6 decade ranges (10% overranging). A companion 1 kV amplifier will be introduced in the near future.

You can be assured of the accuracy of the 745A in the engineering lab, on production-line test stations, and in other unprotected environments—specified accuracy is maintained in an ambient temperature range of 20°-30°C with line voltage changes of ±10%.

For automated testing, frequency range and voltage range can be selected by electrical closures to ground (frequency coverage is four overlapping ranges, 10 Hz to 110 kHz). Frequency within any chosen range also can be selected by an externally-supplied, adjustable voltage (+1 V to +10 V).

Shorting the output causes no harm—it is current limited. If overloaded, the 745A turns on the front panel overload lamp but restores normal operation automatically when the overload is removed.

To measure errors in the device under test, the switch for the specific error range is depressed. The output amplitude can be adjusted within a small range with a separate control, and the percentage change is on the wide, slide-rule-type scale. Bring the output of the tested device back to a reference point, and the Calibrator reads the percentage amplitude error.

Specifications*

Output voltage ranges: 6 ranges† with 10% overrange as follows:

Range	Settability
1 mV	.100000 mV to 1.099999 mV in 1 nV steps
10 mV	1.00000 mV to 10.99999 mV in 10 nV steps
100 mV	10.0000 mV to 109.9999 mV in 100 nV steps
1 V	.100000 V to 1.099999 V in 1 μV steps
10 V	1.00000 V to 10.99999 V in 10 μV steps
100 V	10.0000 V to 109.9999 V in 100 μV steps

Output frequency ranges: continuously adjustable from 10 Hz to 110 kHz in 4 decade ranges with 10% overlap.

Error measurement: 2 ranges with zero center dial, ±0.3% or ±3%.

Accuracy: accuracy met after a 1-hr warmup period at 25°C ±5°C with <95% R.H. for a 90-day period.

Voltage: specifications are relative to a 5 mA thermocouple calibrated by the National Bureau of Standards.

Range	Accuracy
50 Hz to 20 kHz	±(0.02% of setting +0.002% of range +10 μV)
20 Hz to 50 Hz 20 kHz to 110 kHz	±(0.05% of setting +0.005% of range +50 μV)
10 Hz to 20 Hz	±(0.2% of setting +0.005% of range +50 μV)

Frequency: ±(2% of setting +0.2% of end scale).

Error measurement: ±(0.5% of setting +0.5% of range).

Voltage stability: (stability met after 1 hour warmup period at constant temperature with less than 95% relative humidity). Long term: ±0.01% of setting for 6 months. Short term: ±0.002% of setting for 24 hours.

Total distortion and noise: ±(0.05% of setting +10 μV over 100 kHz bandwidth) on all ranges.

Load regulations: (no load to full load) ±0.01% of voltage setting on 1, 10, 100 mV range, output resistance <1Ω, 3 kΩ minimum load resistance. ±0.002% of voltage setting on 1, 10, 100 V range for output current of 50 mA at greater than 20% of voltage range, decreasing to 25 mA at 10% of voltage range. Error is included in accuracy specification for voltage output >100 mV. Overload protected.

Maximum capacitive load: 1000 pF on all ranges.

Line regulation: less than ±0.001% of setting change in output voltage for a ±10% change in line voltage.

Remote programming: all voltage, frequency, and %-error measurement ranges programmable.

Power requirements: 115/230 V ac ±10%, 50 Hz to 400 Hz, 70 W nominal, 100 W maximum.

Dimensions: 16¾" wide, 8½" high, 18¼" deep (425 x 216 x 464 mm) rack mount kit furnished with instrument.

Weight: net 65 lbs (29,3 kg); shipping 80 lbs (36,3 kg).

Accessories furnished: rack mount kit; 22 pin printed circuit board extender; 15 pin printed circuit board extender.

Accessories available: rear output mating plug, (HP Part No. 1251-0469, Deutsch Part No. 6641).

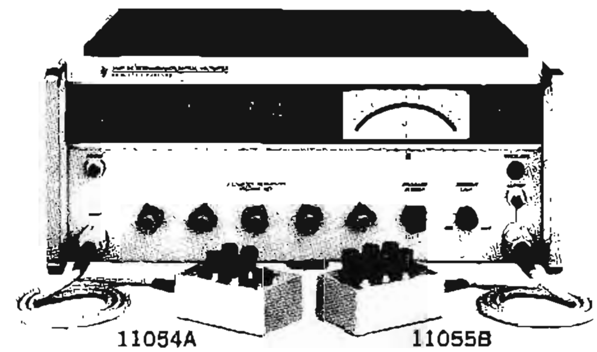
Price: HP Model 745A, $4500.

*Refer to data sheet for complete specifications.
†Companion amplifier providing a 1000 V range to be announced.

DC STANDARD/ΔVOLTMETER

So much instrument at so great a value

Model 740B



DC standard

The 740B is an ultra-stable, high-resolution dc calibration source which delivers output voltage from zero to 1000 V with specified accuracy of ±(0.002% of setting +0.0004% of range). Designed for calibrating digital voltmeters, differential voltmeters, potentiometers, voltage dividers and for general standards lab application, the 740B has 6-digit resolution with discrete steps of 1 ppm at full scale.

The 740B will deliver current up to 50 mA and may be set at any desired limit between 5 mA and 50 mA by a continuously adjustable front-panel control. A front-panel indicator displays overload conditions as the load current exceeds the current limit setting. Low output impedance is maintained by remote sensing terminals which control the output voltage at the load. The entire circuit is floating and guarded.

The stability of the 740B is dependent primarily on the stability of the reference source and the stability of the precision wire-wound resistors which comprise the decade and range dividers. The heart of the reference voltage supply is a temperature-compensated Zener diode which, with other critical components, is housed in a proportionally controlled oven.

Differential voltmeter

As a differential voltmeter, the 740B measures voltage from 0 to 1000 V dc with an input resistance of $>10^{10}\Omega$ independent of null condition. Meter sensitivity pushbuttons allow input voltages to be measured to 6 digits for a maximum resolution of 1 ppm of range, with a maximum usable sensitivity of 1 μV full scale. Specified accuracy is ±(0.005% of reading +0.0004% of range +1 μV).

As a differential voltmeter, the 740B is unique in maintaining an input impedance of $>10^{10}\Omega$ (on all ranges above 10 mV) regardless of whether or not the voltage dials are nulled. This feature simplifies operation by eliminating any calculations of loading error by the voltmeter. In addition, the high-input impedance simplifies the measurement or comparison of standard cells or other devices that are sensitive to small current drains.

Voltage setting is indicated by 5 digital display tubes plus an individually calibrated taut-band meter.

High-impedance voltmeter

The HP 740B is also a ±2% floating and guarded voltmeter with ranges from 1 μV to 1 kV. Input impedance is $>10^{10}\Omega$ on most ranges.

Precision DC amplifier

The instrument can be used as a dc power amplifier, in differential voltmeter or voltmeter modes, by connecting the source to the input terminals and taking the output from the terminals that normally supply the standard calibrated voltages. It is thus possible to augment the capabilities of a standard cell, for example, by using the amplifier as an impedance converter to provide power amplification. The available gain depends on the selected voltage range. The 740B functions as a unity gain amplifier on the 1 V and higher ranges, but on lower ranges the gain increases in 20 dB steps to a maximum of 60 dB on the 1 mV range.

By taking output from a rear-panel recorder connector, the 740B supplies up to 120 dB of voltage gain (depending upon range).

Specifications

DC Standard

Ranges

Output voltage: 0 to 1000 V* in 4 decade ranges as follows; 0 to 1 V in 1 μV steps; 0 to 10 V in 10 μV steps; 0 to 100 V in 100 μV steps; 0 to 1000 V in 1 mV steps. Digital display tubes indicate first 5 digits; meter displays 6th digit.

Performance

Accuracy (<70% RH, constant line, load and temperature ±1°C. Calibrated at factory at 115 V and 23°C.)
30 day: ±(0.002% of setting + 0.0004% of range).
90 day: ±(0.005% of setting + 0.0004% of range).

Stability (<70% RH, constant line, load and temperature ±1°C):

Period	Zero stability ppm of range	Voltage stability (excludes zero stability) setting + range
1 hr	±1 ppm	±(0 ppm +1 ppm)
24 hr	±2 ppm	±(5 ppm +1 ppm)

Temperature coefficient

10°C to 40°C: $<\pm 0.0002\%$ of setting/°C or $\pm 0.0001\%$ of range/°C, whichever is greater.

Line regulation: $<\pm(0.0005\%$ of setting $+0.0001\%$ of range) for 10% line voltage change.

Load regulation (no load to full load): $<(0.0005\%$ of setting $+10\ \mu V)$.

Output characteristics

Terminals: plus and minus output, plus and minus sense, circuit guard, and chassis ground. Minus output and circuit guard can be floated up to ±500 V with respect to chassis ground.

Output current: maximum output current 50 mA at 1 V output, decreasing linearly to 20 mA at 1000 V output. Current limiter continuously adjustable from 10% to 100% of maximum output current.

Output resistance: $<(0.0002 + 0.0001E_{out})\Omega$.

Noise (rms value):

Range	0.01 Hz - 1 Hz	1 Hz - 1 MHz
1 V	<1 μV	<100 μV
10 V	<10 μV	<100 μV
100 V	<100 μV	<1 mV
1000 V	<1 mV	<10 mV

DC differential voltmeter

Ranges

Voltage: 1 mV to 1000 V* in 7 decade ranges.

Resolution: 6-digit readout yields resolution of 0.0001% of range (6th digit indicated on meter).

Performance

Accuracy (<70% RH, constant line and temperature ±1°C. Calibrated at factory at 115 V and 23°C.)

30 day: $\pm(0.005\%$ of reading $+0.0004\%$ of range $\pm 1\ \mu V)$.

90 day: $\pm(0.008\%$ of reading $+0.0004\%$ of range $+1\ \mu V)$.

Stability (<70% RH, constant line and temperature ±1°C):

Period	Zero stability	Reading stability (excludes zero stability) reading + range
1 hr	±(1 ppm of range +1 μV)	±(0 ppm +1 ppm)
24 hr	±(1 ppm of range +2 μV)	±(5 ppm +1 ppm)

Temperature coefficient

10°C to 40°C: $<\pm(0.0002\%$ of reading $+1\ \mu V)$/°C.

Line regulation: $<\pm(0.001\%$ of reading $+2\ \mu V)$ for 10% line voltage change.

Input characteristics

Terminals: plus and minus input, circuit guard and chassis ground. Minus input and circuit guard can be floated up to ±500 V with respect to chassis ground.

Input resistance (independent of null)

100 mV to 1000 V ranges: $>10^{10}\ \Omega$.

10 mV range: $>10^{9}\ \Omega$.

1 mV range: $>10^{8}\ \Omega$.

Effective common-mode rejection (ECMR): ECMR is the ratio of the common-mode signal to the resultant error in readout with 1 kΩ unbalance resistor in either lead.

At 60 Hz and above: >120 dB.

Normal-mode rejection (NMR): NMR is the ratio of the ac normal-mode signal to the resultant error in readout.

At 60 Hz and above: >100 dB.

Maximum ac normal-mode signal: 25 V rms.

Overload protection: 1000 V* dc may be applied on any range or sensitivity without damaging instrument.

DC voltmeter

Voltage ranges: 1 μV to 1000 V* in 10 decade ranges.

Accuracy: $\pm(2\%$ of range $+0.1\ \mu V)$.

Input resistance: 100 mV to 1000 V range: $>10^{10}\ \Omega$; 10 mV range: $>10^{9}\ \Omega$; 1 μV to 1 mV range: $>10^{8}\ \Omega$.

Zero drift: <2 μV per day; zero control limits: >±10 μV.

Normal-mode rejection: same as DC Differential Voltmeter.

DC amplifier

Voltage gain: 1 mV range, 60 dB; 10 mV range, 40 dB; 100 mV range, 20 dB; 1 V to 1000 V ranges, 0 dB.

Bandwidth: dc to 0.2 Hz.

Gain accuracy: $\pm(0.01\%$ of input $+0.0005\%$ of range $+2\ \mu V)$ referred to input.

Linearity: ±0.002% on any range.

Stability, temperature coefficient, line regulation, input resistance, ECMR, NMR, and overload protection: same as DC Differential Voltmeter.

Load regulation, output current, and output resistance: same as DC Standard.

Noise (rms value, referred to input):

Range	0.01 Hz - 1 Hz	1 Hz - 1 MHz
1 mV	<0.2 μV	<100 μV
10 mV	<0.4 μV	<100 μV
100 mV	<1 μV	<100 μV
1 V	<1 μV	<100 μV
10 V	<10 μV	<100 μV
100 V	<100 μV	<1 mV
1000 V	<1 mV	<10 mV

General

Recorder output: provides voltage proportional to meter deflection in all modes of operation. Adjustable output supplies up to ±1 V dc across 1 kΩ load; voltage polarity same as meter deflection.

Operating temperature: 10°C to 40°C unless specified otherwise.

Storage temperature: −40°C to +65°C.

RFI: meets MIL-I-6181D#.

Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <125 W.

Dimensions: full module, 16¾" wide, 6⅞" high, 18¼" deep. (425 x 175 x 464 mm).

Weight: net 47.3 lb (21.3 kg); shipping 60 lb (27 kg).

Accessories furnished

11054A input cable assembly; 4 banana jacks mounted on terminal box with 3-ft cable and mating connector. Terminals include positive and negative input, circuit guard, and chassis ground. Positive and negative terminals are solid copper, gold flashed. A switch allows reduction of input resistance to 2 MΩ.

11055B output cable assembly; 6 banana jacks mounted on terminal box with 3-ft cable and mating connector. Terminals include positive and negative output, positive and negative sense, circuit guard, and chassis ground. Output and sense terminals are solid copper, gold flashed.

Price: HP 740B, $2450.

*Maximum of −500 V dc with respect to line ground can be applied to or obtained from the HP 740B.

#Positive or negative output terminals of the output box (HP 11055B) connected to chassis, and guard and chassis terminals of the input box (HP 11054A) connected together.

DC TRANSFER STANDARD
Portable instrument transfers std. voltages
Model 735A

The HP 735A is a general-purpose laboratory transfer standard. It may be used as a 1 V standard output with standard cell accuracy, a standard cell comparator with seven digits, or as a 0 to 1000 μV standard source for dc and potentiometric measurements.

Specifications

Standard outputs: 1.00000 V; 1.018 + △*; 1.019 + △*; 0 to 1000 μV △*.

Transfer accuracy: (after 30 min. warmup) 2 ppm between saturated standard cells or unsaturated standard cells; 10 ppm standard cell to 1 V; 10 ppm saturated standard cell to unsaturated standard cells.

Stability: (after 30 min. warmup) better than 10 ppm/month.

Line regulation: <1 μV for 10% line change.

Output impedance: 1 kΩ ±1%.

Short-circuit current: <1.5 mA.

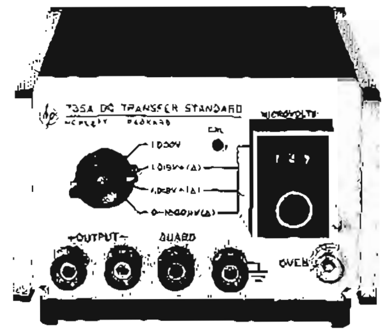
Temperature coefficient: <1 ppm/°C, 0° to +50°C.

Variable output

- **Range:** 0 to 1000 μV.
- **Accuracy:** 0.1% to ±1.5 μV.
- **Resolution:** 1 μV.
- **Output impedance:** 146Ω ±1%.

Output noise: dc to 1 Hz <1 μV p-p. 1 Hz to 1 MHz: <100 μV rms.

Output: floating and guarded.



735A

Power: 115 or 230 V ±10%, 50 to 400 Hz, 12 W.

Output terminals: four 5-way binding posts. Positive, negative, circuit-guard shield, and chassis ground, positive and negative terminals are solid copper with gold flash. A maximum of 500 V dc may be connected between chassis ground and guard or circuit ground.

Dimensions: standard 1/3 module: 5⅛" wide, 3" high (without removable feet), 11" deep (130 x 76 x 279 mm).

Weight: net 5½ lbs (2,5 kg); shipping 8 lbs (3,6 kg).

Price: HP 735A DC Transfer Standard, $400.

*3-digit direct-reading 0 to 1000 μV offset voltage.

ULTRA-ACCURATE TRANSFER STANDARD
Mean of four 735A's with 120 days calculated drift
Model E02-735A

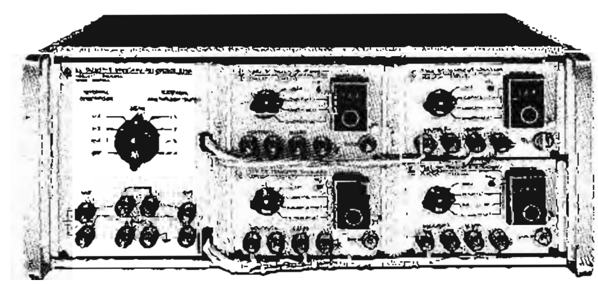
The Model E02-735A consists of four 735A Transfer Standards, with a nine position switch mounted in a 1052A combining case. The four instruments can be connected in parallel to the output terminals resulting in the arithmetical mean of the four voltages. In the 1.018 position of the function switch, a graph is furnished with the instrument showing drift deviation from a straight line over a 120 day period. With this graph, the accuracy of the bank of 735A's can be predicted within a fraction of a ppm for a 120 day calibration period. An external voltmeter can be inserted in the circuit so that when the output terminals are connected to a saturated standard cell or another external voltage, the meter will read the difference between the mean of the four 735A's and the external voltage.

In other positions of the E02-735A switch, the (No. 1) 735A can be connected opposing each of the other 735A's so that the meter reads the difference of the two voltages Each of the four 735A's can also be connected to the output terminals so that an external source can oppose any one of the 735A's with the meter reading the difference in voltages.

Specifications

(In addition to the specifications of the Model 735A.)

A graph is furnished with each E02-735A showing that the arithmetical mean of the four 735A's in the 1.018 position of the function switch has a drift deviation from a straight line of <±1 μV, 95% of the time, for 120 days.



E02-735A

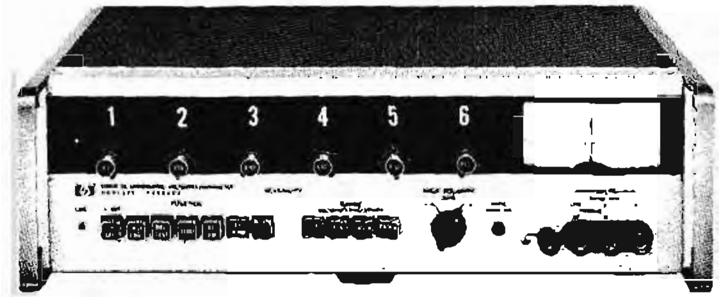
Power: 115 or 230 V ±10%, 50 to 400 Hz, 48W.

Dimensions: 16¾" wide, 7¼" high, 18¾" deep (425 x 185 x 467 mm).

Weight: net 35 lbs (15,8 kg); shipping 42 lbs (18,9 kg).

Price: HP E02-735A, $2455.

DC Δ VOLT/RATIOMETER
1 ppm stability with ±0.002% accuracy
Models 3420A & 3420B



3420B

Differential voltmeter

As a dc differential voltmeter the HP 3420A/B measures dc voltages in four ranges: 1 V, 10 V, 100 V and 1000 V full scale with an accuracy of ±(0.002% of reading +0.0002% of range) with a 10% over-range on all ranges.

The 3420A/B has infinite (>10^{11} ohms) input resistance at null on 1 V and 10 V ranges with at least 10 MΩ off null on all ranges. The 6-digit in-line read-out plus meter gives a meter resolution of 0.2 ppm of range.

Ratiometer

The HP 3420A/B may be used to measure resistance divider ratios and voltage ratios rapidly without using conventional, tedious, mathematical computations. Voltage and resistance ratios can be measured from 10^6:1 to 1:1 in four ranges; X1, X0.1, X0.01 and X0.001. The resolution is 0.2 ppm of range. Accuracy is 20 ppm of reading +4 ppm of range.

Specifications*

DC differential voltmeter

Ranges

Voltage: ±1 V, ±10 V, ±100 V and ±1000 V with up to 10% over-ranging available on all ranges.

Resolution: 6-digit readout yields resolution of 1 ppm of range; 0.2 ppm of range indicated on meter.

Performance rating

Accuracy

30 day: ±(0.002% of reading +0.0002% of range) at 23°C ±1°C, <70% RH.

90 day: ±(0.003% of reading +0.0002% of range) at 23°C ±1°C, <70% RH.

Stability: (at 23°C ±1°C, <70% RH): 1 hr: <1 ppm of reading; 24 hr: <5 ppm of reading.

Temperature coefficient: <4 ppm of range /°C (20°C-30°C) <5 ppm of range /°C (10°C-20°C and 30°C-40°C).

Zero adjustment range: >±12 ppm of range.

Meter noise: <0.2 ppm of range p-p.

Input characteristics

Inputs: floated binding posts on front panel can be operated up to ±500 V dc (350 V rms) with respect to chassis ground.

Input resistance: >10^{11} at null, <70% RH; at least 10 MΩ off null (1 V, 10 V ranges); 10 MΩ (100 V, 1000V ranges).

Effective common-mode rejection (ECMR)

DC: >140 dB on all ranges, <70% RH.

60 Hz and above: >150 dB on all ranges, <70% RH.

AC normal mode-rejection (ACNMR)

60 Hz and above: >102 dB.

Maximum AC normal-mode signal: 25 V rms on 1 V range, 200 V rms on 10 V, 100 V, 1000 V ranges.

Overload protection: ±1100 V dc may be applied on any range or sensitivity for up to 1 min without damaging instrument. Meter indicates within 5 s after removal of overload.

DC ratiometer

Ranges

Ratio: X1, X.1, X.01 and X.001.

Resolution: 6-digit readout yields resolution of 1 ppm of range; 0.2 ppm of range indicated on meter.

Performance rating

Accuracy

30 day: ±(0.002% of reading +0.0004% of range) at 23°C ±1°C, <70% RH.

90 day: ±(0.003% of reading +0.0004% of range) at 23°C ±1°C, <70% RH.

Stability: (at 23°C ±1°C, <70% RH) 1 hr: <1 ppm of reading; 24 hr: <5 ppm of reading.

Temperature coefficient: (10°C to 40°C) X1 range: <1 ppm of range per °C.

X.1, X.01, X.001 ranges: <5 ppm of range per °C.

Zero adjustment range: >±12 ppm of range.

Meter noise: <0.2 ppm of range (p-p).

Input characteristics

Input: 3 terminals, A, B, Common

$$\text{Displayed Voltage Ratio} = \frac{E_{(B \text{ to } COM)}}{E_{(A \text{ to } COM)}} \text{ with } E_{(A \text{ to } COM)} > E_{(B \text{ to } COM)}$$

and of same polarity.

Range	A to Common Input Voltage	A to Common	B to Common
X1	10 V	10 kΩ ±0.05%	
X.1	70 V	100 kΩ ±0.05%	>10^{10}Ω at null at
X.01	500 V	1 MΩ ±0.05%	least 10 MΩ ±0.05%
X.001	1000 V	10 MΩ ±0.05%	off null

DC voltmeter

General

Recorder output: fully adjustable 0 to ±1 V supplies 1 mA to 1 kΩ minimum resistance. (In ratiometer mode, recorder ground must be isolated from COM terminal by >10^{10} Ω.)

Recorder output noise: <50 mV p-p (<0.5 ppm of range referred to input at maximum sensitivity).

Operating temperature: instrument will operate within rated specifications from 10°C to 40°C unless otherwise specified.

Power: 3420A: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <2 W.

3420B: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <2 W or rechargeable batteries (8 furnished) 30 hours operation per recharge; input for fast charge mode, <3 W.

Dimensions: 16¾" wide, 5" (without removable feet) high, x 11¼" deep (425 x 127 x 286 mm).

Weight: 3420A net 20 lb (9 kg); shipping 25 lb (11,3 kg). 3420B net 21 lb (9,3 kg); shipping 27 lb (12,2 kg).

Accessories furnished: rack mount kit for 19" rack.

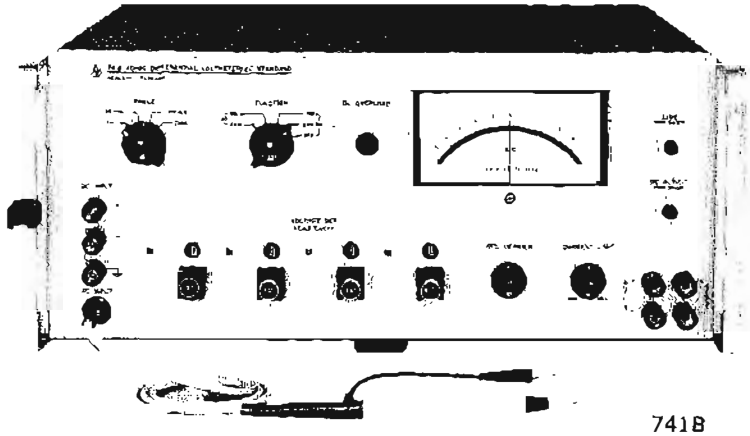
Price: HP 3420A, $1300; HP 3420B, $1450.

*For complete specifications, refer to Data Sheet.

AC-DC ΔVM/DC STANDARD

Multi-function calibration instrument

Model 741B



741B

The Hewlett-Packard Model 741B is a versatile and accurate instrument with 6 modes of operation. Now it is possible to solve most measurement problems with one convenient instrument.

The 741B is easy to use. The 4 most significant digits are digitally displayed; the meter displays the remaining resolution. The decimal point is placed automatically by the range switch. The voltage set switches are concentric with the sensitivity buttons; no confusion about which switch to turn.

DC Standard source

As a dc standard, the 741B delivers 0 to 1000 volts with an accuracy of 0.01% of setting. Designed for calibrating digital voltmeters, differential voltmeters and for general standards lab use, the 741B delivers voltages quickly and easily. Sense terminals allow sensing voltage at distant loads, eliminating errors due to voltage drop in long leads.

DC differential voltmeter

The high input resistance of $>10^9 \Omega$ distinguishes the 741B as a dc differential voltmeter. This high resistance is maintained for voltages up to 1000 volts independent of null. Accuracy is ±0.02% of reading.

AC differential voltmeter

As an ac differential voltmeter, the 741B offers two features unique to ac voltage measurement; high accuracy and low input capacitance. With <5 pF input capacitance, the 741B has a minimal loading effect at higher frequencies.

High impedance ac or dc voltmeter

The model 741B is a ±2% floating dc voltmeter with ranges from 1 mV to 1000 V. It is also a ±2% floating ac voltmeter from 50 mV to 1000 V, with reduced accuracy to the 1 mV range.

Amplifiers

As a voltage amplifier, up to 60 dB gain is available at the recorder terminals.

As a ±0.02% power amplifier, the HP 741B provides unity voltage gain from 0 to 1000 V at the output terminals.

Specifications*

DC standard

Ranges

Voltage: 0 to 1000 V in 4 decade ranges as follows: 0 to 1 V with 1 μV resolution; 0 to 10 V with 10 μV resolution: 0 to 100 V with 100 μV resolution; 0 to 1000 V with 1 mV resolution.

Performance rating

Accuracy:** <80% RH, constant temp ±1°C, line and load. Calibrated at factory at 23°C and 115 V line.

90 day: ±0.01% of setting or ±0.001% of range, whichever is greater +10 μV.

180 day: ±0.015% of setting or ±0.0015% of range, whichever is greater +15 μV.

Stability: <80% RH, constant temp ±1°C, line and load.

1 hr: <(0.0003% of setting +0.0001% of range).

24 hr: <(0.001% of setting +0.0001% of range).

Temperature coefficient: <(0.0003% of setting +0.0001% of range) per °C.

Line regulation: <(0.0001% of setting +1 μV) per 1%.

Load regulation (no load to full load): <(0.001% of setting +10 μV).

Output characteristics

Terminals: plus and minus output, plus and minus sense. Minus output can be floated up to ±500 V dc with respect to chassis ground.

Output current: current limiter continuously adjustable from <4 mA to >20 mA, 0°C to 40°C. Reduced to 10 W maximum from 40°C to 50°C.

Output resistance: $<(0.0005 + 0.0005 E_{out})\Omega$.

Noise (rms value):

Range	DC - 1 Hz	1 Hz - 1 MHz
1 V	<10 μV	<200 μV
10 V	<100 μV	<200 μV
100 V	<1 mV	<1 mV
1000 V	<10 mV	<10 mV

AC differential voltmeter

Ranges

Voltage: 1 V, 10 V, 100 V, 1000 V.

Resolution: 4-digit readout yields resolution of 0.01% of range; 0.002% of range indicated on meter.

Response: responds to average value, calibrated in rms.

Performance rating

Accuracy: <80% RH, constant temp (±1°C) and line. Calibrated at factory at 23°C and 115 V line.

90 day:

Frequency	Voltage	Accuracy ±(% of reading + % of range)
400 - 5 kHz	50 mV - 100 V	0.02% +0.01%
20 Hz - 30 Hz	50 mV - 1 kV	0.2% +0.01%
30 Hz - 50 Hz		0.15% +0.01%
50 Hz - 100 Hz		0.1% +0.01%
100 Hz - 10 kHz		0.04% +0.01%
10 kHz - 50 kHz		0.2% +0.01%
50 kHz - 100 kHz		0.4% +0.01%
20 Hz - 50 kHz	1 mV - 50 mV	0.4% +0.01%

180 day:

20 Hz to 20 kHz: add ±(0.02% of reading +0.01% of range) to 90-day specification.

20 kHz to 100 kHz: add ±(0.4% of reading +0.02% of range) to 90-day specification.

Stability: <80% RH, constant temp ±1°C and line, 20 Hz to 20 kHz.

1 hr: <0.003% of range. **24 hr:** <0.005% of range.

Temperature coefficient:

Temperature	Frequency	Change per °C
5°C - 40°C	20 Hz - 10 kHz	<0.002% of range
	10 kHz - 100 kHz	<0.006% of range
0°C - 5°C	20 Hz - 10 kHz	<0.004% of range
40°C - 50°C	10 kHz - 100 kHz	<0.008% of range

Line regulation: <0.001% of range per 1% line voltage change.

Input characteristics

Input: probe with 3-ft cable can be floated up to ±500 V dc.

Input impedance: 1 MΩ shunted by less than 5 pF.

Overload protection: 1000 V can be applied on any range.

DC differential voltmeter

Voltage ranges: 1 V, 10 V, 100 V, 1000 V.

Resolution: 4-digit readout yields resolution of 0.01% of range; 0.002% of range indicated on meter.

Performance rating

Accuracy:** <80% RH, constant temp ±1°C and line. Calibrated at factory at 23°C and 115 V line. 90 day: ±0.02% of reading or ±0.004% of range, whichever is greater. 180 day: ±0.025% of reading or ±0.004% of range, whichever is greater.

Stability: <80% RH, constant temp ±1°C and line.

1 hr: <(0.0003% of reading +0.0001% of range).

24 hr: <(0.001% of reading +0.0001% of range).

Temperature coefficient: <(0.0003% of reading +0.0001% of range) per °C.

Line regulation: <0.0002% of range per 1% line voltage change.

Input characteristics

Terminals: plus and minus input terminals and chassis ground. Minus input can be floated up to ±500 V dc with respect to chassis ground.

Input resistance: >10⁹Ω, independent of null.

AC normal mode rejection (ACNMR): 50 Hz and above: >80 dB.

Maximum ac normal mode voltage: 50% of dc input or 25 V.

Overload protection: 1000 V can be applied on any range.

High impedance ac/dc voltmeter and power amplifier**

General

Recorder output: available for all modes of operation. Recorder voltage output directly proportional to meter deflection, 60 dB gain (max.), 1 mA into 1 kΩ load.

Power supply: 115 or 230 V ±10%, 50 Hz to 400 Hz, 125 W max.

Dimensions: 16¾" wide, 6⅞" high, 18¼" deep (425 x 175 x 464 mm).

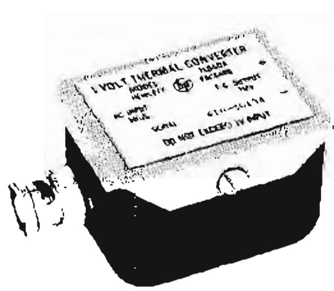
Weight: net 42 lbs (18,9 kg); shipping 55 lbs (24,8 kg).

Accessories furnished: rack mounting kit for 19" rack.

Price: HP 741B, $1875, HP 741B, option 01**, $1875.

*For complete specifications, refer to Data Sheet.
**Option 01: accuracies for DC Δ VM and DC Standard are interchanged.

Models 11049A, 11050A, 11051A Thermal Converters



11050A

Hewlett-Packard Thermal Converters are true rms indicators, yielding a dc output voltage proportional to the temperature rise resulting from the input power. The Models 11049A, 11050A and 11051A offer an exceptionally flat response and nearly constant impedance over a wide frequency range. These characteristics make the thermal converters ideal to check the response of precision ac voltmeters, oscilloscopes and amplifiers.

Specifications

Maximum input voltage:

11094A: 3 V rms; **11050A:** 1 V rms; **11051A:** 0.45 V rms.

Input impedance: 50 ohms ±0.15 ohms to 10 MHz.

Output voltage for maximum input voltage: 7.5 mV dc.

Output impedance: less than 10Ω.

Calibration accuracy

Frequency range	In reference to std.	Standard measurement uncertainty
20 Hz to 20 kHz	within ±0.01%	±0.02%
20 kHz to 50 kHz	within ±0.01%	±0.03%
50 kHz to 1 MHz	within ±0.01%	±0.06%
5 Hz to 20 Hz and 1 MHz to 10 MHz	within ±0.05%	±0.12%
10 MHz to 30 MHz		±0.25%
30 MHz to 60 MHz		±0.50%
60 MHz to 100 MHz		±1.50%

Dimensions: 3" wide, 1¾" high, 1½" deep (7,6 x 4,4 x 3,8 cm).

Weight: net 2.2 oz (62 g); shipping 1 lb (450 g).

Price: HP Model 11049A*, $125; HP Model 11050A*, $125; HP 11051A*, $125.

Option 01*: calibration to 60 MHz, add $25.

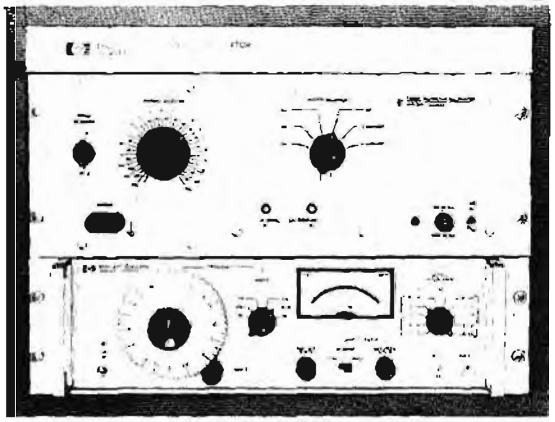
Option 02*: calibration to 100 MHz, add $50.

*Includes individual calibration report with statement of uncertainty, traceable to NBS. Options include individual correctional data sheet attached to calibration report.

VOLTMETER CALIBRATOR

DC, rms and p-p volts; flatness 10 Hz-10 MHz

Model E02-738BR



E02-738BR

Description

The 652A Test Oscillator and the 738BR Voltmeter Calibrator calibrates high-impedance voltmeters and oscilloscopes for both frequency response and voltage accuracy. The system combines two moderately priced basic Hewlett-Packard instruments that calibrate for ac and dc voltage levels from 300 μV to 300 V in precise preselected steps and calibrate for frequency response from 10 Hz to 10 MHz.

The two instruments are available individually or in a single enclosure provided with a rear-access door and power strip as the E02-738BR.

The 738BR is a highly stable precision voltage source with drift less than 0.1% per week for dc voltage, less than 0.2% per week for ac voltage. The 652A provides a convenient constant-amplitude ac output voltage at an adjustable frequency from 10 Hz to 10 MHz. The instrument's expanded meter scale monitors the frequency response rapidly and accurately with ±0.25% flatness.

Specifications

E02-738BR Voltmeter Calibration System

738BR

Voltage range: 300 μV to 300 V, dc or ac (rms and p-p, 400 Hz).

Levels: calibration voltage 300 μV to 300 V in steps of 1, 3, 1.5 and 5; tracking voltages 0.1 to 1 V in 0.1 V steps and 0.05 to 0.5 V in 0.05 V steps.

Accuracy: 300 V working voltage into attenuator, accurate within 0.1% dc and 0.2% ac, after a 30-minute warmup.

Attenuator accuracy: within ±0.1% or ±2.5 μV, whichever is larger, open circuit.

Long-term stability: less than 0.1% dc drift per week, less than 0.2% ac drift per week.

Power: 115 or (230 V must be specified) ±10% 50 to 60 Hz, 350 W.

Dimensions: 19" wide, 7" high, 15¾" deep behind panel (483 x 178 x 400 mm).

Weight: net 38 lbs (17 kg); shipping 53 lbs (24 kg).

Price: HP 738BR, $1100 (rack mount).

652A

Specifications are listed on page 381 of this catalog.

General

Dimensions: 20½" wide, 15⅝" high, 18½" deep (521 x 397 x 470 mm).

Weight: net 75 lbs (33.8 kg); shipping 110 lbs (49.8 kg).

Accessories furnished: cable HP part number 739A-16A, flat response to 10 MHz, BNC to shielded 50Ω terminated dual banana plug.

Price: HP E02-738BR, $2110.

PORTABLE DC NULL VOLTMETER

Battery operation, 0.1 μV resolution

Model 419A

419A

The Model 419A DC Null Meter is a solid-state, battery operated micro-voltmeter with 0.1 μV resolution.

The 419A is an excellent dc null detector for comparing a standard voltage with another source voltage, resistive divider or amplifier. By connecting the two voltages to the + and — floating input terminals, the voltages oppose each other and the instrument under test may be adjusted to the exact dc voltage of the standard instrument. This is accomplished by nulling the difference between the two sources on the 419A's 3 μV range with a resolution of 0.1 μV. Internal noise is very low, even at this resolution.

The 419A is operated from a rechargeable battery-power source so that it can be isolated from the ac power line, eliminating ground loops.

The 419A offers a feature not available in any other dc null meter. . . . an adjustable internal nulling supply. An infinite input impedance is obtained (even on the 3 μV range) when used as a null detector with the internal nulling supply.

Additional applications

(1) The 419A, because of its high-input impedance and sensitivity, may be used for measurements where a voltage must be read, compared or adjusted across a resistor.

(2) Transistor collector voltages can be measured.

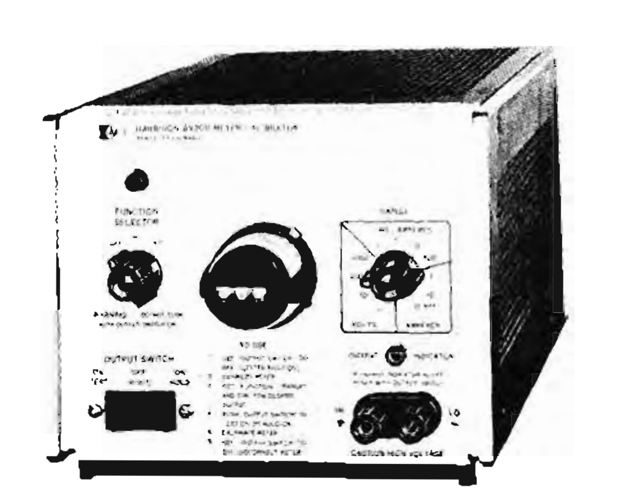
(3) Voltages may be measured across a resistive divider.

(4) Because of its high sensitivity, the 419A may be used to measure thermocouple voltages and other low-level transducer sources.

(5) Nerve potentials in biology and medicine as well as chemically-generated emf may be measured.

For complete specifications, see page 219.

AC/DC METER CALIBRATOR
Four calibrators in one case
Model 6920B



6920B

Can be used to check:

1. DC Voltmeters up to 1000 volts
2. AC Voltmeters up to 1000 volts
3. DC Ammeters up to 5 amps
4. AC Ammeters up to 5 amps

Description

Model 6920B is a versatile ac/dc meter calibrator, capable of both constant voltage and constant current output. Its absolute accuracy makes it suitable for laboratory or production testing of panel meters, multimeters, and other meters having accuracy of the order of 1.0% or higher. This calibrator has been designed for convenience, and combines in one instrument all the outputs needed to test the more commonly used meters. Model 6920B has been packaged in an HP cabinet module suitable for bench or rack use.

Output switch

An output switch selects the safest mode of operation for the particular type of meter being tested. A "lock" position leaves the testing parameters in operation to free both hands for attaching and disconnecting successive meters. A "test" position, springloaded so that the meter calibrator output is presented to the terminals only while finger pressure is applied, facilitates testing meters with several full-scale values and reduces the danger of burn-out.

AC Output waveshape

When the function switch is set on "AC", the output waveshape is sinusoidal (to a first approximation) and has the same frequency as the input line power applied to the instrument. The feedback loop which controls and regulates this AC is actually monitoring the average value of the ac output, although the front panel controls are calibrated in terms of rms. Thus this calibrator is suitable for use with average reading ac voltmeters scaled in rms. Moreover, it is not improper to use this calibrator with true rms meters provided the input line waveshape has a negligible amount of harmonic distortion. The meter calibrator's contribution to the total harmonic distortion present in its output is small compared to its overall accuracy.

Specifications

Input: 115 V ac ±10%, single phase, 58-62 Hz, 0.7 A, 65 W max.

Output voltage ranges:

0.01-1 V current capability 0-5 A
0.1-10 V current capability 0-1 A
1-100 V current capability 0-100 mA
10-1000 V current capability 0-10 mA

Above output voltage ranges and maximum current capabilities for each range apply in full for either dc or ac operation.

Output current ranges: (5 A maximum output)

1-100 μA voltage capability 0-500 V
0.01-1 mA voltage capability 0-500 V
0.1-10 mA voltage capability 0-500 V
1-100 mA voltage capability 0-50 V
0.01-1 A voltage capability 0-5 V
0.1-10 A voltage capability 0-0.5 V

Above output current ranges and maximum voltage capabilities for each range apply in full for either dc or 60 Hz, operation.

Output accuracy: DC—0.2% of set value plus 1 digit. AC—0.4% of set value plus 1 digit. Above accuracy applicable over a temperature range from 15°C to 35°C and over full input voltage range.

Controls:

FUNCTION SWITCH—This is a 3-position switch: "OFF", "AC", and "DC". In the "OFF" position the ac power input is disconnected from the unit. In the "AC" position the meter calibrator produces an ac output; similarly, in the "DC" position the calibrator produces a dc output.

RANGE SWITCH—10 positions, one for each voltage and current range.

CALIBRATED OUTPUT CONTROL—Digital potentiometer readout control (3 significant digits) determines exact value of output.

OUTPUT SWITCH—Switch described above.

Output terminals: two front panel terminals are provided; these are the output terminals for both ac and dc operation. In voltage ranges, the negative terminal is grounded.

Ripple: in dc operation the output ripple is typically less than 1.0% rms of the output range switch setting.

Operating temperature range: 0-50°C.

Size: 6¾" (172 mm) H x 7-13/16" (198 mm) W x 11" (279 mm) D.

Weight: 15 lbs (6,8 kg) net, 17 lbs (7,71 kg) shipping.

Price: $695.

Option 05: 50 Hz ac input regulation realignment, add $25.

Option 28: 230 V ac ±10%, single phase input, add $10.

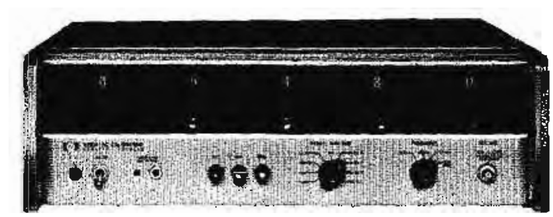
AC METER CALIBRATOR

Low-cost, 0.25% accuracy

Model 6921A

Advantages:

- Constant voltage or constant current output
- Programming accuracy—0.25%
- High output power—up to 25 watts
- Overvoltage and overcurrent load protection
- Handles fully reactive loads
- Easily calibrated
- Low cost
- Front-panel choice of 3 output frequencies



Description

Model 6921A is a calibrated ac source that can provide a constant voltage or a constant current output. The output waveshape is sinusoidal and its *rms* amplitude is within 0.25% of the set value.

Output frequencies of 60 Hz, 400 Hz, and 1 kHz (with an accuracy of 10%) are standard with the calibrator; or an external oscillator (of 1-2 V p-p amplitude) can be used to obtain any output frequency between 50 Hz and 2 kHz (without degrading the accuracy of the calibrator).

The calibrator has four output voltage ranges and five output current ranges (see specification chart). A decade readout of the settings is conveniently located on the front panel. Model 6921A can be used for calibrating ac voltmeters and ammeters and for testing other ac devices. Its relatively high output power and ability to operate into a full reactive load makes it particularly suitable for calibrating large, moving-vane type meters. This instrument can also be used as a leveling amplifier which provides a constant output despite amplitude variations of an input signal between 1-2 V p-p.

Specifications

Input: 115/230 V ac ±10%, 1ϕ, 48-440 Hz, 120 W nominal.

Output voltage (rms): voltage setability in the chart below indicates the minimum and maximum limits for each range. The calibrator can be set to zero volts in each range, but performance within spec is not guaranteed below the lower limit. The current limit in the 14 V and 140 V ranges is internally switched to lower values when the voltage is set above 5 V and 50 V, respectively.

Voltage range	Output capability		Resolution
	Voltage setability	Current limit	
1.4 V	0.1000–1.4000 V	5 A	0.1 mV
14 V	1.000–5.000 V 5.001–14.000 V	5 A 2 A	1 mV
140 V	10.00–50.00 V 50.01–140.00 V	0.5 A 0.2 A	10 mV
140 V x 2 (280 V)	20.00–280.00 V	0.1 A	20 mV

Current range	Current setability	Current limit	resolution
1.4 mA	.1000–1.4000 mA	140 V	.1 μA
14 mA	1.000–14.000 mA	140 V	1 μA
140 mA	10.00–140.00 mA	140 V	10 μA
1.4 A	.1000–0.5000 A 0.5001–1.4000 A	50 V 20 V	100 μA 100 μA
5 A	0.500–5.000 A	5 V	1 mA

Output voltage and current accuracy: 0.25% of output voltage or current setting after one hour warm-up.

Output frequency: one of three internal frequencies, 60 Hz, 400 Hz, or 1 kHz, can be selected by means of a front panel switch. Frequency accuracy is ±10% of setting.

External oscillator input: unit can be driven by input from external oscillator at any frequency of from 50-2 kHz while meeting all specifications. Input signal must be 1-2 V ac p-p.

Output distortion:

Second harmonic: less than 0.5%.

Third harmonic: less than 0.1%.

Temperature coefficient: less than 0.01% of each output voltage or current range per °C from 0°C to 55°C.

Stability: total drift for 24 hours is less than 0.1% of any range under constant ambient temperature conditions and after 1-hour warm up.

Load regulation: less than 0.1% of voltage or current setting for no load to full load change.

Line regulation: less than 0.01% of voltage or current setting for any line voltage change within input rating.

Temperature ranges: operating: 0 to +55°C. Storage: −40 to +75°C.

Overload protection: the unit and its load circuits are fully protected against any overload condition including a continuous short circuit.

Output terminals: HI, COMMON, and GND terminals are included on the front panel. They can be floated up to 300 volts off ground.

Cooling: convection cooling is employed. There are no moving parts.

Controls: output dials and range and frequency switches are included on the front panel.

Size: 16½" (41.9 cm) W x 5" (12.7 cm) H x 17¾" (45 cm) D.

Weight: net 28.2 lbs (12,8 kg). Shipping 32.16 lbs (14,5 kg).

Price: $975.

Voltage, current and resistance measurements are easy, fast and accurate with electronic instruments using meter movements. Most electronic voltmeters, ammeters and ohmmeters use rectifiers, amplifiers and other circuits to generate a current proportional to the quantity being measured, which then drives a meter movement. Devices of this type are called analog instruments.

Meter Movements—the meter-movement readout should continue to be popular since it is economical and suitable for many jobs. It also lends itself well to special, nonlinear scales such as dB scales.

The pivot-jewel suspension is being replaced more and more by taut-band suspension. This has resulted in excellent repeatability with hysteresis virtually eliminated. This repeatability, in turn, makes practical the individually-calibrated meter scale. Both of these improvements are standard in most HP analog voltmeters.

Figure 1 shows scales for two different individually calibrated meters printed on one face by Hewlett-Packard's calibrator. By combining HP-produced taut-band meter movements with individually calibrated meter faces, Hewlett-Packard's meters are outstanding in ruggedness and precision.

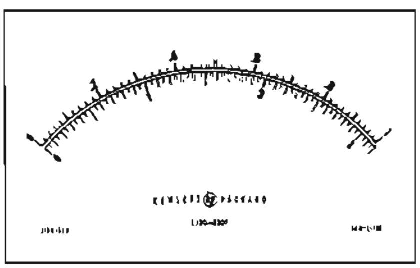


Figure 1. Scales for two different individually calibrated meters printed on one face by Hewlett-Packard's calibrator

DC voltage measurements

The dc voltmeter represents a straightforward application of electronics to measuring instruments. This instrument usually has a dc amplifier preceding the meter movement.

Dc amplifiers can be classified as (a) direct-coupled and (b) chopper stabilized.

Direct-coupled amplifiers are attractive for their economy and find application in lower-cost electronic voltmeters.

The direct-coupled amplifier is used to obtain sensitive ranges and higher input impedance than can be realized with non-electronic types of voltmeters.

An amplifier also limits the maximum current supplied to the meter movement so that there is little danger that unexpected overloads will burn out the meter movement. The HP 427A is representative of this class of instruments.

To supply ranges of a few millivolts or microvolts full scale, chopper stabilized amplifiers are generally used. Hewlett-Packard choppers convert the input dc to a proportional ac with zero offsets of 1 μV or less. The ac signal is first amplified and then converted to dc (demodulated). The HP 410C uses this technique to minimize the drift characteristics of direct-coupled amplifiers.

The HP solid-state 419A DC Null Voltmeter also uses a chopper-stabilized amplifier and has 0.1 μV resolution with 18 ranges from 3 μV to 1000 V. An internal, adjustable, bucking voltage allows the operator to null the input signal with a front-panel control, making the input impedance effectively infinite. This dc null voltmeter is powered by rechargeable batteries.

Automatic polarity and range selection features are available. The operator can detect polarity and measure any voltage within the range of the instrument without setting controls. The meter indication is automatically maintained between 1/3 and full scale, while the range also is automatically displayed. These features are offered in the HP 414A Autovoltmeter.

DC current measurements

For most dc current measurements, the meter movement, by itself, serves the purpose admirably. In these cases, the meter coil requires relatively few turns to generate sufficient magnetic flux for deflecting the meter pointer. For lower current measurements, the sensitivity of the meter movement must be increased. This is usually accomplished by adding more turns on the coil. These added turns increase the resistance of the current path which can be troublesome in low-impedance circuits.

Electronic instruments overcome this difficulty by measuring the small voltage drop across a low-value resistance placed in series with the current to be measured. The HP 412A and 425A Voltmeters are equipped with internal-calibrated shunt resistors for reading dc currents without accessory equipment.

Resistance measurements

Resistance is customarily determined through the familiar Ohm's relation: $E = IR$. By applying a known voltage, E, to the unknown resistance, R, and then measuring the current, I, passing through it, R can be computed.

A modified procedure for doing this is incorporated in the HP 410B, 410C, 412A, and 427A multi-function voltmeters.

The HP 414A employs a feedback-stabilized current source, allowing the use of a linear ohms scale and avoiding a special meter scale for resistance measurements. The resulting meter scales are easy to read with good resolution at lower-resistance values.

To measure extremely low resistances such as are found in short lengths of large wire, relay and switch contacts, earth ground terminals or in commutator brushes, the HP 4328A Milliohmmeter is recommended. (See page 222.) The HP 4328A measures resistance from 0.001 to 100 ohms full scale over 11 ranges with ±2% accuracy. (No additional error is caused by series reactances up to 2 times full scale resistance.)

Although the four terminal method is used to insure accurate measurements, only two probes are connected to the sample. To eliminate error due to thermal emf, contact potential differences and electrolytic polarization, the milliohmmeter is internally driven by a 1 kHz signal. The probes are floating and contain dc blocking capacitors to protect the 4328A from damage and to prevent measuring error when the probes come in contact with a dc circuit. Thus, the resistance of a sample can be measured at dc potentials.

Resistance measurements in the 4328A are accomplished by two major circuits. (Figure 2.) One is a 1 kHz constant-current oscillator which supplies a current to the resistance under test. The other is a voltmeter which senses voltage drop across the resistance under test and calibrates it in ohms. The voltmeter incorporates a phase-discriminator eliminating errors caused by series reactance.

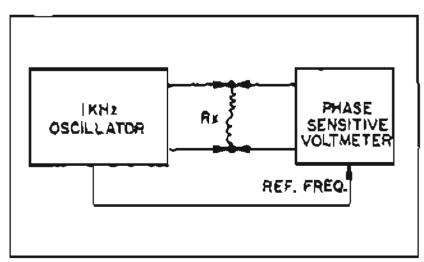


Figure 2. Simplified block diagram of HP 4328A Milliohmmeter.

With the 4328A, the voltage and current applied to the sample are extremely small. The current is constant for each range and varies from 150 μA rms on the 100Ω range to 150 mA on the 1 mΩ range. Even when the resistance value of the sample is greater than the range setting, the voltage protective circuit prevents any voltage higher than 20 mV from being applied to the sample.

The HP 4329A is a solid-state ohmmeter designed to measure very high resistance values found in resins, porcelain and insulating oils. This one instrument can also measure voltage and current. Accessories include a cell for resistivity measurements. Refer to page 223 for additional information.

AC voltage measurements

Electronic instruments for measuring ac voltages also use an amplifier with the meter movement. Analog ac voltmeters are ac-to-dc converters which derive a dc current proportional to the ac input being measured, employing this current for meter deflection. In some situations, conversion to dc by use of external probe diodes precedes amplification. The required amplifiers must then be dc amplifiers, either direct-coupled or chopper type. In other cases, the dc may be derived as a final step with sufficient power available to directly drive the meter movement of the voltmeter. Any ac amplifier may readily be a broadband dc amplifier preceded by an input-blocking capacitor. For detailed information on dc amplifiers, refer to Hewlett-Packard Application Note 69.

Analog (meter) indicating ac voltmeters fall into three broad categories: average - responding, peak - responding, and rms-responding. Ac voltmeters in general use are average and peak-responding types, although rms values are of principal interest.

Average-responding voltmeters

Probably the most widely used measurement technique combining acceptable accuracy and reasonable cost is the average-responding (absolute average) method. Figure 3 shows a typical arrangement for making an average measurement. The signal is amplified (or attenuated) and fed to the meter circuit through a diode bridge. For good linearity, the amplifier should be a current source at all frequencies of interest.

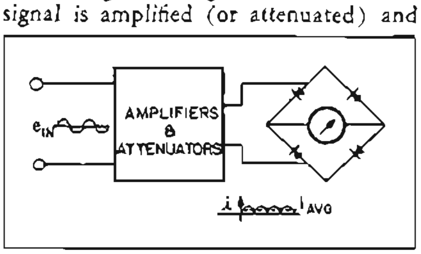


Figure 3. Average-responding voltmeter.

The average value of an ac voltage is simply the average value of voltage measured point by point along the waveform. For a sine wave and any waveform symmetrical about zero, the true average value is zero. However, a resistive load is heated by both the positive and negative current excursions in proportion to the absolute average of voltage above and below zero. Accordingly, when we speak of average voltage, we mean the average value of a full-wave rectified voltage. This value for sine wave is 0.636 times the peak voltage.

For a sinusoidal waveform, then, the rms value can easily be calibrated on a meter responding to the average value because the rms value is greater by the constant $k = 0.707/0.636 = 1.11$. Many waveforms encountered in electronic measurements are sinusoidal; in these instances, the average-responding meter, calibrated in the rms value of a sine wave, provides an accurate indication of the rms value. The widely used HP 400 series Voltmeters are average-responding voltmeters.

Average - responding voltmeter error due to harmonic distortion is low—less than 3% for about 10% harmonic distortion.

AC microvoltmeter

Most broadband average-responding voltmeters are limited in sensitivity (100 μV full scale) by inherent noise and spurious signals. An extention of the average-responding voltmeter, the new HP 3410A uses a synchronous phase-lock detector to read very low-level signals (3 μV full scale) obscured in other instruments by noise. Noise and spurious signals up to 20 dB above full scale can be tolerated.

The block diagram in Figure 4 illustrates the basic operation of the HP 3410A AC Microvoltmeter. The circuit consists of four major sections: the input or signal conditioning circuit, the phase-lock loop, an inhibit circuit and a meter circuit. When tuned to any discrete frequency between 5 Hz and 600 kHz, the meter indicates the rectified average value of the signal. All noise and non-harmonically related signals are rejected. Most voltmeters using this technique require a clean, high-level reference signal input from the test signal source, or that the system under test use the local oscillator output of the voltmeter. When using the HP 3410A, such a hook-up is not necessary. By using a phase-lock oscillator to drive the synchronous detector, the need for a reference input is eliminated. Some useful 3410A applications are measuring frequency of signals in noise, separating closely-spaced coherent signals, measuring power supply ripple, measuring signal-to-noise ratios, calibrating attentuators and measuring summing junction voltages. Refer to HP Journal, Vol. 18, No. 9.

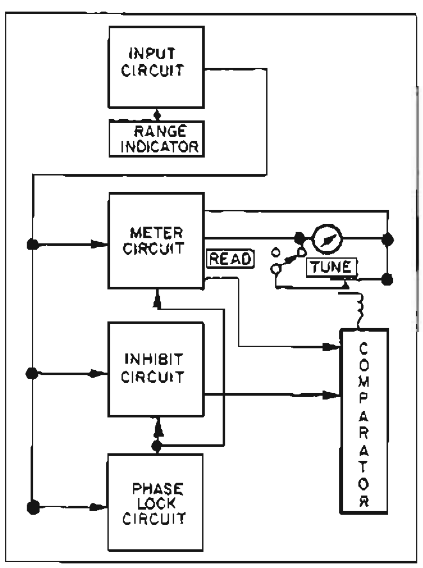


Figure 4. Block diagram of HP 3410A AC Microvoltmeter.

RF voltmeters

Conventional voltmeters responding to the absolute average or the true rms value of an ac waveform are sometimes limited in sensitivity and bandwidth by the input impedance converter, amplifier and detector. These restrictions may be relieved by sampling the signal prior to amplification and detection. This technique constructs low-frequency equivalents of high-frequency signals and permits voltmeters to make measurements over wide frequency and voltage ranges.

The HP 3406A uses an incoherent sampling technique. Unlike coherent sampling, it requires neither a triggering source nor that the input signal be periodic. The sampling voltmeter operates equally well with sinusoidal, pulsed, random or frequency-modulated signals.

The HP 3406A Sampling Voltmeter responds to the absolute-average values of unknown voltages and is calibrated to read both the rms value of a sine wave and dBm in 50 ohm systems. Its sensitivity is high enough to measure voltages as small as 50 μV over a 25 kHz to >1 GHz frequency range. Voltage scales are linear, and resolution is 20 μV on the 1 mV range. Unlike some RF voltmeters with peak detectors that are rms-responding on the lower ranges and gradually change to peak-detecting on the higher ranges, the HP 3406A is average-responding on all ranges. This means that measurements of non-sinusoidal voltages are more accurate because its detector law does not change with the amplitude of the input signal.

An output connector from the zero-order hold circuit is available at the rear panel of the instrument for connection to other measuring equipment. Since the statistics available at this point are the same as those of the input signal, properties such as peak, average and rms can be measured by instruments with narrow bandwidth capabilities. Peak voltages, amplitude modulation envelopes, true rms values, pulse height information, and probability density functions of broadband signals can be determined by observing the output of the zero-order hold circuit. Much of this information has never before been accessible for broadband signals. For a detailed description of applications and operation of the HP 3406A Sampling RF Voltmeter, ask for a copy of the HP Journal, Volume 17, No. 11.

Recently introduced, the HP 8405A RF Vector Voltmeter, can measure amplitudes and phase angles simultaneously from 1 to 1000 MHz. The 8405A RF Vector Voltmeter operates on the principle of coherent sampling.

Peak-responding voltmeter

Peak-responding voltmeters can perform over a bandwidth extending to several hundred MHz. They have a low-shunt capacitance to minimize circuit loading. Good linearity is possible for input sinusoidal signals of 0.5 volts and above. For signals smaller than 0.5 volts, special compensation techniques must be used to achieve linear meter indications.

The indication of the peak-responding voltmeter block diagram shown in Figure 5 places the rectifier in the input circuit where it charges the small input capacitor to the peak value of the input signal. This voltage is passed to a dc amplifier, which drives the meter.

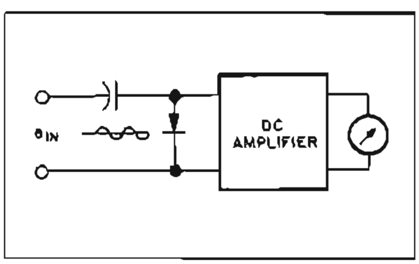


Figure 5. Peak-responding voltmeter.

Since ac-to-dc conversion is usually accomplished in the peak-responding voltmeter at the input, a dc meter circuit is required. Often dc volts, ohms and ampere scales are added to make the peak-responding meter a multi-function instrument as is the HP 410C.

Like the average-responding voltmeters, peak-responding voltmeters are usually calibrated in the rms value of a sine wave. The average-responding type, therefore, indicates 1.11 times higher than the average voltage, while the peak-responding type indicated 0.707 times the peak voltage. Consequently, both meters may be in error if the measured signal is not a pure sine wave. Peak-reading instruments are generally sensitive to harmonic distortion, and care must be taken in the interpretation of the measured peak value of a non-sinusoidal waveform. For a detailed discussion of the limits of error introduced into peak and average-responding voltmeters by various harmonics, refer to HP Application Note 60.

RMS-responding voltmeter

The true-rms measurements technique is most ofen used when a high degree of accuracy is required. Instrument indication is proportional to the rms heating value of the impressed waveform. Mathematically, the root-mean-square (rms) value of any complex quantity is obtained by summing the squares of each component and taking the square root of the sum, defined as the equivalent heating power of the waveform.

The 3400A uses the thermocouple approach to measure the true rms value of waveforms. When a signal is applied, the dc voltage generated at the output of the thermocouple is proportional to the true rms value of the input. Nonlinear characteristics of the thermocouple have previously been a problem in accuracy calibration. Other problems have been sluggish response and tendency to burn out.

These thermocouple problems have been solved in the 3400A by using a thermocouple pair which acts as a summing point. The output of the ac amplifier (as shown in Figure 6) and the feedback from the dc emitter follower are inputs to the two thermocouple heaters. The difference between the two thermocouple voltages is the dc input to the chopper amplifier. This difference is modulated, amplified, demodulated, and supplied to the meter. This voltage is also fed back to TC 2 (Figure 6). This amplified dc voltage represents the true rms value of the ac signal applied to the input after it is attenuated for range. By using two matched thermocouples and measuring the dc difference, the output of the dc amplifier is linear. Using two thermocouples also provides stability against ambient temperature changes.

The dc voltage driving the meter is available at the dc output. This dc voltage provides a true rms ac-to-dc converter output.

The true rms value is measured independently of the wave-shaped provided that the peak excursions of the measured waveform do not exceed the dynamic range of the instrument. Distortion is not an error-contributing factor. This arrangement allows the Model 3400A to provide accurate readings of the rms value of complex waveforms having crest factors (ratio of peak-to-rms) as high as 10:1 at full scale. At 10% of full scale deflection, where there is less likelihood of amplifier saturation, waveforms with crest factors as high as 100:1 can be permitted.

Voltmeter considerations

The most appropriate instrument for ac or dc voltage measurement is the instrument realiably giving the performance needed for the existing conditions. Some considerations are:

Accuracy—Before we can discuss meter accuracy we must have a familiarity with the various meter scales available. Many instruments have meter scales marked in both volts and decibel (dB) units. It should be noted that dB and voltage are complements of each other. That is, if a voltage scale is made linear, the dB scale on the same meter face will be logarithmic or nonlinear. Likewise, if the dB scale is made linear, then the voltage scale becomes nonlinear. The term "linear-log scale" is applied to an instrument that has a linear dB scale and therefore a nonlinear voltage scale. Several different types of meter faces are illustrated in Figure 7.

Accuracy specifications are usually expressed in one of three ways: 1. (percent of the full-scale value) 2. (percent of the reading) 3. (percent of reading + percent of full-scale). The first is probably the most commonly used accuracy specification. The second, (percent of reading) is more commonly applied to meters having a logarithmic scale. The last method has been used more recently to obtain a tighter accuracy specification on a linear-scale instrument.

To understand the relative value of applying several accuracy specifications to any given instrument, percent uncertainty should be understood. Percent uncertainty can be defined as the ratio (in percent) of the calculated reading uncertainty to the actual meter reading, both expressed in the same scale units.

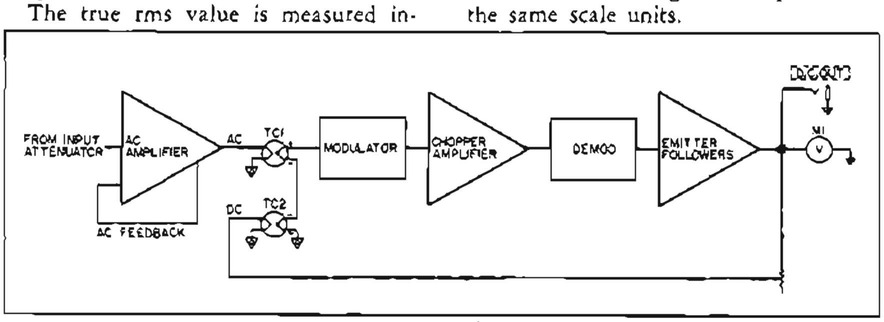


Figure 6. True rms-responding voltmeter.

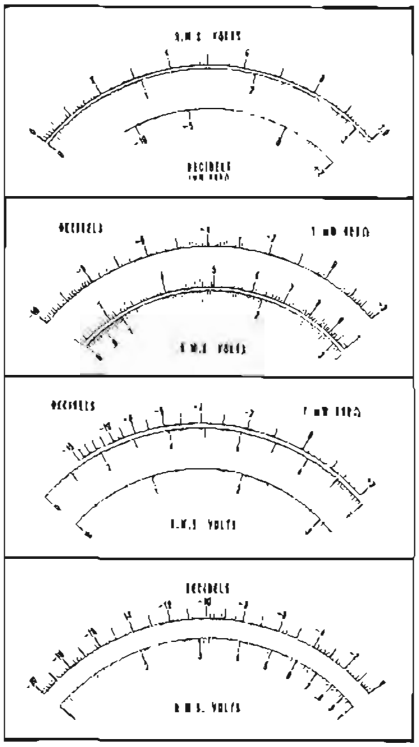


Figure 7. Four different types of meter scales available. (a) Linear 0-3 V and 0-10 V scales plus a dB scale. (b) Linear dB scale plus nonlinear (logarithmic) voltage scales. (c) dB scale placed on larger arc for greater resolution. (d) Linear −20 to 0 dB scale useful for acoustical and communications applications.

If the uncertainty is calculated from the (percent of reading) spec and then divided by the reading, the percent uncertainty will be constant for all readings and, thus, have the same value as the accuracy spec. Applying this type of accuracy specification to an instrument is practical only if the lower end of the scale is greatly expanded.

The (percent-of-reading) spec is employed for instruments having a log scale. If this type of spec is employed for linear-scale instruments, the percent uncertainty will be unrealistically small for the lower portion of the scale. Many linear-scale instruments commonly employ (percent of full-scale) specification. However, most meters of this type are capable of better accuracy than the percent uncertainty indicates. Hewlett-Packard uses the two-part accuracy specification to take advantage of the upper-scale accuracy and yet maintain a reasonable specification for the lower portion of the scale. (See Figure 8.)

Downranging is a method by which the improved upper-scale accuracy is utilized. In Figure 8 note that the knee of the curve for the two-part accuracy specification occurs at about 30 percent of full-scale. Thus, it is convenient to design voltage ranges in a 1-3-10 sequence. With this approach, all readings can be made on the upper two-thirds of the scale where accuracy is best. Downranging is illustrated by the inset in Figure 8 showing a case where a maximum uncertainty of approximately 2 percent can be attained.

For a thorough evaluation of accuracy, the following should be considered: Does it apply at all input-voltage levels up to maximum overrange point? (Linearity specifications may be added to qualify this point.) Does it apply to all frequencies throughout its specified bandwidth? Does it apply on all ranges? Does it apply over a useful temperature range for the application? If not, is temperature coefficient specified?

An affirmative answer to all items is required for a complete accuracy specification. Accuracy ratings generally apply for a zero-impedance source; the same accuracies can be achieved for higher source impedances by calculating the loading effect of the input impedance on the source. Complex impedances may limit the usefulness of this technique with ac voltmeters.

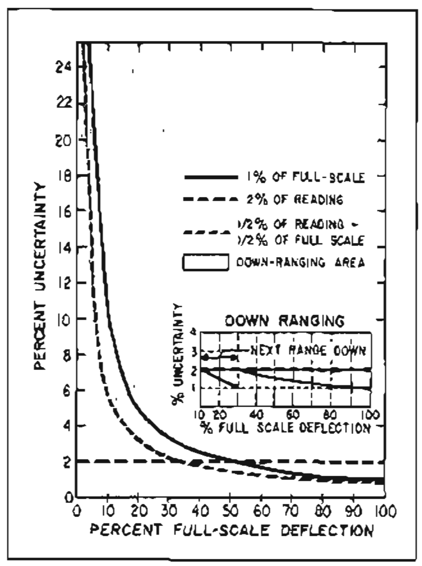


Figure 8. Percent uncertainty for three methods of specifying accuracy.

Outputs — Some voltmeters provide several analog outputs besides the meter reading. For instance, there may be both ac and dc output proportional to the pointer deflection. The ac output is useful for monitoring the waveform on an oscilloscope or to lower the output impedance of the circuit under test. The dc output can be used to drive a strip chart or X-Y recorder for a permanent record, or to drive a dc digital voltmeter to increase accuracy and resolution of broadband instruments.

Battery operation—For field work, an instrument powered by internal batteries is necessary. If an area contains troublesome ground loops, a battery powered instrument should be used to remove the ground path.

SENSITIVITY VS. BANDWIDTH—Noise is a function of bandwidth. A voltmeter with a broad bandwidth will pick up and generate more noise and is less sensitive than one operating over a narrow range of frequencies. For example, an instrument with a bandwidth of 10 Hz to 10 MHz typically can have a sensitivity of 1 mV. On the other hand, a voltmeter with bandwidth extending only to 500 kHz could have a sensitivity of 100 μV.

AC current probe

The HP 456A Current Probe enables ac current to be measured without disturbing the circuit. This probe clips around the wire carrying the current to be measured and, in effect, makes the wire the one-turn primary of a transformer formed by ferrite cores and a many-turn secondary within the probe. The signal induced in the secondary is amplified and can be applied to any suitable ac voltmeter for measurement. The amplifier constants are chosen so that 1 mA in the wire being measured produces 1 mV at the amplifier output. Current is read directly on the voltmeter.

Summary

The basic specifications for Hewlett-Packard analog voltmeters are summarized in Table I. To help you select a voltmeter suitable to your needs, our guidelines are restated as follows:

(1) For measurements involving dc applications, select the instrument with the broadest capability meeting your requirements.

(2) For ac measurements involving sine waves with only modest amounts of distortion (<10%), the average-responding voltmeter provides the best accuracy and most sensitivity per dollar.

(3) For ac measurements involving low-level signals that may be obscured by noise or other unrelated signals, the tuned voltmeter provides the best accuracy and most sensitivity per dollar.

(4) For high-frequency measurements (>10 MHz), the peak-responding voltmeter with the diode-probe input is the most economical choice. Peak-responding circuits are acceptable if inaccuracies caused by distortion in the input waveform can be tolerated.

(5) For measurements where it is important to determine the effective power of waveforms that depart from a true sinusoidal form, the true rms-responding voltmeter is the appropriate choice.

(6) For very wide bandwidths (up to 1 GHz) and high-sensitivity measurements of sinusoidal or non-sinusoidal waveforms, the HP 3406A is the proper choice. Although the 3406A is average-responding, it has a sample hold output which makes analysis of waveforms possible.

Table 1 Hewlett-Packard Analog Voltmeters

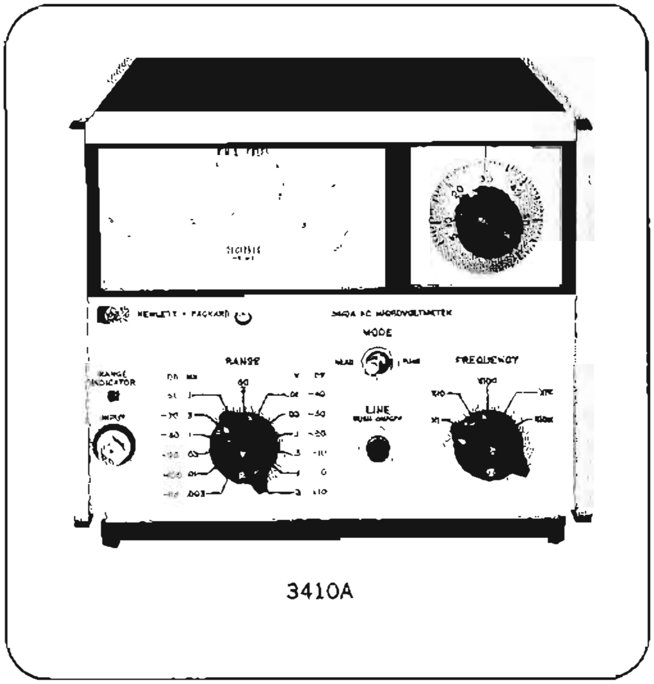
DC VOLTMETERS	Voltage Range	Frequency Range Accuracy at F.S.*	Input Impedance	Model	See Page
DC NULL VOLTMETER Internal nulling supply battery operation dc amplifier, Ammeter 30 pA-30 nA	±3 μV - ±1 kV end scale 0.1 μV resolution (18 ranges)	dc ±2% +1 μV	100 k - 100 MΩ depending on range (infinite when nulled)	419A	219
DC NULL VOLTMETER Amplifier	±1 mV - ±1 kV end scale (13 ranges)	dc ±2%	10M - 200 MΩ depending on range	413A	218
AC VOLTMETERS	**Voltage Range**	**Frequency Range Typical Accuracy**	**Response Input Impedance**	**Model**	**See Page**
BATTERY OPERATED AC VOLTMETER	1 mV - 300 V (12 ranges)	1 Hz - 1 MHz ±3% - ±5%	Average 2 MΩ/<25 - 60 pF	403A	211
RECHARGEABLE BATTERY AC VOLTMETER	1 mV - 300 V (12 ranges)	5 Hz - 2 MHz ±2% - ±5%	Average 2 MΩ/<30 - 60 pF	403B	211
VACUUM-TUBE VOLTMETER, also useful as ac amplifier	1 mV - 300 V (12 ranges)	10 Hz - 4 MHz ±2% - ±5%	Average 10 MΩ/15 - 25 pF	400D	210
Similar to 400D except has 1% accuracy		±1% - ±5%		400H	210
Similar to 400H except has linear 12 dB log scale	−70 dB - +52 dB (12 ranges)	±2% - ±5%		400L	210
FAST-RESPONSE AC VOLTMETER 100 kHz low-pass filter ac amplifier	100 μV - 300 V (14 ranges)	20 Hz - 4 MHz ±1% - ±4%	Average 10 MΩ/10 - 25 pF	400F	207
Similar to 400F except has linear 12 dB log scale	−90 dB - +52 dB	±1% - ±4%		400FL	207
HIGH ACCURACY dB VOLTMETER 20 dB log scale (0 dB = 1 V)	−100 dB - +60 dB (8 ranges)	20 Hz - 4 MHz ±0.2 dB - 0.4 dB	Average 10 MΩ/10 - 25 pF	400GL	208
HIGH ACCURACY AC VOLTMETER has dc output (±0.5%) for driving recorder	1 mV - 300 V (12 ranges)	10 Hz - 10 MHz ±1% - ±5%	Average 10 MΩ/8 - 21 pF	400E	209
Similar to 400E except has linear 12 dB log scale uppermost	−70 dB - +52 dB (12 ranges)	±1% - ±5%		400EL	209
AC MICROVOLTMETER; measures signals obscured by noise	3 μV - 3 V (13 ranges) −110 dBm to +10 dBm	5Hz - 600 kHz ±3% to ±10%	Average 10 MΩ/<10 - 20 pF	3410A	206
RMS VOLTMETER provides rms readings of complex signals. Has dc output for driving DVM's or recorders	1 mV - 300 V (12 ranges)	10 Hz - 10 MHz ±1% - ±5%	10 MΩ/15 - 40 pF	3400A	212
SAMPLING RF VOLTMETER provides true rms measurements when used with 3400A. Many accessories	1 mV - 3 V (8 ranges)	10 kHz - >1.2 GHz ±3% - ±13%	Statistical Average: Input Z depends on probe tip used	3406A	216
RF MILLIVOLTMETER	10 mV - 10 V (7 ranges)	500 kHz - 1 GHz ±3% - 1 dB	Average Input Z depends on probe tip used	411A	217
VECTOR VOLTMETER phase and amplitude measurements	100 μV - 10 V (9 ranges)	1 MHz - 1 GHz ±0.5 dB - ±1 dB	Average 0.1 MΩ/2.5 pF	8405A	467
MILLIOHMMETER; two probes used when making 4 terminal measurements	0.001 to 100Ω F.S. (11 ranges)	1 kHz (fixed) ±2% F.S.	Max. output Voltage: 20 mV	4328A	222
HIGH RESISTANCE METER and picoammeter	0.5MΩ to 2 x 10^{16}Ω F.S. 7 ranges 0.05pA to 20 μA	Voltage: ±10% Current: ±5%	Max. output Voltage: 1 kV	4329A	223
MULTIFUNCTION METERS	**Voltage Range (Accuracy)**	**Current Range (Accuracy)**	**Resistance Range (Accuracy)**	**Model**	**See Page**
AUTOVOLTMETER has automatic ranging and polarity; input impedance 10 - 100 MΩ	DC: ±5 mV - ±1500 V ±(0.5% f.s., +0.5% rdg) 12 ranges		5 Ω - 1.5 MΩ (±1% rdg, ±0.5% f.s.) 12 ranges	414A	218
BATTERY-OPERATED MULTIFUNCTION METER has 10 MΩ dc input impedance and 10 MΩ/20 pF ac input impedance	DC: ±100 mV - ±1000 V (±2%) 9 ranges AC: 10 mV - 300 V 10 Hz - 1 MHz (±2%) 10 ranges		10 Ω - 10 MΩ midscale ±5%; from .3 to 3 on the meter scale 7 ranges	427A	213
VERSATILE VOLTMETER has 100 MΩ dc input impedance and 10 MΩ/1.5 pF ac impedance	DC: ±15 mV - ±1500 V (±2%) 11 ranges AC: 0.5 V - 300 V 20 Hz - >700 MHz (±3% at 400 Hz) 7 ranges	DC: ±1.5 μA to ±150 mA (±3%) 11 ranges	10 Ω - 10 MΩ midscale; ±5% from .3 to 3 on the meter scale 7 ranges	410C	214
VACUUM-TUBE VOLTMETER has 122 MΩ dc input impedance and 10 MΩ/1.5 pF ac impedance	DC: ±1 V - ±1000 V (±3%) 7 ranges AC: 1 - 300 V 20 Hz - 700 MHz (±3% at 400 Hz) 6 ranges		10Ω - 10 MΩ midscale; ±5% from 3 to 30 on meter scale (1Ω on X1 range)	410B	215
DC VACUUM-TUBE VOLTMETER has 10 MΩ to 200 MΩ input impedance	DC: ±1 mV - ±1000 V (±1%) 13 ranges	DC: ±1 μA to ±1 A (±2%) 13 ranges	1 Ω - 100 MΩ (±5% midscale) 9 ranges	412A	220
DC MICROVOLT-AMMETER has 1 MΩ input impedance	DC: ±10 μV - ±1 V (±3%) 11 ranges	DC: ±10 pA to ±3 mA (±3%) 18 ranges		425A	221
CURRENT METERS	**Current Range**	**Accuracy**	**Frequency Range**	**Model**	**See Page**
DC MILLIAMMETER with clip-on probe eliminates direct connection	1 mA - 10 A f.s. (9 ranges)	±3%	dc-400 Hz	428B	224
AC CLIP-ON CURRENT PROBE makes measurements without breaking circuit	1 mA - 1 A rms (to 25 A with divider)	±2% to 3 dB	25 Hz - 20 MHz	456A	225

*For exact accuracy refer to page designated.

AC MICROVOLTMETER

Measure signals obscured by noise

Model 3410A



3410A

Uses:

- Measure amplitude of signal buried in noise
- Measure amplitude of ripple frequency
- Measure amplitude of superimposed frequency
- Use as a Preamp/Noise Discriminator for frequency measurements

The HP Model 3410A AC Microvoltmeter is a tuneable, phase lock voltmeter designed to measure low level repetitive signals obscured by noise or in the presence of other non-harmonically related signals. Its sensitivity is 3 μV to 3 V full scale in 13 ranges over a frequency range of 5 Hz to 600 kHz. Signals obscured by noise 20 dB above full scale can be detected and measured with no degradation in accuracy.

Frequency of low level and noise repetitive signals can be accurately measured using a frequency counter connected to the local oscillator output on the rear panel of the 3410A. This signal is a 4 V square wave, phase locked to the tuned input signal. Counter sensitivity can be increased to better than 300 nanovolts (the point at which phase lock is lost on the 3 microvolt range) with excellent noise discrimination.

A dc recorder output enhances the usefulness of the 3410A as a sensitive detector for graphic recording.

Specifications

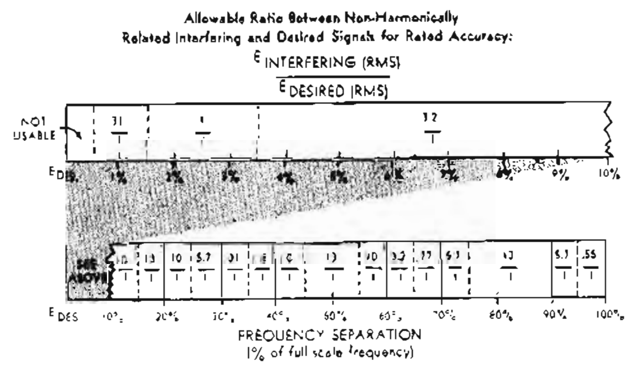
Voltage range: 3 μV full scale to 3 V full scale in 13 ranges.

Voltage accuracy: (% of full scale).

Frequency

	5 Hz – 10 Hz	10 Hz – 25 Hz	25 Hz – 100 Hz	100 Hz – 50 kHz	50 kHz – 600 kHz
30 μV TO 3 V	±10%	±3%			±5%
10 μV	±15%*	±10%*	±3%		±5%
3 μV		±20%*	±10%	±3%	±10%

*At lower frequencies and microvolt signal levels, meter fluctuations in the READ MODE may give the impression of an unstable lock condition. However, the 3410A will lock and track at these lower frequencies and provide a stable voltage indication.



Frequency range: 5 Hz to 600 kHz in 5 decade ranges.

Frequency dial accuracy: ±10% full scale (unlocked).

Phase lock range: pull in ±1% of full scale frequency. Track ±5% of full scale frequency. Tracking speed 0.5% of full scale frequency/second.

Maximum noise rejection: 20 dB rms above full scale on all ranges for rated accuracy.

Input impedance: 10 mV to 3 V range, 10 MΩ shunted by <10 pF. 3 μV to 3 mV range, 10 MΩ shunted by <20 pF.

Meter indication: responds to average value of input waveform; calibrated in rms value of sine wave. Linear voltage scales 0 to 1 and 0 to 3; dB scale −12 to +2 dB (0 dB = 1 mW into 600Ω).

Local oscillator output: >4 V square wave into open circuit at the same frequency as the phase locked input signal.

DC output: 1 V into 1000Ω for full scale, proportional to meter deflection; ±0.5 V adjustable offset level.

AC power: 115 or 230 V ±10%, 50 to 400 Hz, 22 W.

Weight: net 10 lbs (4,5 kg); shipping 12.5 lbs (5,6 kg).

Dimensions: 7¾" wide, 6¼" high (without removable feet), 11" deep (197 x 159 x 279 mm).

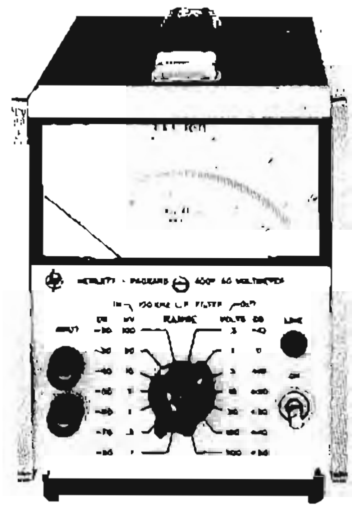
Accessories available: HP 11074A Voltage Divider Probe. Provides 10:1 division ratio to extend 3410A input to 30 V rms full scale, $50.

Price: HP 3410A, $875. HP 3410A Option 01, dB scale uppermost, add $10.

AC VOLTMETERS

Measure 20 Hz to 4 MHz, 100 µV to 300 V

Models 400F, 400FL



400F

Description

The HP 400F/FL Solid-State AC Voltmeters are ruggedly built precision instruments for measuring ac voltages from 100 microvolts to 300 V rms full scale. They cover a frequency range from 20 Hz to 4 MHz and have constant 10 megohm input resistance on all ranges. Input capacity is 25 pF on the 100 µV to 300 mV range and 10 pF on the 1 volt to 300 volt range. The instruments are simple to operate and give direct voltage and dBm readings. The 400F/FL may also be used as stable, high-gain ac amplifiers with up to 80 dB amplification.

100 kHz low pass filter

In order to reduce the effect of unwanted high frequencies (noise, etc.) on the accuracy of measuring lower frequency signals, a 100 kHz low-pass filter is provided. It may be activated by a front-panel switch. The filter is effective on all ranges but will be of greater use on more sensitive ranges. It has 3 dB of attenuation at 100 kHz ±5 kHz.

Battery operation

The Models 400F/FL can be operated from two 35-to-55-volt batteries connected to the rear-panel battery terminals. This feature is ideal for communications usage or when ground loops cause trouble.

Model 400F

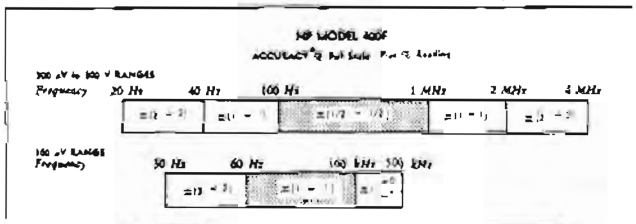
The 400F has all the characteristics mentioned in the general description with ½% of reading plus ½% of full scale accuracy on a 4½" mirror-backed taut-band meter. The meter is individually calibrated with 100 divisions to provide greater resolution. The Model 400F Option 01 with dB scale uppermost is recommended for greater resolution in dB measurements.

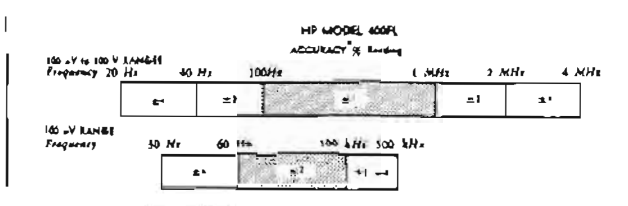
Model 400FL

The 400FL has all the characteristics mentioned in the general description with 1% of reading accuracy on a linear 12 dB logarithmic scale. This meter is also individually calibrated with 120 divisions and is ideal for dB measurements. It incorporates a Hewlett-Packard taut-band, mirror-backed, logarithmic meter. A range switch changes sensitivity in 10 dB steps which, combined with the 12 dB scale, provides the overlap desirable in decibel-level measurements.

Specifications

Frequency range: 20 Hz to 4 MHz.
Voltage range: 100 µV to 300 V full scale, 14 ranges.



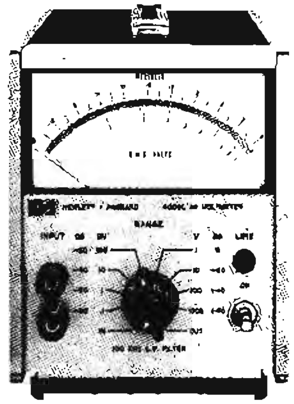


Voltage Ranges	Filter In	Filter Out
300 µV to 300 V	<5 µV	<30 µV
100 µV	<5 µV	<15 µV

AC VOLTMETER

20 dB linear scale, measures −100 to +60 dB

400GL



400GL

Description

The HP Model 400GL features 20 dB dynamic range on a large 4½ inch linear scale—permitting measurements of voltages of widely different levels with a minimum of range switching. This is especially beneficial when measuring input and output levels of devices such as amplifiers and attenuators, since it saves times and reduces errors. The 400GL has only one voltage scale; reading time is faster and the possibility of reading errors is further minimized. Furthermore, accuracy and resolution is uniform over the entire scale, making each range completely usable.

In order to reduce the effect of unwanted high frequencies (noise, etc.) on the accuracy of measuring small low frequency signals, a switchable low pass filter is provided. When activated, the filter attenuates frequencies above 100 kHz.

For field applications and for ground loop isolation, the 400GL can be battery operated by connecting two 35-50 volt batteries to the rear panel terminals.

The 400GL can also be used as a stable, high gain 4 MHz amplifier, with up to 80 dB gain on the lower ranges. Output is proportional to the voltage indicated on the meter.

Specifications

Voltage range: 100 µV to 1000 V full scale, 8 ranges.

Frequency range: 20 Hz to 4 MHz.

Calibration: responds to average value of input waveform; calibrated in rms value of a sine wave. Linear dB scale, 100 divisions from −20 to 0 dB. Logarithmic voltage scale 0 dB = 1 V.

Accuracy (dB of Reading):

	20 Hz – 40 Hz	40 Hz – 500 kHz	500 kHz – 2 MHz	2 MHz – 4 MHz
1 mV - 1000 V* Ranges	±0.4 dB	±0.2 dB	±0.4 dB	+0.2 dB −0.4 dB

	30 Hz – 60 Hz	60 Hz – 100 kHz	100 kHz – 500 kHz
100 µV Range	±0.4 dB	±0.2 dB	+0.2 dB −0.1 dB

* For input voltages greater than 300 volts, the high frequency range is limited to 100 kHz.

Noise referred to Input (1000 ohm termination):

	Filter in	Filter out
1 mV - 1000 V	<5 µV	<30 µV
100 µV Range	<5 µV	<15 µV

Note: Noise adds to the signal approximately by the relation:

$$\text{Reading} = \sqrt{(\text{signal})^2 + (\text{Noise})^2}$$

Temperature range: 0 to +55°C.

Recovery from overload: <2 seconds for 80 dB overload (1200 V max. input).

Input impedance: resistance: 10 MΩ all ranges,
capacitance: <30 pF for 100 µV-100 mV ranges.
<15 pF for 1 V-1000 V ranges.

Amplifier ac output: 1 V rms open circuit (full scale) and is proportional to meter indication on the voltage scale; output impedance 600 ohms. Frequency response 20 Hz to 4 MHz.

AC power: 115 or 230 V ±10%, 50 to 400 Hz, 5 W.

External battery operation: terminals are provided on rear panel; positive and negative voltages between 35 V and 55 V are required; current drain from each battery is approximately 45 mA. (External switching and on/off monitoring should be used for battery operation.)

Dimensions: 5⅛" wide, 6¼" high (without removable feet), 11" deep (130 x 159 x 279 mm).

Weight: net 6 lbs (2,7 kg); shipping 8 lbs (3,6 kg).

Accessories available: HP 11074A, 10:1 Voltage Divider Probe.

Price: HP 400GL, $325.

Voltage divider probe

The Voltage Divider Probe (HP 11074A) with a banana post to BNC adapter (HP 10111A) provides low input capacitance at the point of measurement when using the 400 series voltmeters.

Specifications

Input impedance: 10 megohms shunted by 10 pF.

Division ratio: 10:1.

Division ratio accuracy: ±2%.

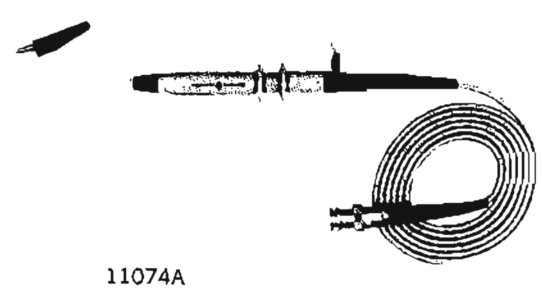
Bandwidth: dc to 10 MHz.

Maximum input voltage: 1000 V rms.

Terminals: alligator clip contactor with BNC output connector.

Length and weight: 5 feet, approximately 4 oz.

Price: HP 11074A Voltage Divider Probe, $50. HP 10111A Adapter, $7.
HP 11076A Instrument Case (refer to page 227). Price, $45.



11074A

AC VOLTMETERS
Measure 10 Hz to 10 MHz, 1 mV to 300 V
Models 400E, 400EL

Description

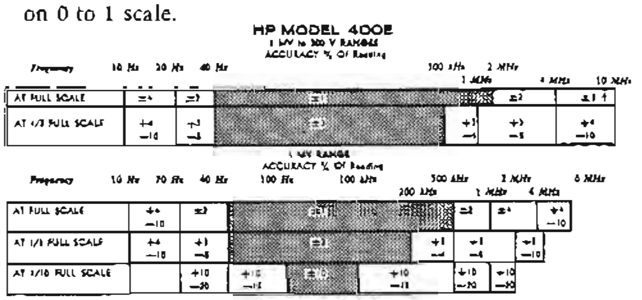
The HP 400E/EL Solid-State AC Voltmeters are ruggedly built precision instruments for measuring ac voltages from 1 mV to 300 V rms full scale. They cover a frequency range from 10 Hz to 10 MHz and have constant 10 MΩ input resistance on all ranges. Input capacity is <25 pF on the 1 mV to 1 volt range and <12 pF on the 3 volt to 300 volt range. The instruments are simple to operate and give direct voltage and dBm readings.

Specifications, 400E, 400EL

Voltage range: 1 mV to 300 V full scale, 12 ranges.
Frequency range: 10 Hz to 10 MHz.

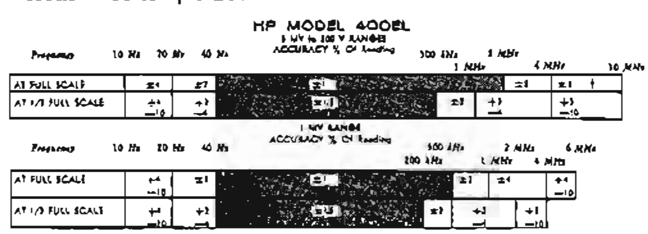
Model 400E

Calibration: reads rms value of sine wave; voltage indication proportional to absolute average value of applied wave; dB scale −10 to +2 dB, 10 dB between ranges; 100 divisions on 0 to 1 scale.

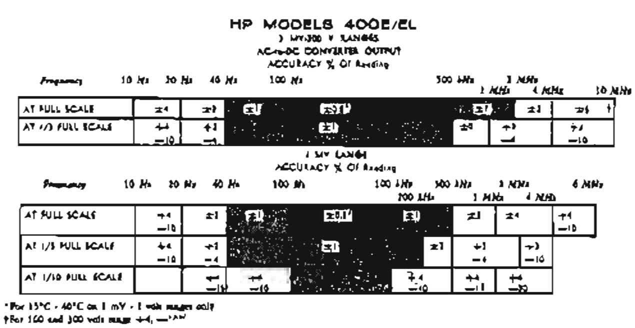


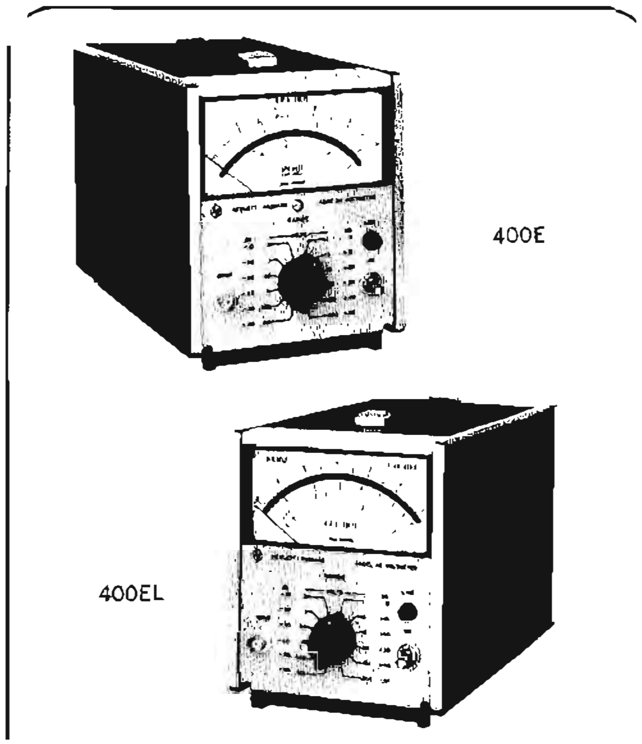
Model 400EL

Calibration: reads rms value of sine wave; voltage indication proportional to absolute average value of applied wave; linear dB scale −10 dB to +2 dB, 10 dB between ranges; logarithmic voltage scales 0.3 to 1 and 0.8 to 3; 120 divisions from −10 to +2 dB.



Model 400/EL





Input Impedance: 10 MΩ shunted by <25 pF on the 1 mV to 1 V ranges, and 10 MΩ shunted by <12 pF on the 3 V to 300 V ranges.

Amplifier ac output: 150 mV rms ±10% for full scale meter indication; output impedance 50Ω, 10 Hz to 10 MHz (105 mV on the 1 mV range); accuracy ±10%, 10 Hz to 4 MHz.

AC-DC converter output: 1 V dc output for full scale meter deflection (linear output).
Output resistance: 1000Ω ±5%.
Response time: 2 s to within 1% of final value for a step change.

Meter response time: 1< s, 0 to full scale.

Temperature range: 0 to +55°C (except where noted on accuracy charts).

AC power: 115 or 230 V ±10%, 50 to 400 Hz, 5 W.

External battery operation: terminals are provided on rear panel; positive and negative voltages between 35 V and 55 V are required; current drain from each voltage is 54 mA (external switching and on/off monitoring should be used for battery operation).

Dimensions: standard 1/3 module 5⅛" wide, 6¼" high (without removable feet), 11" deep (130 x 165 x 279 mm).

Weight: net 6 lbs (2,7 kg); shipping 8 lbs (3,6 kg).

Accessories available: 11076A Instrument Case (refer to page 227, $45. 11074, 10:1 voltage divider probe, $50.

Price: HP 400E, $325, HP 400EL, $335.
Option 01 (400E only): reads directly in volts and dB with dB scale uppermost, add $10.
H05-400E/EL: constant input capacity available on special order, price on request (optimum performance for 11074A Voltage Divider Probe).

VACUUM TUBE VOLTMETERS

Quality linear and log voltmeters

Models 400D, 400H, 400L

400D

400H

400L

Description

Model 400D is essentially a low-priced precision voltmeter offering wide voltage range, 2% accuracy and the broad frequency coverage 10 Hz to 4 MHz.

Model 400H is an adaptation of Model 400D but offering individual meter-face calibration and 1% accuracy on an extra large 5″ mirror-scale meter.

Model 400L, a logarithmic version of Model 400D, has an accuracy of ±2% of reading or ±1% of full scale, whichever is more accurate. The 5″ meter is mirror-backed.

Special dB-measuring options

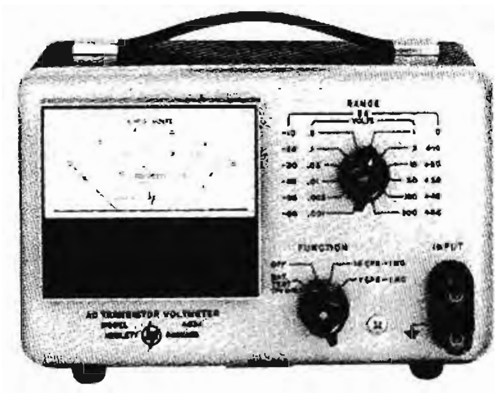
As normally supplied, Models 400D and 400H read direct in volts and dB, with the voltage scale uppermost. For greater resolution in dB measuring, these instruments are available as Models 400D Option 01, and 400H Option 01 ($25 extra) with the dB meter scale uppermost.

Specifications

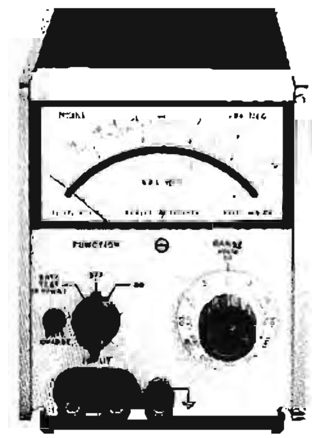
	400D,DR	400H,HR	400L,LR
Voltage range:	1.0 mV to 300 V full scale, 12 ranges	1.0 Mv to 300 V full scale, 12 ranges	−70 dB to +52 dB in 12 ranges 1.0 mV to 300 V full scale, 12 ranges
Frequency range:	10 Hz to 4 MHz		
Accuracy:	10 Hz to 20 Hz: ±5% f.s. 20 Hz to 1 MHz: ±2% f.s. 1 MHz to 2 MHz: ±3% f.s. 2 MHz to 4 MHz: ±10% f.s.	10 Hz to 20 Hz: ±5% f.s. 20 Hz to 50 Hz: ±2% f.s. 50 Hz to 500 kHz: ±1% f.s. 500 kHz to 1 MHz: ±2% f.s. 1 MHz to 2 MHz: ±3% f.s. 2 MHz to 4 MHz: ±10% f.s.	10 Hz to 20 Hz: ±5% of rdg. 20 Hz to 50 Hz: ±3% of rdg. or ±2% of f.s.† 50 Hz to 500 kHz: ±2% of rdg. or ±1% of f.s.† 500 kHz to 1 MHz: ±3% of rdg. or ±2% of f.s.† 1 MHz to 2 MHz: ±4% of rdg. or ±3% of f.s.† 2 MHz to 4 MHz: ±10% of rdg.
Calibration:	reads rms value of sine wave; voltage indication proportional to average value of applied wave; linear voltage scale 0 to 3 and 0 to 1; dB scale −12 to +2 dB (0 dB = 1 mW in 600 ohms); 10 dB interval between ranges		reads rms value of sine wave; logarithmic voltage scale 0.3 to 1 and 0.8 to 3; linear dB scale, −10 dB to +2 dB (based on 0 dB = 1 mW in 600 ohms); 10 dB intervals between ranges
Input impedance:	10 megohms shunted by <20 pF on ranges 1 to 300 V; <35 pF on ranges 0.001 to 0.3 V		
Amplifier:	output 0.15 V max.; internal impedance 50 ohms; max. gain 150 on 0.001 range		
Power:	115 or (230 volts must be specified) ±10%, 50 to 400 Hz; 80 watts (100 watts for 400 H,L)		
Dimensions:	cabinet mount: 7½″ wide, 11½″ high, 12″ deep (191 x 292 x 305 mm) rack mount: 19″ wide, 7″ high, 10⅞″ deep behind panel (483 x 389 x 276 mm)		
Weight:	net 18 lbs (8,1 kg), shipping 19 lbs (8,6 kg) (cabinet mount); net 21 lbs (9,45 kg), shipping 31 lbs (14 kg) (rack mount)		
Price:	HP 400D, $275* HP 400DR, $280**	HP 400H, $375* HP 400HR, $380**	HP 400L, $385* HP 400LR, $390**

*Cabinet. † % of full scale (f.s.) or % of reading (rdg.) whichever is more accurate.
**Rack mount.

AC VOLTMETERS
Solid-state, battery-operated, portable
Model 403A, B



403A



403B

Description

Models 403A and 403B ac voltmeters are versatile, general-purpose instruments for laboratory and production work and are ideal for use in the field, since they are solid-state, battery-operated and portable.

Both measure from 100 microvolts to 300 volts, the 403A covering 1 Hz to 1 MHz and the 403B covering 5 Hz to 2 MHz. Both operate from internal batteries and, thus, may be completely isolated from the power-line and external grounds, permitting accurate measurements at power-line frequency and its harmonics without concern for beat effects. Isolation from external ground also permits use where ground loops are troublesome. Turnover effect and waveform errors are minimized because the meters respond to the average value of the input signal.

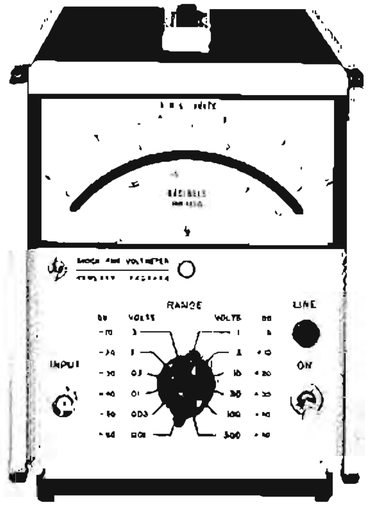
The 403B operates from an ac line as well as from the internal battery pack, and batteries recharge during ac operation. Battery charge may be easily checked with a front-panel switch to assure reliable measurements. Normally, about 15 hours of ac operation recharges the batteries; but an internal adjustment is provided which nearly doubles the charging rate. You can use the Model 403B while its batteries charge. A sturdy taut-band meter eliminates friction and provides greater precision and repeatability.

For improved resolution in dB measurements, the 403B Option 01 is available. This version spreads out the dB scale by making it the top scale of the meter.

Specifications

HP Model	403A	403B	403B (Option 01.)
Range	0.001 to 300 V rms full scale, 12 ranges, in a 1, 3, 10 sequence.		
Accuracy	within ±3% of full scale, 5 Hz to 500 kHz; within ±5% of full scale, 1 to 5 Hz and 500 kHz to 1 MHz	within ±2% of full scale from 10 Hz to 1 MHz; within ±5% of full scale from 5 to 10 Hz and 1 to 2 MHz, except ±10% 1 to 2 MHz on the 300 V range (0 to 50°C)*	within ±0.2 dB of full scale from 10 Hz to 1 MHz; within ±0.4 dB of full scale from 5 to 10 Hz and 1 to 2 MHz, except ±0.8 dB 1 to 2 MHz on the 300 V range (0 to 50°C)*
Input impedance	2 megohms shunted by <60 pF, 0.001 to 0.1V ranges; 2MΩ shunted by <25 pF on 0.3 to 300 volt ranges	2 megohms; shunted by <60 pF; 0.001 to 0.03 V ranges; <30 pF, 0.1 to 300 V ranges	same as 403B
Maximum input	600 V peak, 0.3 V and higher ranges; 25 V rms on 0.1 V and lower ranges (fused).	600 V peak, 0.3 to 300 V range; 25 V rms, 60 V peak, 0.001 to 0.1 V ranges (fused).	same as 403B
Power	5 standard radio-type mercury cells, battery life approx. 400 hours	4 rechargeable batteries, 40 hours' operation per recharge, up to 500 recharging cycles; self-contained recharging circuit functions during operation from ac line	same as 403B
Dimensions	8½" wide, 5½" high, 6⅜" deep (210 x 140 x 162 mm)	5⅛" wide, 6¼" high (without removable feet), 8" deep (130 x 159 x 203 mm)	same as 403B
Weight	net 4¾ lbs (2,1 kg); shipping 7 lbs (3,2 kg)	net 6½ lbs (2,9 kg); shipping 8 lbs (3,6 kg)	same as 403B
Price	$320	$340	$365

RMS VOLTMETER
Specified ac to dc converter
Model 3400A



3400A

Description

The Hewlett-Packard Model 3400A is a true root-mean-square (rms) voltmeter, providing a meter indication proportional to the dc heating power of the input waveform. In addition to its meter indication, the Model 3400A provides a dc output proportional to meter deflection making it a useful true rms detector for graphic recording and digitizing with a dc digital voltmeter, such as the HP Model 3440A.

Versatility

Versatility of the Model 3400A is enhanced by its wide 10-Hz to 10-MHz frequency response, high crest factor, 1-mV to 300-Volt full-scale sensitivity and 10-MΩ input impedance. Six-decade frequency coverage makes the 3400A extremely flexible for all of your audio and most rf measurements and permits the measurement of broadband noise and fast-rise pulse. A wide range of sensitivity (12 ranges) allows you to measure anything from "down in the grass" signal and noise, to transmitter and amplifier outputs (with 30-dB overload protection). Pulses or other non-sinusoids with crest factors (ratio of peak to rms) up to 10:1 can be measured full scale. Crest factor is inversely proportional to meter deflection, permitting up to 100:1 crest factor at 10% of full scale. The ability of the 3400A to accept waveforms with such large crest factors insures accurate noise and pulse measurements, without the need for correction factors. Permanent plots of measured data and higher resolution measurements can be obtained by connecting an X-Y plotter, strip chart recorder or digital voltmeter to the convenient rear-panel dc output. The dc output provides a linear 0 to 1-volt drive, proportional to meter deflection.

True-rms current measurements can be made conveniently by using the HP Model 456A Current Probe with the Model 3400A. See page 225.

Specifications

Voltage range: 1 mV to 300 V, 12 ranges.

DB range: −72 to +52 dBm (0 dBm = 1 mW into 600Ω).

Frequency range: 10 Hz to 10 MHz.

Response: responds to rms value (heating value) of the input signal for all waveforms.

Meter accuracy: % of full scale (20°C to 30°C)*

10 Hz 50 Hz 1 MHz 2 MHz 3 MHz 10 MHz

±5%	±1%	±2%	±3%	±5%

Ac-to-dc converter accuracy: % of full scale (20°C to 30°C)*

10 Hz 50 Hz 1 MHz 2 MHz 3 MHz 10 MHz

±5%	±0.75%	±2%	±3%	±5%

Crest factor: (ratio of peak amplitude to rms amplitude): 10 to 1 at full scale (except where limited by maximum input) inversely proportional to pointer deflection, (e.g., 20 to 1 at half-scale, 100 to 1 at tenth scale).

Maximum dc input: 600 V on any range.

Input impedance: from 0.001 V to 0.3 V range: 10 MΩ shunted by <50 pF. From 1.0 V to 300 V range: 10 MΩ shunted by <20 pF.

Response time: for a step function, <5 seconds to respond to final value.

Ac overload: 30 dB above full scale or 800 V peak, whichever is less, on each range.

Output: negative 1 V dc into open circuit at full-scale deflection, proportional to pointer deflection. (From 10-100% of full scale.) 1 mA maximum; nominal source impedance is 1000Ω. Output noise <1 mV p-p.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 7 W.

Dimensions: 5⅛" wide, 6¼" high (without removable feet), 11" deep (⅓ module). (130 x 159 x 279 mm).

Weight: net: 7¼ lbs (3,3 kg); shipping: 10 lbs (4,5 kg).

Accessories furnished: 10110A Adapter, BNC to dual banana jack.

Accessories available: 11001A Cable, 45 in. long, male BNC to dual banana plug, $6.00. 10503A Cable, 4 ft. long, male BNC connectors, $7.00. 11002A Test Lead, dual banana plug to alligator clips, $8.00. 11003A Test Leads, dual banana plug to probe and alligator clip, $10. 11076A Carrying Case (refer to page 228), $45.00. HP Model 456A AC Current Probe, 1 mV/1mA, $225.

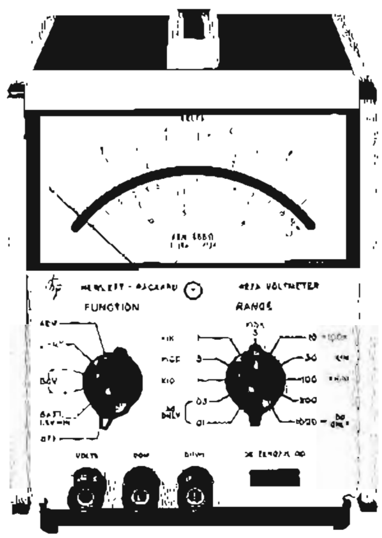
Price: HP 3400A, $525.

HP Model 3400A (Option 01) spreads out the dB scale by making it the top scale of the meter, add $25.

Rear terminals in parallel with front panel terminals and linear log scale uppermost on the meter face are available on special order.

*TC: ±0.1% from 0°C to 20°C and 30°C to 55°C.

MULTI-FUNCTION METER
Low-cost, solid state, battery operated
Model 427A



427A

Description

The Hewlett-Packard Model 427A is a portable, versatile, low cost multi-function meter which is valuable in any laboratory, production line, service department, or in the field. It is capable of measuring dc voltages from 100 mV to 1 kV full scale; ac voltage from 10 mV to 300 V full scale at frequencies up to 1 MHz (>500 MHz with the 11096A High Frequency Probe); and resistance from 10Ω to 10 MΩ center scale.

The 427A will operate continuously for more than 300 hours on its internal 22.5 V dry cell battery. AC line and battery operation is available as an option.

Specifications

DC voltmeter

Ranges: ±100 mV to ±1000 V in 9 ranges in 10 dB steps.

Accuracy: ±2% of range.

Input resistance: 10 MΩ.

AC normal-mode rejection (ACNMR): ACNMR is the ratio of the normal-mode signal to the resultant error in read-out. 50 Hz and above: >80 dB.

Overload protection: 1200 V dc.

AC voltmeter

Ranges: 10 mV to 300 V in 10 ranges in 10 dB steps.

Frequency range: 10 Hz to 1 MHz.

Response: responds to average value, calibrated in rms.

Accuracy:

Frequency	Range	
	.01 V to 30 V	100 V to 300 V
10 Hz to 100 kHz	2% of range	2% of range
100 kHz to 1 MHz	2% of range	

Input impedance: 10 mV to 1 V range, 10 MΩ shunted by <40 pF; 3 V to 300 V range, 10 MΩ shunted by <20 pF.

Overload protection: 10 mV to 1 V range, 100 V; 3 V to 300 V range, 450 V.

Ohmmeter

Ranges: 10Ω to 10 MΩ center scale in 7 decade ranges.

Accuracy (from .3 to 3 on scale): ±5% of reading.

Source current (ohms terminal positive). Short circuit current: from 10 mA on the X10 range to 0.1 μA on the X10 M range.

Open circuit voltage: from 0.1 V on the X10 range to 1 V on the X10 M range.

Input: may be floated up to ±500 V dc above chassis ground. Ohms input open in any function except ohms. Volts input open when instrument is off.

Operating temperature: 0°C to 50°C.

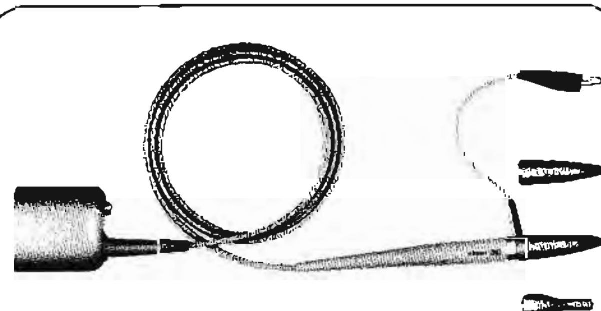
Power: >300-hr operation per battery.

HP 427A: 22.5 V dry cell battery, Eveready No. 763 or RCA VS102. HP 427A Option 01: battery operation or ac line operation, selectable on rear panel. 115 V or 230 V ±20% 50 Hz to 400 Hz, <0.5 W.

Dimensions (standard ⅓ module): 5⅛" wide, 6¼" high (without removable feet), 8" deep (130 x 159 x 203 mm).

Weight: net 5.3 lb (2,4 kg); shipping 7 lb (3,2 kg).

Price (includes battery): HP 427A, $225.
HP 427A Option 01, add $25.



11096A

Accessories available:

HP 11096A High Frequency AC Probe extends range to >500 MHz. With the 11096A you can measure 0.25 to 30 V rms signals out to 500 MHz with better than ±1 dB accuracy. Usable relative measurements can be made up to 1 GHz (3 dB point at 700 MHz). The 11096A is a peak-responding detector calibrated to produce a dc output proportional to the rms value of a sine wave input. Input impedance is 4 MΩ shunted by 2 pF.
Price: HP 11096A, $45.

HP 11075A High Impact Case. A rugged case for carrying, storing and operating the 427A, $45.

HP 11001A 45" test lead, dual banana plug to male BNC, $6.

HP 11002A 60" test lead, dual banana plug to alligator clips, $8.

HP 11003A 60" test lead, dual banana plug to pencil probe and alligator clip, $10.

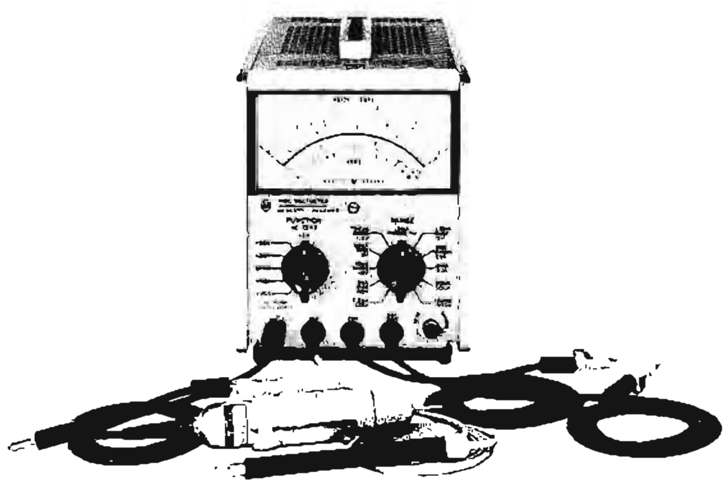
HP 11039A 1000: 1 capacitive voltage divider, 25 kV max, $185.

HP 10111A BNC female to dual banana adapter, $7.

MULTIFUNCTION VOLTMETERS

All-purpose instruments measure to 700 MHz

Models 410C, 410B, accessories



410C

Description

The HP Model 410C is a versatile general-purpose instrument for use anywhere electrical measurements are made. This one instrument measures dc voltages from 15 mV to 1500 V, direct current from 1.5 μA to 150 mA, and resistance from 0.2 Ω to 500 MΩ. With a standard plug-in probe, ac voltages at 20 Hz to 700 MHz from 50 mV to 300 V and comparative indications to 3 GHz are attainable.

410C Specifications

DC voltmeter

Voltage ranges: ±15 mV to ±1500 V full scale in 15, 50 sequence (11 ranges).
Accuracy: ±2% of full scale on any range.
Input resistance: 100 MΩ ±1% on 500 mV range and above, 10 MΩ ±3% on 150 mV range and below.

AC voltmeter

Voltage ranges: 0.5 V to 300 V full scale in 0.5, 1.5, 5 sequence (7 ranges).
Frequency range: 20 Hz to 700 MHz.
Accuracy: ±3% of full scale at 400 Hz for sinusoidal voltages from 0.5 V to 300 V rms. The ac probe responds to the positive peak-above-average value of the applied signal. The meter is calibrated in rms.
Frequency response: ±2% from 100 Hz to 100 MHz (400 Hz ref.), ±10% from 20 Hz to 100 Hz and from 100 MHz to 700 MHz.
Input impedance: input capacitance 1.5 pF, input resistance >10 MΩ at low frequencies. At high frequencies impedance drops off due to dielectric loss.
Safety: the probe body is grounded to chassis at all times for safety. All ac measurements are referenced to chassis.

DC ammeter

Current ranges: ±1.5 μA to ±150 mA full scale in 1.5, 5 sequence (11 ranges).
Accuracy: ±3% of full scale on any range.
Input resistance: decreasing from 9 kΩ on 1.5 μA range to approximately 0.3 Ω on the 150 mA range.
Special current ranges: ±1.5, ±5 and ±15 nA may be measured on the 15, 50 and 150 mV ranges using the dc voltmeter probe, with ±5% accuracy and 10 MΩ input resistance.

Ohmmeter

Resistance range: resistance from 10 Ω to 10 MΩ center scale (7 ranges).
Accuracy: ±5% of reading from .3 to 3 on the meter scale.

Amplifier

Voltage gain: 100 maximum.
AC rejection: 3 dB at 0.5 Hz; approximately 66 dB at 50 Hz and higher frequencies for signals <1600 V peak or 30 times full scale, whichever is smaller.
Isolation: impedance between common and chassis is >10 MΩ in parallel with 0.1 μF. Common may be floated up to 400 V dc above chassis for dc and resistance measurements.
Output: proportional to meter indication; 1.5 V dc at full scale, maximum current, 1 mA.
Output impedance: <3 Ω at dc.
Noise: <0.5% of full scale on any range (p-p).
DC drift: <0.5% of full scale/yr at constant temperature; <0.02% of full scale/°C.
Overload recovery: recover from 100:1 overload in <3 s.

General

Maximum input: DC; 100 V on 15, 50 and 150 mV ranges, 500 V on 0.5 to 15 V ranges, 1600 V on higher ranges. AC: 100 times full scale or 450 V peak, whichever is less.
Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, 20 W maximum.
Dimensions: 5⅛" wide, 6¼" high (without removable feet), 11" deep (130 x 159 x 279 mm) behind panel.
Weight: net 8 lb (4 kg); shipping 12 lb (5, 44 kg).
Accessories furnished: detachable power cord, NEMA plug.
Accessories available: 11076A carrying case (page 227), $45.
Price: HP 410C with HP 11036A Detachable AC Probe, $475. 410C Option 02 (less ac probe), deduct $50.

VACUUM TUBE VOLTMETER
Model 410B

Because of the large number of tasks it will perform, the 410B Vacuum Tube Voltmeter can play a uniquely valuable role in any laboratory, broadcast station or production test department. It combines in one instrument an ac voltmeter covering the frequency range from audio to radar frequencies, a dc voltmeter with 100 MΩ input impedance, and an ohmmeter capable of measuring resistance from 0.2 Ω to 500 MΩ.

410B

410B specifications

Ranges: 1 V to 300 V full scale in 6 ranges; 1, 3, 10, 30, 100 and 300 V ac or dc, and 1000 V dc. Resistance, 0.2 Ω to 500 MΩ in 7 ranges. Midscale reading of 10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ and 10 MΩ.

Accuracy: ±3% of full scale on all ranges for sinusoidal ac voltages at 400 Hz and for dc voltages. The ac portion of the instrument is peak responding, calibrated in rms volts. Ohmmeter accuracy is ±1 Ω at midscale on Rx1 range, ±5% at midscale on all other ranges. (Midscale is 3 to 30 on the meter face.)

Frequency response: ±1 dB, 20 Hz to 700 MHz. Probe resonant frequency is about 1250 MHz, and an indication can be obtained up to 3000 MHz.

Input impedance: input capability is 1.5 pF, input resistance is 10 MΩ at low frequencies. At high frequencies resistance drops off due to dielectric losses. DC input resistance is 122 MΩ for all ranges.

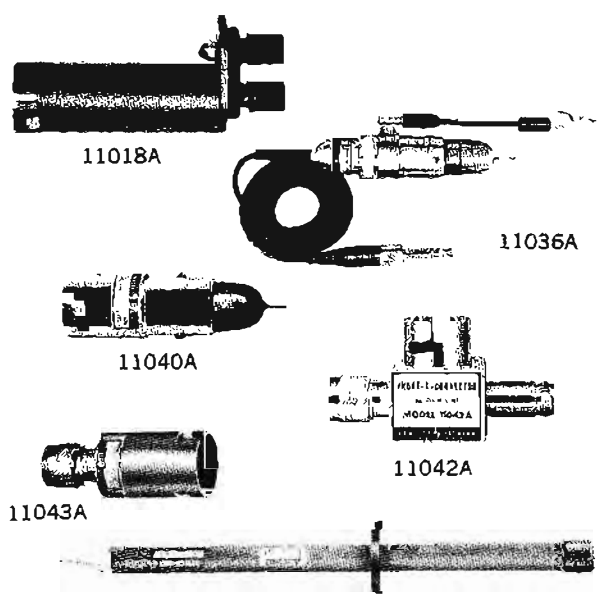
Power: 115 V or (230 V must be specified) ±10%, 50 Hz to 400 Hz, 40 W.

Dimensions: cabinet; 7⅜" wide, 11½" high, 8¾" deep (187 x 292 x 223 mm). Rack; 19" wide, 6³¹⁄₃₂" high, 6" deep behind panel (483 x 177 x 152 mm).

Weight: cabinet; net 12 lb (5,4 kg), shipping 13 lb (5,9 kg). Rack; net 12 lb (5,4 kg), shipping 19 lb (8,6 kg).

Price: HP 410B, $300 (cabinet); HP 410BR, $320 (rack mount).

410 series accessories



11044A/11045A

HP 11039A Capacitive Voltage Divider

Safely measures power voltages to 25 kV (see page 225). Division ratio 1000:1 price 11039A, $185.

(Use HP 11018A adapter to connect to 410 series Voltmeter).

11018A Adapter

Connects 410 series ac probe to dual banana plugs. Price: HP 11018A, $35.

11036A Probe

AC probe for the 410C. Price: HP 11036A, $60.

11040A Capacitive Voltage Divider

For 410 series voltmeters. Increases range so transmitter voltages can be measured quickly, easily. Accuracy, ±1%; division ratio, 100:1; input capacity, approximately 2 pF. Maximum voltage, 2000 V at 50 MHz, decreasing to 100 V at 400 MHz. Frequency range, 10 kHz to 400 MHz. Price: HP 11040A, $35.

11042A Probe Coaxial "T" Connector

For 410 Series voltmeters. Measures voltages between center conductor and sheath of 50 Ω transmission line. Maximum SWR, 1.1 at 500 MHz, 1.2 at 1 GHz. Male and female Type N fittings. Price. HP 11042A, $50.

11043A Probe Coaxial "N" Connector

For 410 Series voltmeters. Measures at open end of 50 Ω transmission line (no terminating resistor). Has male Type N fittings. Price: HP 11043A, $38.

11044A dc Voltage Divider

For 410B Voltmeter. Gives maximum safety and convenience for measuring high voltages as in television receivers, etc. Accuracy, ±5%; division ratio, 100:1. Input impedance, 12 GΩ. Maximum voltage, 30 kV. Maximum current drain, 2.5 μA. Price: HP: 11044A, $50.

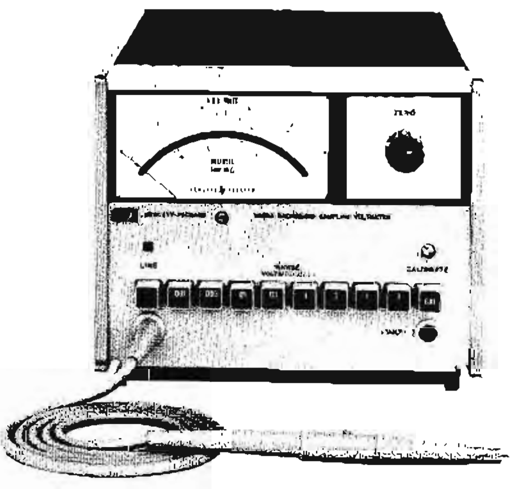
11045A dc Voltage Divider

For 410C Voltmeter. Same as 11044A except input impedance, 10 GΩ. Price: HP 11045A, $50.

RF VOLTMETER

20 μV sensitivity; average-response

Model 3406A



3406A

Description

Average-response (calibrated in rms of a sine wave) of high frequency signals previously impractical can now be made easily with the HP 3406A Sampling Voltmeter. Employing incoherent sampling techniques, the HP 3406A has extremely wide bandwidth (10 kHz to 1.2 GHz) with high input impedance. Signals as small as 50 μV can be resolved on the sampling voltmeter's linear scale. Full scale sensitivity from 1 mV to 3 V is selected in eight 10 dB steps and may be read directly from −62 dBm to +23 dBm for power measurements. Accessory probe tips make the HP 3406A suitable for voltage measurements in many applications such as receivers, amplifiers and coaxial transmission lines.

Measurement indications can be retained on the 3406A meter by depressing a push-button located on the pen-type probe. This feature is useful when measurements are made in awkward positions where the operator cannot observe the meter indication and probe placements at the same time. Other features include a dc recorder output and sample hold output for connection to oscilloscopes, and peak or true rms voltmeters if other than absolute average measurements are required.

Specifications

Voltage range: 1 mV to 3 V full scale in 8 ranges; decibels from −50 to +20 dBm (0 dBm = 1 mW into 50Ω); average-responding instrument calibrated to rms value of sine wave.

Frequency range: 10 kHz to 1.2 GHz; useful sensitivity from 1 kHz to beyond 2 GHz.

Full-scale accuracy (%) with appropriate accessory: (after probe is properly calibrated).

10 kHz	20 kHz	25 kHz	100 kHz	100 MHz	700 MHz	1 GHz	1.2 GHz
±13	±8	±5	±3	±5	±8	±13	

Input impedance: input capacity and resistance will depend upon accessory tip used. 100,000Ω shunted by <2.1 pF at 100 kHz with bare probe; <10 pF with 11072A isolator tip supplied.

Sample Hold Output

Provides ac signal whose unclamped portion has statistics that are narrowly distributed about the statistics of the input, inverted in sign (operating into >200 kΩ load with <1000 pF).

Noise: < 175 μV rms.

Accuracy (after probe is properly calibrated): 0.01 V range and above: same as full scale accuracy of instrument.

0.001 V to 0.003 V range: value of input signal can be computed by taking into account the residual noise of the instrument.

Jitter: meter indicates within ±2% peak of reading 95% of time (as measured with HP 3400A True RMS Voltmeter).

RMS crest factor: 0.001 V to 0.3 V, 20 dB; 1 V, 13 dB; 3 V, 3 dB.

Meter

Meter scales: linear voltage, 0 to 1 and 0 to 3; decibel, −12 to +3. Individually calibrated taut-band meter.

Response time: indicates within specified accuracy in <3 sec.

Jitter: ±1% peak (of reading).

General

DC recorder output: adjustable from 0 to 1.2 mA into 1000 ohms at full scale, proportional to meter deflection.

Overload recovery time: meter indicates within specified accuracy in <5 sec (30 V p-p max.).

Maximum input: ±100 V dc, 30 V p-p.

RFI: conducted and radiated leakage limits are below those specified in MIL-6181D and MIL-1-16910C except for pulses emitted from probe. Spectral intensity of these pulses are nominally 50 nV/$\sqrt{Hz}$; spectrum extends beyond 2 GHz.

Temperature range: instrument, 0°C to +55°C; probe, +10°C to +40°C.

Power: 115 or 230 V ±10%, 50 Hz to 400 Hz, nominally <20 W.

Dimensions: 7¾″ wide, 6¼″ high (without removable feet), 11″ deep (197 x 159 x 279 mm); ½ module.

Weight: net 12 lbs (5,4 kg); shipping 14 lbs (6,4 kg).

Price: HP 3406A, $750.

HP 3406A RF Voltmeter Accessories

Accessories furnished

Nut Driver, HP Part Number 8710-0084: nut driver for tip replacement, $1.

11072A Isolator Tip: eliminates the effect of source impedance variations when the 11063A "T" and 10:1 divider are not used. Frequency range, 10 kHz to 250 MHz; input capacitance, <10 pF; $15.

10213-62102 Ground Clips
5020-0457 Replacement Tips
5060-4991 Ground Lead

Accessories available

11064A Accessory Probe Kit: consists of the following: 11063A 50Ω "T" 11061A 10:1 divider tip; 10218A BNC adapter; 0950-0090 50Ω termination; 10213-62102 ground clips (2 ea.); 5020-0457 probe tip (5 ea.); 5060-4991 ground leads (2 ea). Price HP 11064A, $100.

11063A "T": should be used whenever measurements are made in 50Ω systems; useful to about 1.5 GHz.
VSWR: <1.15 at 1 GHz (bare probe in "T").
Insertion loss: <1 dB up to 1 GHz.
Price: HP 11063A, $55.

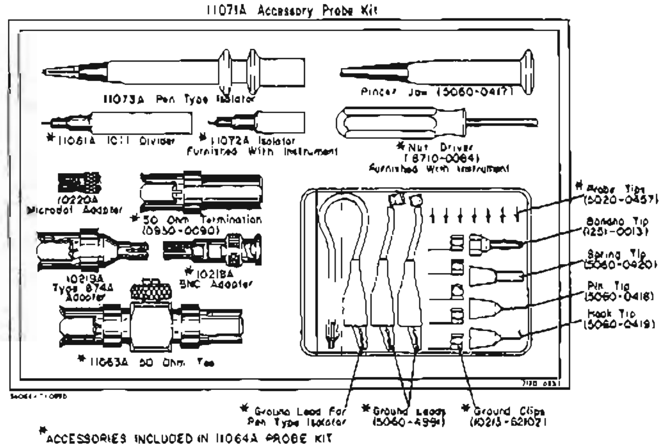
10218A BNC Adapter: probe to male BNC adapter. Frequency range: 10 kHz to 250 MHz. Price: HP 10218A, $6.

11061A 10:1 Divider: as well as dividing the input voltage by a factor of ten, this accessory eliminates the effects of source impedance variations.
Accuracy (divider alone): ±5% 1 kHz-400 MHz.
±12% 400 MHz-1 GHz.
Maximum input: 150 V p-p ac, 600 V dc. Price: HP 11061A, $35.

50 ohm termination: (0950-0090) Price: $39.50.
Ground clips: 2 each (10213-62102) Price: $1.
Probe tips: 5 each (5020-0457) Price: $1.
Ground leads: 2 each (5060-4991) Price: $2.30.

11071A Accessory Probe Kit: consists of all the 11064A accessories plus 11073A Pen Type Probe (with 11073-62101 ground lead); 10219A Type 874A Adapter; 10220A Microdot Adapter; 5060-0418 Pin Tip. 5060-0419 Hook Tip; 5060-0420 Spring Tip; 5060-0417 Pincer Jaw; 1251-0013 Banana Tip. Price: HP 11071A, $185.

11071A Accessory Probe Kit

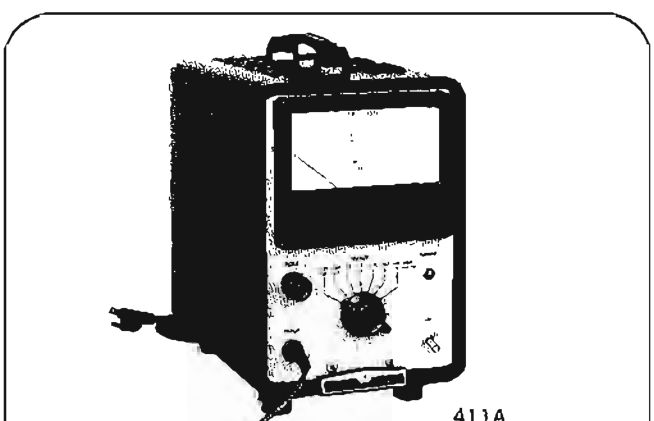


*ACCESSORIES INCLUDED IN 11064A PROBE KIT

11073A Pen Type Isolator: frequency range is 10 kHz to 50 MHz. Various accessories adapt the 11073A to alligator jaws and other tips which facilitate point-to-point measurements. Input capacitance: <10 pF. Price: HP 11073A, $45.

10219A Type 874A Adapter: Price: HP 10219A, $15.
10220A Microdot Adapter: Price: HP 10220A, $4.
Pincer jaw: (5060-0417). Price: $4.
Ground lead for pen type isolator: (11073-62101). Price: $2.70.
Ground leads: 2 each (5060-4991). Price: $2.30.
Ground clips: 5 each (10213-62102). Price: $1.
Probe tips: 7 each (5020-0457). Price: $1.
Banana tip: (1251-0013). Price: $0.50.
Spring tip: (5060-0420). Price: $0.50.
Pin tip: (5060-0418). Price: $0.50.
Hook tip: (5060-0419). Price: $0.50.

RF MILLIVOLTMETER
Measurements, 10 mV to 10 V, 500 kHz to 1 GHz
Model 411A



411A

Description

RF voltmeter offers millivolt sensitivity and two easy-reading linear voltage scales in 1-to-3 ratio. Range is 10 mV to 10 V full scale rms, 500 kHz to 1 GHz. DB scale is calibrated from +3 to −12 dB. Accuracy is ±3% of full scale to ±1 dB, depending upon frequency and probe used. Five probe tips increase versatility. The probe tips, available individually, are offered along with a spare diode cartridge as a complete set in a compact kit. Galvanometer recorder output. For detailed information and complete specifications, refer to data sheet.

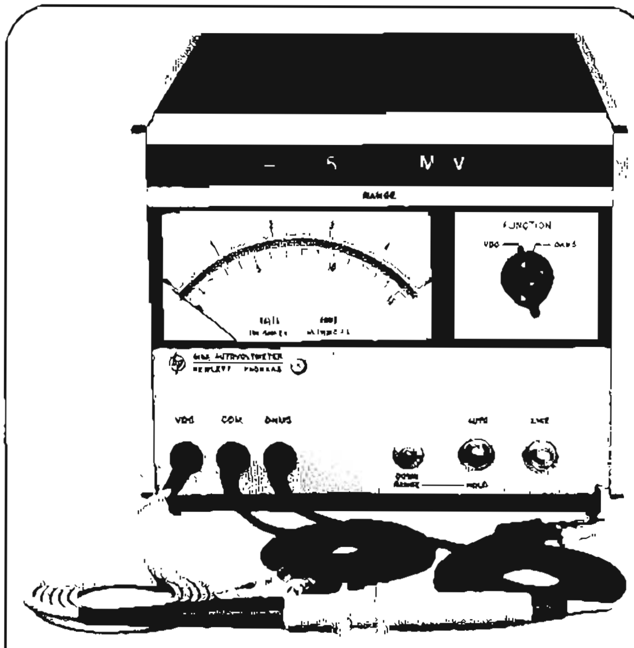
BNC open circuit probe tip furnished with the instrument. HP 11027A Probe Kit includes a pen-type probe tip, a VHF probe tip, a type N-tee, a 100:1 Capacitor divider and a spare diode cartridge: $153.

Price: HP 411A, $450. (cabinet); HP 411AR, $455 (rack).

AUTOVOLTMETER

Automatic voltage and resistance measurements

Model 414A



414A

Description

The 414A is a 12-range, all solid-state dc volt-ohmmeter which provides accurate measurements immediately because of its automatic range selection. Operation is simply touch and read. Both range and polarity are displayed by illuminated characters and the meter pointer indicates the correct reading for the range that has been automatically selected.

Specifications

DC voltmeter

Voltage Ranges: ±5 mV to ±1500 V in 12 ranges in a 5-15 sequence. Automatic or manual range selection.

Accuracy: ±(0.5% of reading +0.5% of range).

Input: voltage probe and common lead. COM lead can be floated up to ±500 Vdc above chassis ground.

Input Resistance: 100 MΩ on 50 mV range and above; 10 MΩ on 5 mV and 15 mV ranges.

AC Normal-Mode Rejection: reading not affected by 50 Hz or 60 Hz signal having peak values less than the following:
In Auto: 15% of dc input.
In Hold: 600% of range.

Ohmmeter (linear scale)

Resistance ranges: 5Ω to 1.5 MΩ in 12 linear ranges in 5-15 sequence (manual or automatic range selection).

Accuracy: ±(1% of reading +0.5% of range).

Source current: up to 5 kΩ range, 1 mA; above 5 kΩ range, 1 μA.

General

Automatic range selection: automatically selects correct voltage and resistance range in less than 300 ms.

Manual range selection: down-ranges one range each time down-range button is pressed. Starts over at 1500 V from 5 mV range.

Polarity selection: automatic.

Operating temperature: instrument will operate within specifications from 0°C to +50°C.

Power: 115 or 230 V ±10%, 50 to 400 Hz, <18 W.

Dimensions: (½ module) 7¾" wide, 6¼" high (without removable feet), 11" deep (197 x 159 x 279 mm).

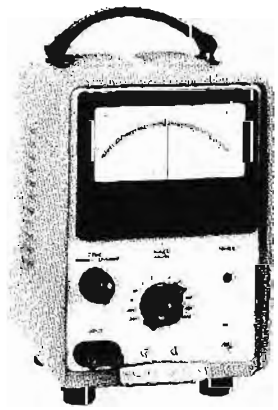
Weight: net 10¼ lbs (4,6 kg); shipping 13 lbs (6,4 kg).

Price: HP 414A, $690.

DC NULL VOLTMETER

Floating, high-impedance input; 1 mV end-scale sensitivity

Model 413A



413A

The 413A has 13 zero-centered ranges running from 1 mV to 1000 V end scale.

High-input impedance (10 MΩ on the most sensitive range, 200 MΩ on the 300 mV range and above) makes the 413A especially valuable in resistance bridge measurements. Accuracy of this instrument is within 2% of end scale.

Specifications

Voltmeter

Range: positive and negative voltages from 1 mV to 1000 V end scale in 13 zero-centered ranges.

Accuracy: ±2% of end scale.

Limits of zero control: more than ± end scale on any range when using expanded scale.

Input Resistance: 10 MΩ on 1, 3 and 10 mV ranges; 30 MΩ on 30 mV range; 100 MΩ on 100 mV range; 200 MΩ on 300 mV range and above.

AC rejection: a voltage at power line or twice power-line frequency 40 dB greater than end scale affects reading <1%: peak voltage must not exceed 1500 V.

Amplifier (refer to data sheet for detailed specifications)

Gain: 0.001 to 1000 in 13 steps.

General

Input terminals: dual banana jacks.

Input isolation: >100 MΩ shunted by 0.1 μF to case (power-line ground).

Common signal rejection: may be operated with up to 500 V dc or 130 V ac above ground.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 35 W.

Dimensions: cabinet 7½" wide, 11½" high, 10" deep (191 x 292 x 254 mm); rack mount 19" wide, 5⁷⁄₃₂" high, 6⅝" deep (483 x 134 x 168 mm).

Weight: cabinet net 12 lbs (5,4 kg), shipping 14 lbs (6.4 kg); rack net 12 lbs (5,4 kg), shipping 19 lbs (8,6 kg).

Price: HP 413A, $385 (cabinet); HP 413AR, $390 (rack).

DC NULL VOLT-AMMETER

18 Voltage, 7 current ranges; 0.1 μV resolution

Model 419A

Eighteen voltage ranges with 0.1 μV resolution on the lowest range set this HP solid-state DC Null Voltmeter apart from previous dc null meters. The accuracy of this rechargeable battery-operated instrument is ±2% of end scale ±0.1 μV on all ranges. Noise is less than 0.3 μV p-p, and drift is less than 0.5 μV/day.

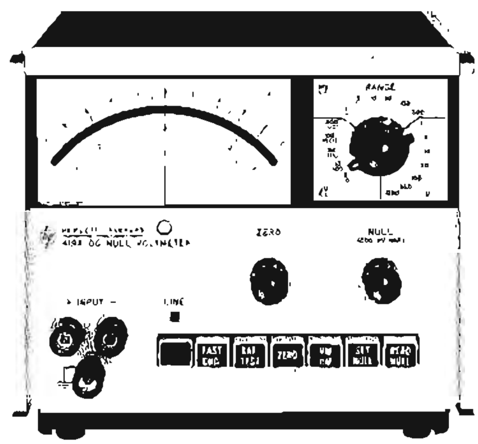
An internal bucking source allows input voltages up to 300 mV to be nulled giving an infinite input impedance. Input impedance above the 300 mV range is 100 megohms.

Pushbutton selection provides convenience-versatility

Seven pushbuttons allow the operator to select rapidly the desired function of the HP 419A. This dc null voltmeter operates from the ac line or from the internal rechargeable batteries. During operation from the ac line the batteries are trickle-charged. A fast-charge pushbutton is provided to increase the charging rate, recharging the batteries in approximately 16 hours. Battery voltage may be easily checked with the battery-test pushbutton. The zero pushbutton enables the operator to compensate for any internal offsets before making a measurement. When this pushbutton is depressed, the positive leg of the voltmeter is disconnected from the positive input terminal and connected to the negative input terminal.

When the VM pushbutton is depressed the HP 419A functions as a zero-center scale 3 μV to 1000 V dc voltmeter.

When the AM pushbutton is depressed, the HP 419A functions as a zero-center scale 30 pA to 30 nA ammeter.



419A

Specifications

DC null voltmeter

Ranges: ±3 μV to ±1000 V dc in 18 zero-center ranges.
Accuracy: ±(2% of range ±0.1 μV).
Zero control range: >±15 μV.
Zero drift: <0.5 μV/day after 30 min warm-up.
Zero temperature coefficient: <0.05 μV/°C.
Response time: 3 s to within 95% of final reading on 3 μV range; 1 s to within 95% of final reading on 10 μV to 1000 V ranges.
Noise: <0.3 μV p-p, input shorted.
[Noise amplitude approximates Gaussian distribution. RMS value (standard deviation) is <0.075 μV, p-p noise value is <0.3 μV 95% of the time.]
Input characteristics
At null: infinite resistance on 3 μV through 300 mV ranges in SET NULL mode. Negative input terminal can be floated up to ±500 V dc from powerline ground.
Off null:

Voltage range	Input resistance
3 μV - 3 mV	100 kΩ
10 mV - 30 mV	1 MΩ
100 mV - 300 mV	10 MΩ
1 V - 1000 V	100 MΩ

Negative input terminal can be floated up to ±500 V dc from powerline ground.
AC normal-mode rejection: ac voltages 50 Hz and above and 80 dB greater than end scale affect reading less than 2%. Peak ac voltage not to exceed maximum overload voltage.

DC ammeter

Ranges: ±30 pA to ±30 nA in 7 zero-center ranges.
Accuracy: ±(3% of range +1 pA).
Zero control range: >±150 pA.
Zero drift: <5 pA/day after 30 min warm-up.
Zero temperature coefficient: <0.5 pA/°C.
Noise: <3 pA p-p, input shorted.
Input resistance: 100 kΩ on all ranges.

Amplifier

Gain: 110 dB on 3 μV range, decreases 10 dB per range.
Output: 0 to ±1 V at 1 mA maximum for end-scale reading. Output level adjustable for convenience when used with recorders.
Output resistance: depends on setting of output level control. <35Ω when output control is set to maximum.
Noise: 0.01 Hz to 5 Hz: same as voltmeter (referred to input). >5 Hz: <10 mV rms (referred to output).

General

Overload protection: the following voltages can be applied without damage to instrument.
1 V to 1000 V range: 1200 V dc.
10 mV to 300 mV range: 500 V dc.
3 μV to 300 mV range: 50 V dc.
Operating temperature: instrument will operate within specifications from 0°C to 50°C.
Operating humidity: <70% RH.
Storage temperature: −20°C to +50°C.
Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <1.5 W, or 4 internal rechargeable batteries (furnished). 30-hr operation per recharge. Operation from ac line permissible during recharge.
Dimensions: 7¾″ wide, 6¼″ high (without removable feet), 8″ deep (197 x 159 x 203 mm).
Weight: net 8.3 lb (3,7 kg); shipping 11 lb (5 kg).
Price: HP 419A, $450.

DC VOLT-OHM-AMMETER

1% accuracy vtvm is also ohmmeter, ammeter

Model 412A

412A

Features:

- Versatile, measures voltage, resistance, current
- Floating input
- High input resistance
- Use as a 60 dB amplifier
- Individually calibrated meter minimizes tracking error

Description

The HP Model 412A is a multipurpose meter designed to measure dc voltage, current, and resistance with laboratory accuracy and yet be of great utility in production-line test-bench work. Simplicity of operation and low cost permit its use wherever dc measurements are made.

Model 412A may also be used as a stable 60 dB amplifier which has an output proportional to meter indication.

There are only three controls; a lever-type function selector, a 13-position range switch, and a lever-type polarity switch. The extreme stability of the 412A makes it easier to use by eliminating the need for constantly re-zeroing the meter. The stability of the HP 412A is such that the usual front-panel, zero-set control has been eliminated.

The precision six-inch meter has two scales used for both voltage and current and a third scale which is calibrated in ohms. The meter face has a mirror back for greatest accuracy in reading.

Specifications

Voltmeter

Voltage range: pos. and neg. voltages from 1 mV to 1000 V full scale, 13 ranges.

Accuracy: ±1% of full scale on any range.

Input resistance: 10 megohms ±1% on 1 mV, 3 mV and 10 mV ranges; 30 megohms ±1% on 30 mV range; 100 megohms ±1% on 100 mV range; 200 megohms ±1% on 300 mV range and above.

AC rejection: a voltage at power line or twice power line frequency 40 dB greater than full scale affects reading less than 1%. Peak voltage must not exceed 1,500 volts.

Ammeter

Current range: pos. and neg. currents from 1 μA to 1 A full scale, 13 ranges.

Accuracy: ±2% of full scale on any range.

Input resistance: decreasing from 1000 ohms on 1 μA range to 0.1 ohm on 1 A range.

Ohmmeter

Resistance range: resistance from 1 ohm to 100 megohms center scale, 9 ranges.

Accuracy: ±5% of reading at center scale.

Short circuit current: from 0.01 μA on the X100MΩ range to 10 mA on the X1Ω range.

Amplifier

Voltage gain: 1000 maximum.

DC bandwidth: dc to 0.7 Hz on all voltage ranges.

Output: proportional to meter indication; 1 V at full scale; max. current, 1 mA (full scale corresponds to 1 on upper scale).

Output impedance: less than 2 ohms at dc.

Noise: less than 2.0 μV rms referred to the input.

Drift: negligible.

General

Common terminal isolation: may be operated up to 500 V dc, or 130 V ac above ground.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 47 W max.

Dimensions: cabinet: 7½" wide, 11½" high, 10" deep (191 x 292 x 254 mm); rack mount: 19" wide, 5-7/32" high, 7½" deep behind panel (483 x 134 x 191 mm).

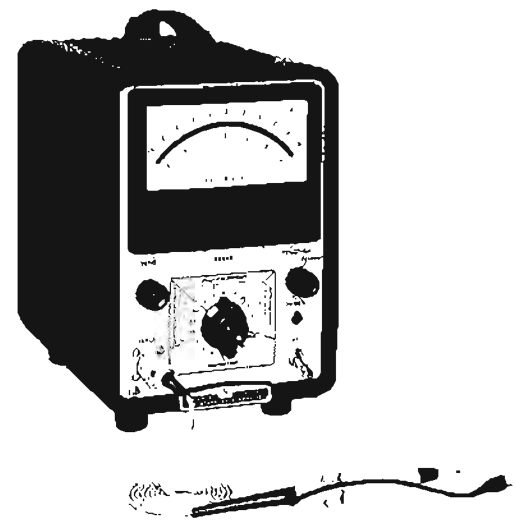
Weight: net: 12 lbs (5,5 kg); shipping: 14 lbs (6,4 kg) (cabinet); net 12 lbs (5,5 kg); shipping: 20 lbs (9 kg) (rack mount).

Price: HP 412A, $450 (cabinet).
HP 412AR, $455 (rack mount).

DC MICROVOLT-AMMETER

10 μV, 10 pA full scale sensitivity

Model 425A



425A

Description

Hewlett-Packard 425A DC Microvolt-Ammeter makes measurements of extremely small dc voltages and currents, even in the presence of relatively strong ac signals.

Since the 425A measures dc voltages from 1 μV to 1 V and dc currents from 1 pA to 3 mA, it is an extremely useful tool in all branches of scientific measurement. For example, it can be used to study nerve potentials for the biologist and medical researcher and to study chemically generated emf, minute voltages in thermocouples, and current in ionization chambers.

Since currents as small as 1 pA can be measured directly, the Model 425A is valuable for measuring transistor currents and photomultiplier currents in ionization chambers. Thus this meter has great utility in physics research, as well as in electronics. Further, its current and voltage sensitivity permit measurement of both extremely high and very low resistances.

Model 425A is provided with output terminals so that it may be used as a dc amplifier having 100 dB (10^5) voltage gain. Output from the amplifier is 1 V for an end-scale deflection or 1 mA into approximately 1000 ohms, so that it will operate either a potentiometer or galvanometer recorder to make permanent records of measurements.

Specifications

Microvolt-ammeter

Voltage range: pos. and neg. voltages from 10 μV end scale to 1 V end scale, 11 steps, 1, 3, 10 sequence.

Current range: pos. and neg. currents from 10 pA end scale to 3 mA end scale, 18 steps, 1, 3, 10 sequence.

Input impedance: voltage ranges, 1 megohm ±3%; current range, depends on range, 1 megohm to 0.33 ohm.

Accuracy: within ±3% of range; line frequency variations ±5 Hz affect accuracy less than ±2%.

Amplifier

Gain: 100,000 maximum.

DC bandwidth:
dc to 0.1 Hz on 10 μV range.
dc to 0.3 Hz on 30 μV range.
dc to 0.7 Hz on 100 μV range and above.

Output: 0 to 1 V for end-scale reading, adjustable (5000-ohm shunt potentiometer), 1 mA maximum at 1 V output.

Output impedance: depends on setting of output potentiometer; 10 ohms when potentiometer is set for maximum output.

Noise: 0 to 1 Hz: <0.25 μV rms referred to input (noise amplitude approximates Gausian distribution. P-P noise value is <1.0 μV 95% of the time). >1 Hz: <5 mV rms referred to output.

Drift: after 15 minutes' warm-up, drift is less than ±4 μV per day referred to input.

General

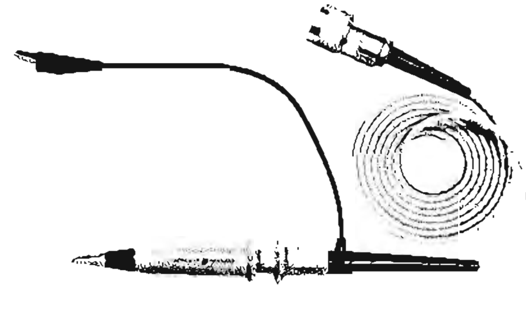
Power: 115 or (230 volts must be specified) ±10%, 60 Hz, 46 W; 50 Hz operation is available as option 01.

Dimensions: cabinet: 7⅜" wide, 11¾" high, 12" deep (186 x 299 x 305 mm); rack mount: 19" wide, 7" high, 11" deep behind panel (483 x 178 x 279 mm).

Weight: net 17 lbs (7,7 kg); shipping 18 lbs (8,2 kg) (cabinet); net 21 lbs (9,5 kg); shipping 29 lbs (13,2 kg) (rack mount).

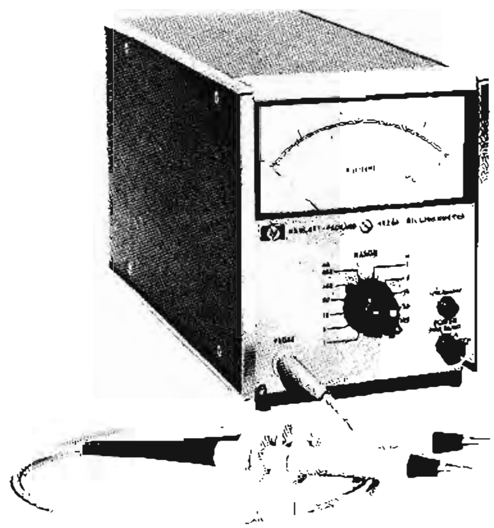
Accessories available: 11021A 1000:1 Divider Probe, increases range of 425A to 1000 volts; division accuracy ±2%, input resistance 10 megohms, $55.

Price: HP 425A, $550 (cabinet). HP 425AR, $555 (rack mount). HP 425A Option 01, for operation from 50 Hz power, no extra charge.



11021A Divider Probe

MILLIOHMMETER
Convenient two probe measurements
Model 4328A



4328A

Description

The HP 4328A Milliohmmeter is a portable instrument for measurement of low resistances. It uses a Kelvin Bridge method to obtain high sensitivity. It has both current and voltage drives incorporated in one probe so only two probes are needed in the actual measurement. Maximum sensitivity is 20 μohms, making it ideal for measuring the contact resistance of switches, relays and connectors; it is also useful for safe testing of fuses and squibs.

A unique phase discriminator in the meter circuit permits accurate resistive measurements on samples with a series reactance up to twice full scale resistance.

Specifications

Range: 0.001 to 100 ohms full scale in a 1, 3, 10 sequence.
Accuracy: ±2% of full scale. No additional error is caused by series reactance of samples up to 2 times full scale.
Measuring frequency: 1000 Hz ±100 Hz.
Voltage across sample: 200 μV peak at full scale.
Maximum voltage across sample: 20 mV peak in any case.
Superimposed DC: 150 V dc maximum may be superimposed on samples from an external source.
Recorder output: 0.1 V dc output at full scale meter deflection.

Range (ohms)	Applied Current (mA)	Maximum Dissipation in Samples (μW)
0.001	150	23
0.003	50	8
0.01	15	2.3
0.03	5	0.8
0.1	1.5	0.23
0.3	0.5	0.08
1	0.15	0.023
3	0.05	0.008
10	0.015	0.0023
30	0.005	0.0008
100	0.0015	0.00023

General

Power requirements: 115/230 V switch ±10%, 50 to 60 Hz, 1.5 W.
Weight: 7 lbs (3,2 kg).
Dimensions: 5⅛" wide, 6-3/32" high, 11" deep.
Accessories furnished: Model 16005A Probe, 16006A Probe and 16007A Test Leads. Detachable Power Cord.
Price: HP 4328A, $450; Option 01 (rechargeable battery operation), add $25.

DECADE CAPACITOR
High accuracy from 40 pF to 1.2 μF
Model 4440B

Description

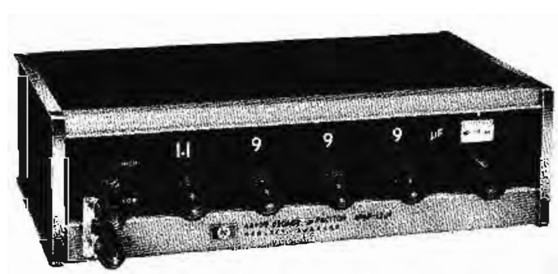
The HP 4440B Decade Capacitor is a high accuracy instrument providing usable capacitances from 40 pF to 1.2 μF. Its 0.25% accuracy makes it an ideal aid for circuit design or ac bridge measurements. The 4440B is also highly suited for production line testing and use as a working standard.

Use of silvered-mica capacitors in four decades of 100 pF provides higher accuracy, low dissipation factors and good temperature coefficients. An air capacitor vernier provides 100 pF (from 40 pF to 140 pF) with resolution of 1 pF. Capacitors are housed in a double shield in such a way that increased capacitance from two terminals to three terminals is held to 1 pF.

Specifications

Capacitance: 40 pF to 1.2 μF in steps of 100 pF with a 40 pF to 140 pF variable air capacitor providing continuous adjustment to better than 2 pF between steps. 0.1 μF x 11 steps +0.01 μF x 9 steps +0.001 μF x 9 steps +0.0001 μF x 9 steps +40 to 140 pF.
Direct reading accuracy: ±(0.25% +3 pF) at 1 kHz for three-terminal connection, capacitance increase for two-terminal connection is less than 1 pF.
Resonant frequency: typical values of the resonant frequency are 450 kHz at 1 μF, 4 MHz at 0.01 μF and 40 MHz at 100 pF.
Dissipation factor: 0.001 maximum at 1 kHz.
Temperature coefficient: +70 ppm/°C.
Insulation resistance: 5 G ohms minimum, after 5 minutes at 500 V dc.
Maximum voltage: 500 V peak.
Weight: 5½ lbs (2,5 kg).
Dimensions: 11" wide (264 mm), 6" deep (152 mm), 3" high (76 mm).
Price: HP 4440B $260.

Manufactured by Yokogawa-Hewlett-Packard Ltd., Tokyo



4440B

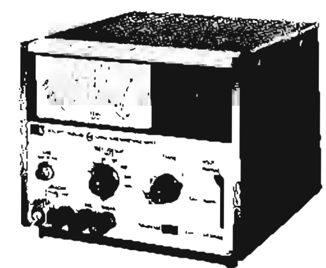
RESISTANCE METER
Wide range for high resistance, low current
Model 4329A

Description

The HP 4329A is a solid-state insulation resistance meter designed for easy, accurate and direct readings of the very high resistance values typically found in synthetic resins, porcelain, insulating oils and similar materials. It is also useful for measurements in electrical components like capacitors, transformers, switches and cables. Seven fully regulated dc test voltages (between 10 and 1000 V) are provided as test sources.

Selected scales are identified by illuminated indicators on the meter face. Selected resistance or current multiplying factors are also illuminated for rapid, error-free measurement. Three resistance scales and one current scale are provided. The HP 4329A is instantly convertible from ungrounded- to grounded-sample operation via a simple relocation of the front panel ground strap from "guard" to "+" position. The instrument cabinet itself is always at ground potential. Test voltage shorts or sample breakdown currents will not damage instrument circuitry.

The HP 4329A also has a current measurement capability. Minute currents as low as 0.05 pA can be readily measured. The standard instrument package includes HP 16117A Low Noise Test Leads: these are used in most types of measurement. An HP 16008A resistivity cell is also available for use with the high resistance meter, for those customers engaged in measurement of volume and surface resistivity of sheet samples.



4329A

Specifications

Current measurement

Measuring scale: 0.5 x 10^{-13} to 2 x 10^{-5} A in 8 ranges.

Meter scale: 0 to 20 in 40 linear divisions.
Input resistance: 10^{4} to $10^{11}\Omega$ ±1%, depending on range.
Accuracy: ±5% of full scale deflection (there can be an additional ±3% error at the top decade).

General

Recorder output: 0 to 100 mV dc, proportional to meter deflection; 1 kΩ input resistance.
Power: 115/230 V ±10%, 50-60 Hz, 3 W.
Dimensions: 6½" high (166 mm), 7-13/16" wide (198 mm), 11" deep (277 mm).
Weight: 8 lbs (3,5 kg).
Accessory furnished: HP 16117A Low Noise Test Leads.
Price: HP 4329A, $750.

Resistance measurement

Test voltage	10 V ±3%	25 V ±3%	50 V ±3%	100 V ±3%	250 V ±3%	500 V ±3%	1000 V ±3%
Measuring range	5×10^{5}–$2 \times 10^{14}\Omega$ 8 ranges	1.25×10^{6}–$5 \times 10^{14}\Omega$ 8 ranges	2.5×10^{6}–$1 \times 10^{15}\Omega$ 8 ranges	5×10^{6}–$2 \times 10^{15}\Omega$ 8 ranges	1.25×10^{7}–$5 \times 10^{15}\Omega$ 8 ranges	2.5×10^{7}–$1 \times 10^{16}\Omega$ 8 ranges	5×10^{7}–$2 \times 10^{16}\Omega$ 8 ranges
Meter scale	0.5–20 (∞)	0.125–5 (∞)	0.25–10 (∞)	0.5–20 (∞)	0.125–5 (∞)	0.25–10 (∞)	0.5–20 (∞)
Overall accuracy*	5	1	2	5	1	2	5

*Equals ±10% of reading when selected scale does not exceed values shown in this specification.
Notes: Specifications stated are after initial ∞ and full-scale calibration. Up-ranging assures greater accuracy when operating near full-scale deflection. Error decreases to about ±3% at the low-resistance end of each decade, and ±5% at the center-scale of each decade. There can be an additional ±3% error at the top decade of each test.

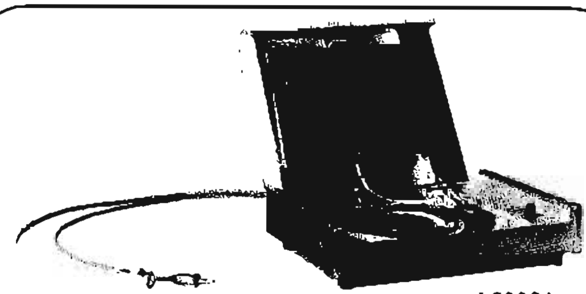
Model 16008A Resistivity Cell

Description

The HP 16008A can safely, rapidly and conveniently measure the volume and surface resistivity of sheet insulation materials. Conversion from volume to surface resistivity measurement requires operation of one switch only; no lead interchange or disconnection is necessary. Designed for use with the HP 4329A Resistance Meter (other voltage supplies and picoammeters may be used), the complete system allows direct measurement of volume resistivity up to approximately 4 x $10^{18}\Omega$ (on samples 0.1 cm thick)—and surface resistivity up to approximately 4 x $10^{17}\Omega$. Test voltages up to 1000 V may be used. Excellent sample-to-electrode contact is maintained through use of a conducting plastic layer bonded to the inner electrode's outer surface. An interlock switch automatically disconnects the test voltage when the cover is raised. Convenient low noise test leads are supplied for direct connection to the HP 4329A.

Specifications

Inner electrode: 50 mmØ.
Guard electrode: 50 mmØ.
Auxiliary electrode: 100 x 120 mm.
Maximum sample size: 125 x 125 x 7 mm.
Maximum test voltage: 1000 V dc.
Dimensions: 2" high (49 mm), 7-13/16" wide (198 mm), 6⅛" deep (156 mm).
Weight: 3 lbs (1,4 kg).
Price: HP 16008A, $200.



16008A

Manufactured by Yokogawa-Hewlett-Packard Ltd., Tokyo

CLIP-ON MILLIAMMETER

Measures current without interrupting circuit

Model 428B and probes

428B

Description

Direct current from 0.02 milliampere to 10 amperes can be measured with the HP 428B without interrupting the circuits and without the error-producing loading of conventional methods.

For any measurement of dc within its range, simply clamp the jaws of the 428B around a wire and read.

This ease and speed of operation are unparalleled, especially for applications where many dc measurements must be made. Wide current range of the 428B will handle most signals directly. For even greater sensitivity, several loops may be put through the probe, increasing the sensitivity by the same factor as the number of loops.

In addition to making current measurements directly, the 428B is also valuable for measuring sums and differences of currents in separate wires. When the probe is clipped around two wires carrying current in the same direction, their sum is indicated on the meter; when one of the wires is reversed, their difference is measured. Thus, current balancing is possible by obtaining a zero difference reading.

Model 428B provides an output voltage proportional to the measured current, which is useful for driving recorders or making low-frequency (dc to 400 Hz) current measurements.

Specifications

Current range: 1 mA to 10 A full scale, nine ranges.

Accuracy: ±3% of full scale ±0.1 mA, from 0°C to 55°C. (When instrument is calibrated to probe.)

Probe inductance: less than 0.5 μH.

Probe induced voltage: less than 15 mV peak (worst case at 20 kHz and harmonics).

Output: variable linear output level with switch position for calibrated 1 V into open circuit (corresponds to full scale deflection). 1.5 V max. into open circuit in uncalibrated position. 0.73 ±.01 V into 1 KΩ in calibrated position.

Noise: 1 mA range, <15 mV rms across 1 KΩ.
3 mA range, <5 mV rms across 1 kΩ.
10 mA through 10 A ranges, <2 mV rms across 1 KΩ.

Frequency range: dc to 400 Hz (3 dB point).

AC rejection: signals above 5 Hz with peak value less than full scale affect meter accuracy less than 2%. (Except at 40 kHz carrier frequency and its harmonics). On the 10 A range, ac peak value is limited to 4 A.

Power: 115 or 230 V ±10%, 50 to 60 Hz, approx. 70 W.

Operating temperature range: −20°C to +55°C.

Storage temperature: −40°C to +65°C.

Probe insulation: 300 V maximum.

Probe tip size: approximately 1/2" by 21/32"; aperture diameter 5/32".

Dimensions: 7½" wide, 11½" high, 14¼" deep (191 x 292 x 272 mm); rack mount: 19" wide, 6 31/32" high, 13" deep (483 x 177 x 330 mm).

Weight: net 17 lbs (7,7 kg), shipping 19 lbs (8,6 kg) (cabinet); net 24 lbs (10,8 kg), shipping 33 lbs (14,9 kg) (rack mount).

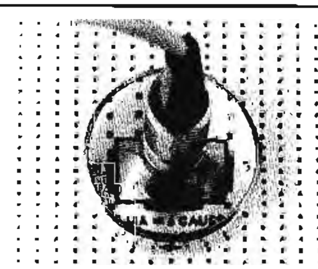
Price: HP 428B, $650 (cabinet).
HP 428BR, $655 (rack mount).

Accessories available

3529A

3529A magnetometer probe

The HP 3529A Magnetometer Probe is useful in applications where determination must be made of the direction or magnitude of a magnetic field. It is useful in applications ranging from acoustical transducer design to investigations involving the Zeeman effect. Conversion factor is 1:1, producing a reading on the 428B in milliamperes which is directly equal to the measured field strength in milligauss. Range is 1 milligauss to 10 gauss with the 428B. The bandwidth is dc to 80 Hz, and accuracy is ±3% of full scale when the probe is calibrated with the instrument. Price: HP 3529A, $95.



C11-3529A

C11-3529A magnetometer probe

The C11-3529A is a special magnetometer probe used to convert the Hewlett-Packard 428A or 428B DC Milliammeter into a direct reading magnetometer (1 G = 1 mA indication on 428 A/B meter). The C11-3529A Magnetometer Probe is specifically designed to measure the relative magnetic field strength of individual bar magnets on twistor memory cards used in the Western Electric Electronic Switching System (No. 1ESS). Refer to data sheet for further information. Price: HP C11-3529A, $170.

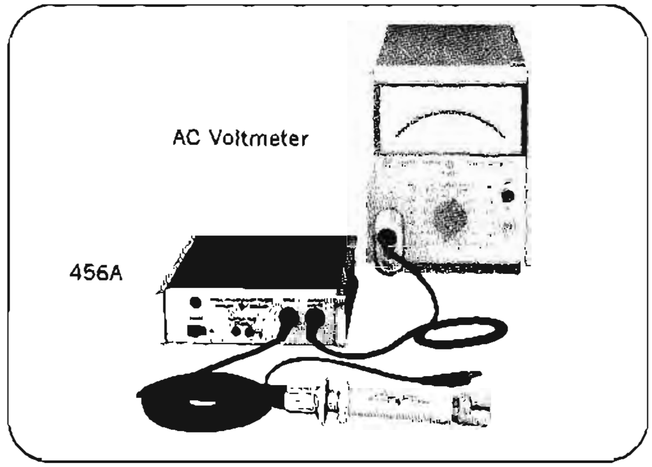
VOLTMETER ACCESSORIES
Voltage dividers, current probe for VM's.
Model 456A, 11000 Series

456A AC current probe

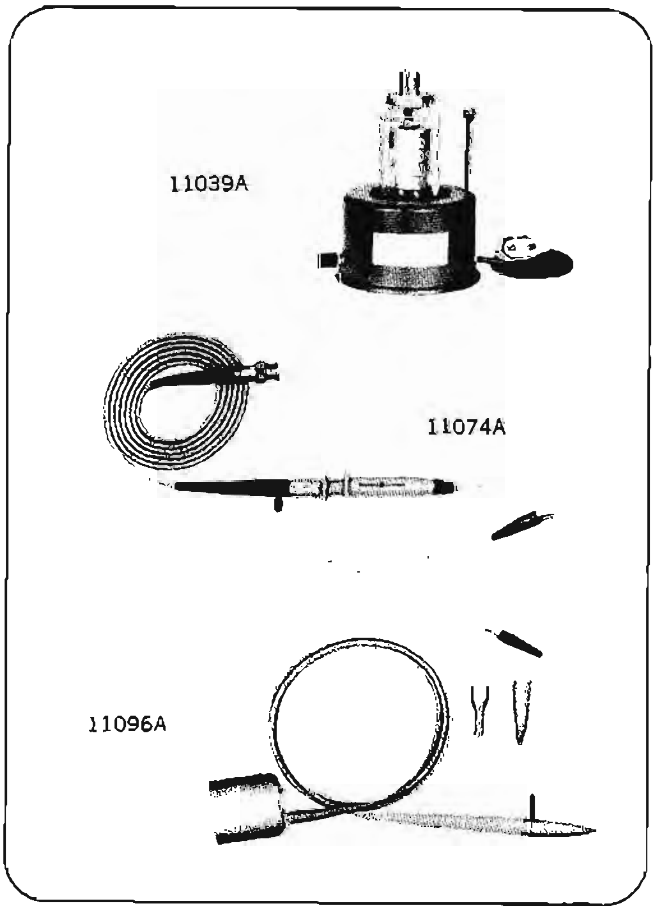
Your conventional voltmeter or oscilloscope can measure current quickly and dependably—without direct connection to the circuit under test or any appreciable loading to the test circuit. The HP 456A AC Current Probe clamps around the current-carrying wire and provides a voltage output you can read on a voltmeter or scope. Model 456A's 1 mA to 1 mV conversion permits direct reading up to 1 ampere rms.

Specifications, 456A

Sensitivity: 1 mV/mA ±1% at 1 kHz.
Frequency response: ±2%, 100 Hz to 3 MHz; ±5%, 60 Hz to 4 MHz; −3 dB at <25 Hz and >20 MHz.
Pulse response: *rise time is <20 ns, sag <16%/ms.*
Maximum input: 1 A rms, 1.5 A peak; 100 mA above 5 MHz.
Effect of dc current: *no appreciable effect on sensitivity and distortion from dc current up to 0.5 A.*
Input impedance: (*impedance added in series with measured wire by probe*) less than 50 milliohms in series with 0.05 μH (*this is approximately the inductance of 1½" of hookup wire*).
Probe shunt capacity: approx. 4 pF added from wire to ground.
Distortion at 1 kHz: *for* 0.5 A *input at least* 50 dB *down; for* 10 mA input at least 70 dB down.
Equivalent input noise: <50 μA rms (100 μA when ac powered).
Output impedance: 220 ohms at 1 kHz; approximately +1 V dc *component; should work into load of not less than* 100,000 ohms shunted by approximately 25 pF.
Power: two Mallory TR 233R and one TR 234 batteries (1420-0005 and 1420-0006); battery life approximately 400 hours; ac power supply optional, 115 or (230 V must be specified) ±10% 50 to 400 Hz 1 W.



Dimensions: 5" wide, 1½" high (127 x 38 x 152 mm), 6" deep; probe cable is 5' long; 2' output cable terminated with dual banana plug. Probe aperture: 5⁄32" (4 mm) diameter.
Weight: net 2 lbs, 4 oz (1 kg); shipping 3 lbs, 10 oz (1,6 kg).
Accessory available: 456A-11A AC Supply for field installation, $55. 11028A 100:1 Current Divider, $48.
Price: HP 456A with batteries, $225.
Option 01: *ac supply installed in lieu of batteries, add $20.*



11039A capacitive voltage divider

For 400 and 410 series voltmeters. Safely measures power voltages to 25 kV; accuracy ±3%. Division ratio, 1000:1. Input capacity, 15 pF ±1. Maximum voltage ratings (sea level) 60 Hz, 25 kV; 100 kHz, 22 kV; 1 MHz, 20 kV; 10 MHz, 15 kV; 20 MHz, 7 kV. Usable for dielectric heating, power and ultrasonic voltages. Price: HP 11039A, $185. (HP 11018A should be used to connect the 410 series voltmeter).

11074A voltage divider probe

For 400 Series voltmeters. Provides low-input capacitance and high-input resistance at the point of measurement. Division ratio 10:1 ±2% (400 Hz reference), 10:1 ±2% (100 kHz reference depends on adjustment of compensating capacitor). Bandwidth, dc to 10 MHz. Maximum input voltage 1 kV rms.

Input impedance: 10 MΩ shunted by 10 pF (when connected to an input impedance of 10 MΩ shunted by not more than 25 pF). Price: HP 11074A, $50.

11096A high frequency probe

Converts dc voltmeter with 10 MΩ input resistance to high frequency ac voltmeter. Compatible voltmeters: HP 427A, HP 3430A, HP 3439A and HP 3440A. Voltage range, 0.25 to 30 V rms; transfer accuracy (20-30°C) ±5%, 100 kHz to 100 MHz. Usable for relative measurements from 1 kHz to 1 GHz; peak responding, calibrated to read rms value of a sine wave; input impedance, 4 MΩ shunted by 2 pF; max. input, 30 V rms ac, 200 V dc; accessories provided include a straight tip, a hook tip, a ground clip, and a high frequency adapter that fits available HP adapters for BNC (HP 10218A); GR Type 874 (HP 10219A), Microdot connectors (HP 10220A) and that also fits a 50Ω tee (HP 11536A). Price: HP 11096A, $45.

CABLE ACCESSORIES
Cable assemblies

10501A Cable Assembly

44″ of 50-ohm coaxial cable terminated on one end only with UG-88C/U BNC male connector; HP 10501A, $4 each.

10502A Cable Assembly

9″ of 50-ohm coaxial cable terminated on both ends with UG-88C/U BNC male connectors; HP 10502A, $6 each.

11086A Cable Assembly

24″ of 50-ohm coaxial cable terminated on both ends with UG-88C/U BNC male connectors: HP 11086A, $7 each.

10503A Cable Assembly

4′ of 50-ohm coaxial cable terminated on both ends with UG-88C/U BNC male connectors; HP 10503A, $7 each.

11000A Cable Assembly

Dual banana plugs terminate a section of 50-ohm cable, 44″ over-all; plugs for binding posts spaced ¾″; HP 11000A, $5 each.

11001A Cable Assembly

Identical with 11000A except dual banana plug on one end and UG-88C/U BNC male on the other; HP 11001A, $6 each.

11002A Test Leads

Dual banana plug to alligator clips, 5′; HP 11002A, $8 each.

11003A Test Leads

Dual banana plug to probe and alligator clip, 5′; HP 11003A, $10 each.

11035A Cable Assembly

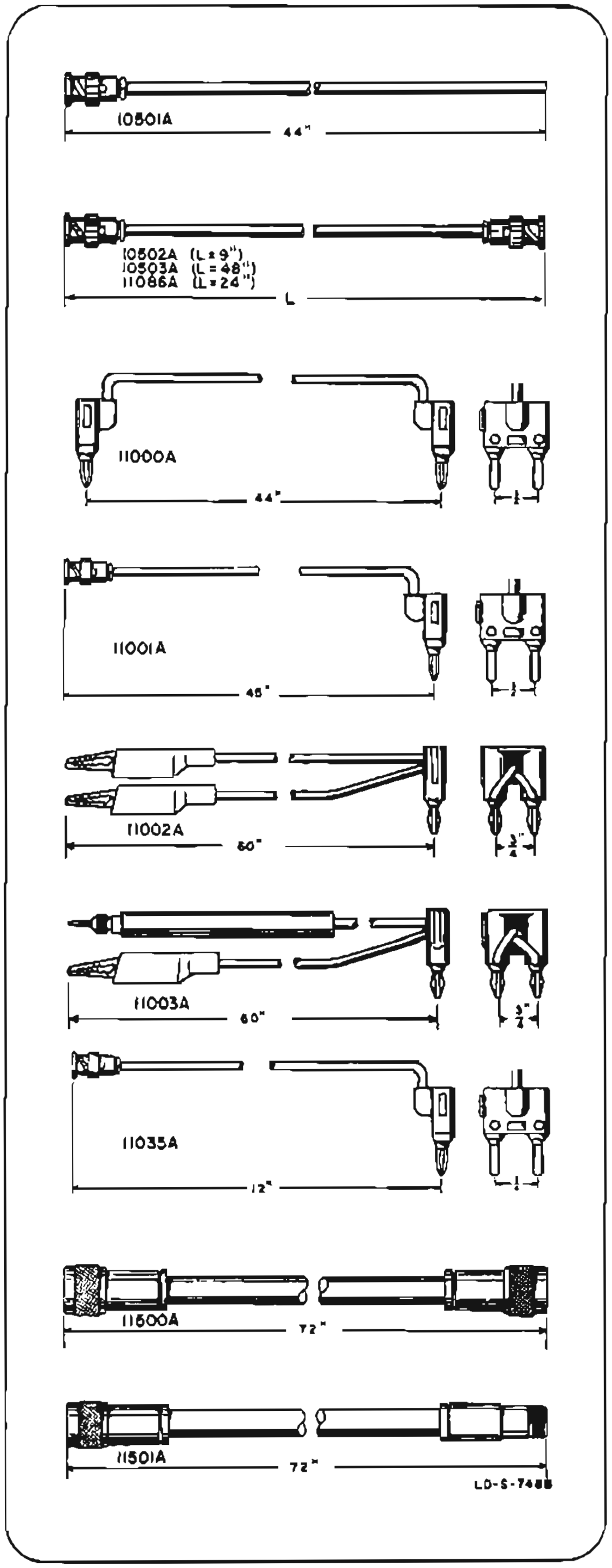
12″ 50-ohm coaxial cable terminated on one end with a dual banana plug and on the other end with a UG-88C/U BNC male connector; HP 11035A, $6 each.

11500A Cable Assembly

6′ of 50-ohm coaxial cable terminated on both ends with UG-21D/U Type N male connectors; HP 11500A, $15 each.

11501A Cable Assembly

6′ of 50-ohm coaxial cable terminated with UG-21D/U Type N male and UG-23D/U Type N female; HP 11501A, $15 each.



MODULAR ENCLOSURE SYSTEM
Versatile instrument packaging

Figure 1. Full rack width cabinets stack one atop the other.

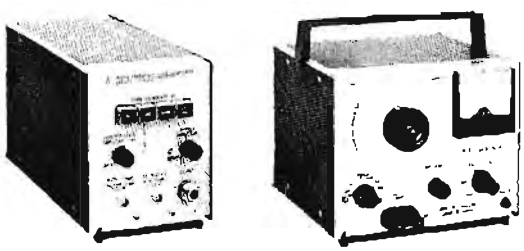


Figure 2. Standard configurations include cabinets one-third and one-half full rack width. Accessory handle 11057A is shown on half-width instrument.

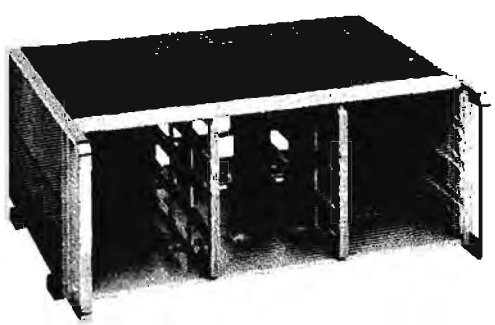


Figure 3. HP 1051A Combining Case.

Figure 4. HP 5060-0797 Rack Adapter Frame and mounting hardware.

The Hewlett-Packard modular enclosure system provides a complete solution to instrument packaging and mounting problems. The system is in accord with EIA standard rack and panel dimensions, yet each enclosure is equally well suited to bench or field use.

The matching enclosures offer an enviable combination of economy, strength and appearance. They are rugged enough to meet many of the stringent military requirements and present a rich, professional appearance which enhances the value of the instrument.

Two types of instruments

Basically, instruments enclosed in the modular system fall into two classes:

1. Those units which require the full EIA rack width. This class of instruments mounts directly in racks with the two brackets and filler-strip included with the instrument. Feet and tilt stand also are provided with full-module instruments for bench use, and the instruments can be stacked conveniently for maximum utilization of available space. For semi-permanent stacking, joining brackets are available which effectively combine two instruments into a single physical unit. Control panel covers are also available for these instruments to protect them when they are transported.
2. Those units which do not need the full rack width. These instruments are standardized at one-half or one-third the width of the full module. Because of their size, they are easily portable and can be used readily in the field, as well as on the bench. Accessory handles 11056A (one-third module) and 11057A (one-half module) are attached easily to these instruments for added handling convenience. In addition, adapter frames are available to mount these units in the standard EIA racks. The HP 1051A, 1052A Combining Cases also can be used for a multi-instrument package that is both portable and easily rack mounted with the hardware provided. Both combining cases and rack adapter frames use blank panels to fill areas not used by instruments and accept one-third width drawers for convenient storage of leads, probes, etc. Model 1052A Combining Cases also accept cooling kits to maintain proper ambient temperature.

Characteristic of both classes of modular instruments is ease of maintenance. Top and bottom covers, as well as side panels, are removable to provide access to all adjustments and test points within the instruments.

Instrument case (1/3 module)

A rugged, high impact plastic instrument case for HP 1/3 module instruments is now available. Instruments can be operated, stored or carried in the splash-proof case. A dual purpose tilt stand also serves as a carrying handle. At the rear of the case is an accessible compartment for the power cord; and in the front lid is a storage space for cables, etc. Refer to page 228 for specifications.

BASIC ACCESSORIES *continued*

Versatile instrument packaging

Specifications

1051A Combining Case (see Figure 3)

Accepts third- or half-module instruments up to 11¼" (286 mm) deep.

Dimensions: 16¾" wide, 7¼" high, 13¼" deep (425 x 185 x 337 mm); hardware furnished for conversion to rack mount 19" wide, 6-31/32" high, 11¼" deep behind panel (483 x 177 x 286 mm).

Weight: net 11 lbs (5 kg); shipping 15 lbs (6,8 kg).

Price: HP 1051A, $110.

1052A Combining Case (not shown)

Accepts third- or half-module instruments up to 16⅜" (416 mm) deep.

Dimensions: 16¾" wide, 7¼" high, 18⅜" deep (425 x 185 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 6-31/32" high, 16⅜" deep behind panel (483 x 177 x 416 mm).

Weight: net 13 lbs (5,9 kg); shipping 18 lbs (8 kg).

Price: HP 1052A, $120.

Rack adapter frame (see Figure 4)

5060-0797 adapter to rack mount third- and/or half-module instruments up to 6-3/32" high (155 mm), $25.

5060-0808 adapter to rack mount third- and/or half-module instruments up to 3" high (75 mm), $25.

Modular enclosure accessories (see Figure 5)

Part Number	Control panel covers EIA panel height (In.)	(mm)	Price
5060-0826	3-15/32	88	$22.50
5060-0827	5-7/32	133	$25.00
5060-0828*	6-31/32	177	$27.50
5060-0829	8-23/32	222	$28.50
5060-0830	10-15/32	266	$30.00
5060-0831	12-7/32	310	$32.50

* Also fits HP 1051A and 1052A.

Joining brackets (see Figure 7)

5060-0215 Joining Bracket Kit for semi-permanently joining any two full-module instruments 11¼" (286 mm) deep behind the front panel, $20.

5060-0216 Joining Bracket Kit for semi-permanently joining any two full-module instruments 16⅜" (416 mm) deep behind the front panel, $25.

Accessory handles (see Figure 2)

11056A Handle for any one-third module instrument, $5.
11057A Handle for any one-half module instrument, $5.

11075A Instrument Case (see Figure 8)

Dimensions: will accept ⅓ module instrument 6½" high, 8" deep.

Weight: net 3 lbs (1,4 kg); shipping 5 lbs (2,3 kg).

Price: HP 11075A, $45.

11076A Instrument Case (see Figure 8)

Dimensions: will accept ⅓ module instrument 6½" high, 11" deep.

Weight: net 3 lbs (1,4 kg); shipping 6 lbs (2,7 kg).

Price: HP 11076A, $45.

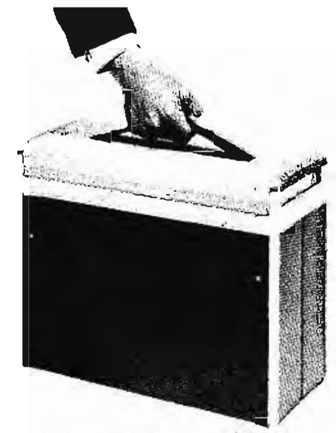


Figure. 5 Instrument covers quickly convert full-width cabinets to easily carried portable units.

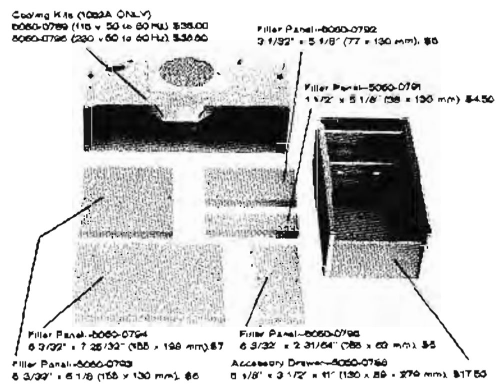


Figure 6. Combining case accessories.

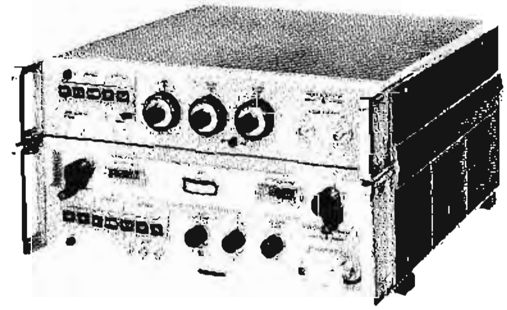


Figure 7. Joining brackets effectively weld instruments into a single physical unit.

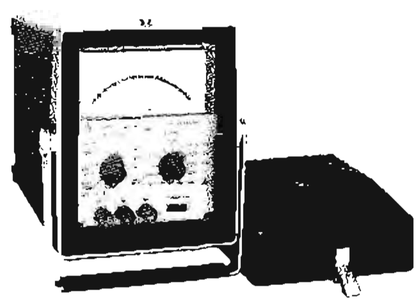


Figure 8. Rugged instrument case and tilt stand.

DIGITAL VOLTMETERS

Digital voltmeters (DVM's) display measurements as discrete numerals, rather than as a pointer deflection on a continuous scale commonly used in analog devices. Direct numerical readout in DVM's reduces human error and tedium, eliminates parallax error and increases reading speed. Automatic polarity and range-changing features reduce operator training, measurement error and possible instrument damage through overload.

Digital instruments are available to measure ac and dc voltages, dc currents resistance and ratio. Other physical variables can also be measured by use of suitable transducers. Many have outputs which can be used to make permanent records of measurements with printers, card and tape punches, and magnetic tape equipment. With data in digital form, it may be processed with no loss of accuracy.

Most popular digital voltmeters on the market today fit into one of the following categories: (1) ramp, (2) staircase ramp, (3) dual slope integrating, (4) integrating, (5) integrating and potentiometric, (6) successive approximation, and (7) continuous balance.

Types currently in use by HP are described below (refer to Table 1, p. 230).

Ramp Types: the operating principle of the ramp digital voltmeter is to measure the time a linear ramp takes to change from the input level to ground (or vice versa). This time period is measured with an electronic time-interval counter and displayed on in-line indicating tubes. The advantages of this type of instrument are low price and simplicity. Conversion of a voltage to a time interval is illustrated by the timing diagram in Figure 1. At the start of a measurement cycle, a ramp voltage is initiated. The ramp is compared continuously with the voltage being measured; at the instant they become equal, a coincidence circuit generates a pulse which opens a gate. The ramp continues until a second comparator circuit senses that the ramp has reached zero volts. The output pulse of this comparator closes the gate.

The time duration of the gate opening is proportional to the input voltage. The gate allows pulses to pass to totalizing circuits, and the number of pulses counted during the gating interval is a measure of the voltage. Figure 2 illustrates the technique used in the HP 3440A Digital Voltmeter.

The 3440A has an accuracy of ±0.05% of reading with reading rates up to 5 per second. These features, coupled with its capability of 10 μV resolution, 4-digit readout, and plug-in versatility, make it a popular and economical choice.

The HP 3430A is a 3-digit DVM priced not much higher than an analog voltmeter.

The speed, convenience, and accuracy of digital readout now becomes available at a moderate price for general-purpose applications in the laboratory, on production test stands, in repair shops, and at inspection stations. The new DVM has a floating input, a feature not commonly found in low cost digital voltmeters. An optional version of the instrument permits ratio measurements, a useful feature for normalizing the readings of dc transducer outputs and taking readings using an external reference. A precision dc amplifier output is an additional benefit of this model.

Referring to Figure 3, the 3430A makes voltage measurements by comparing the input voltage to an internally generated "staircase ramp" voltage. When the input and the staircase ramp voltages are equal, a comparator generates a signal to stop the ramp. Then the instrument displays the number of counts necessary to make the staircase ramp equal to the input. At the end of the sample, a reset pulse resets the staircase to zero and the measurement starts over. The display circuits store each reading until a new reading is completed, eliminating any blinking or counting during computation. The sample rate is fixed at two samples per second.

Integrating types: an integrating digital voltmeter measures the true average of the input voltage over a fixed measuring period, in contrast to ramp-types

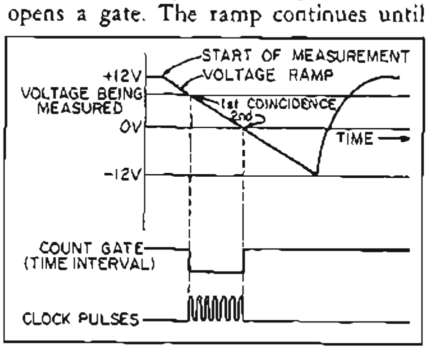


Figure 1. Voltage-to-time conversion.

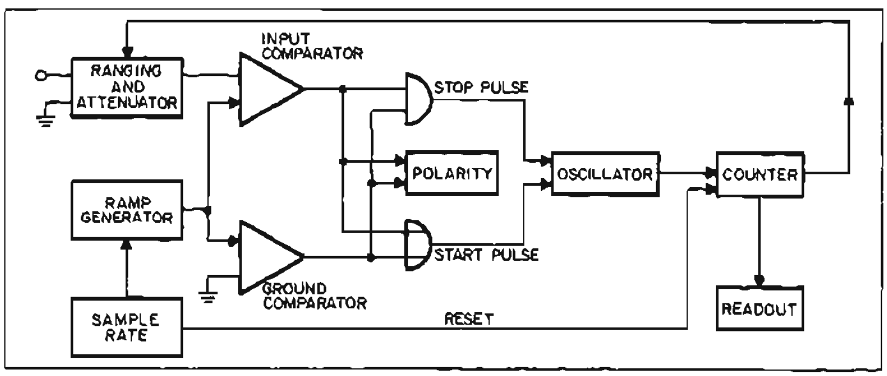


Figure 2. Block diagram of HP 3440A Digital Voltmeter.

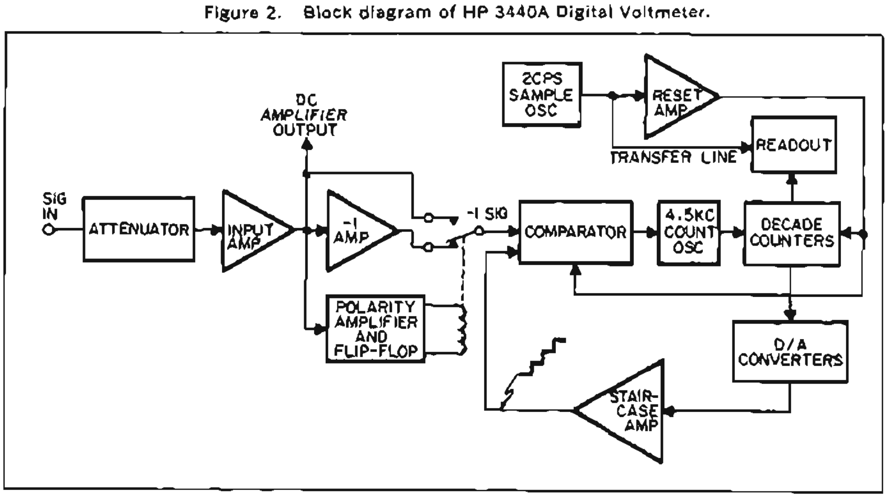


Figure 3. Block diagram of HP 3430A Digital Voltmeter.

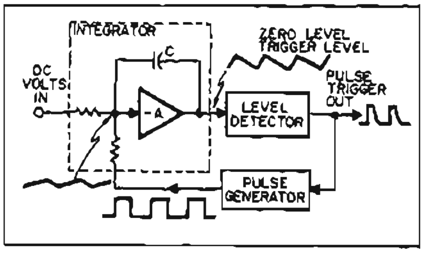


Figure 4. Voltage-to-frequency conversion.

which measure the voltage at the end of the measuring interval. A widely-used technique to accomplish integration is the use of a voltage-to-frequency converter, as indicated in Figure 4. The circuitry functions as a feedback control system which governs the rate of pulse generation, making the average voltage of the rectangular pulse train equal to the dc input voltage.

The major advantage of this type of analog-to-digital conversion is its ability to measure accurately in the presence of large values of superimposed noise, because the input is *integrated* over the sampling interval. The reading represents a true average of the input voltage.

The HP 2402A Integrating Digital Voltmeter, which is in the 0.01%-accuracy class, uses the voltage-to-frequency conversion technique, achieving the ability to reject the effects of superimposed noise. A floated and guarded input circuit eliminates common-mode noise error. Combined, these techniques yield effective common-mode rejection of 126 dB at any frequency.

This model measures the average value of the applied voltage over a 1/60 second sample period. Used in a data system, it provides the benefit of integration and in one second can make 43 separate 5-digit measurements with a maximum resolution of 1 part in 130,000. When used on the bench without external triggering, it takes up to 10 readings per second. In addition, it has constant 10-megohm input resistance and is designed for completely programmable operation within a digital data acquisition system.

DC voltage, ac voltage, resistance, frequency and range (or autorange) can all be selected by remote programming. The simplified block diagram illustrated in Figure 5 represents the basic functional components which enable the HP 2402A to accept analog signals and convert them to digital information.

Basically, the instrument consists of a voltage-to-frequency converter and a counter. A dc voltage applied to an integrating amplifier in the converter is changed to a pulse rate proportional to the applied voltage. AC voltage and resistance inputs are converted to dc voltage before being applied to the converter.

During the 1/60-second interval, the output of the V/F converter is applied to the 10^5 decade (see Figure 5). An interpolation technique is used after the sampling period when pulses are entered into the 10^0 decade. These pulses are proportional to the charge remaining on the integrating capacitor after the 1/60-second sampling time. After the interpolation period, the counts present in all decades are displayed by in-line digital readout tubes.

The V/F converter is isolated from the counter by a shielding technique known as guarding, which isolates the input interconnected between the converter and counter sections by thru-guard transformers and thru-guard relays. Each section has its own power supply.

The converter section includes attenuating and switching circuits in addition to the voltage-to-frequency converter. The counter section includes a time-base generator, decade dividers and control logic circuits in addition to the reversible counter.

The HP 2401C Integrating Digital Voltmeter is also in the 0.01% accuracy class, and uses the voltage-to-frequency conversion technique, achieving outstanding ability to reduce the effects of *superimposed* noise; it achieves *common-mode* noise rejection by guarding.

This model applies especially well to measurements of extremely noisy signals. Measurements down to 99.999 mV full scale can be made without an accessory amplifier. Complete remote-control ability makes it ideal for system applications. It can also be used as an electronic counter to measure frequency or period.

Integrating/Potentiometric Types: by using techniques exploiting the best qualities of several systems, a totally new result is achieved in the HP 3460B. Besides being an integrating-type voltmeter which continually measures the true average of the input voltage, it is also a potentiometric type providing high accu-

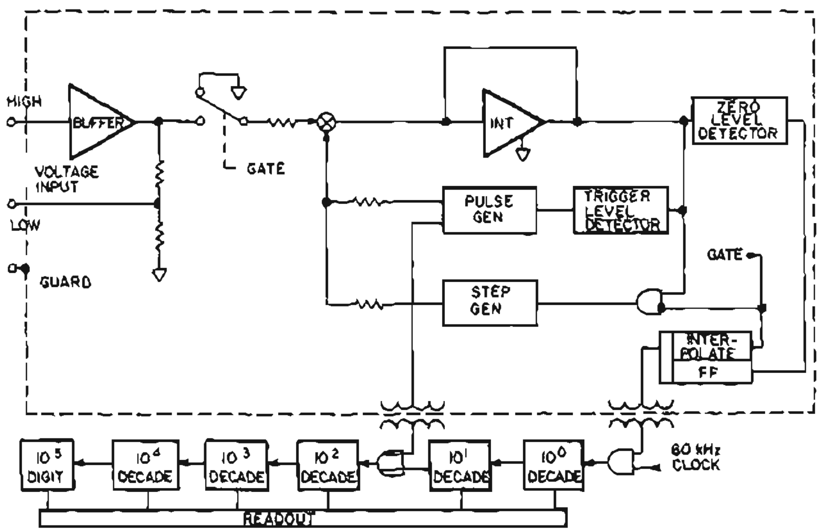


Figure 5. Block Diagram Model 2402A DVM.

Table 1. Hewlett-Packard Digital Voltmeters.

Model (Type)	Accuracy (% of reading)	Number Digits	Overrange %	Speed (Max.) Readings/sec	AC Volts	DC Volts	DC Amps	Ohms	Ratio	Auto Ranging	Floating Input	Guarding (CMR)	Printer Output	Remote Ranging	Remote Triggering	Plug-Ins	Systems Application	Limit Test
Dual-slope/ Integrating																		
3450A (pg 241)	0.008	5	120	15	▲	X		▲	†	X	X	X	▲	▲	X	▲	X	▲
Integrating/ Potentiometric																		
H04/3460A(pg 250)	0.005	6	120	1		X				X	X	X	X	X	X		X	
3460B (pg 248)	0.004	5	120	15	+	X		+		X	X	X	X	X	X		X	
Integrating																		
HP-2402A (pg 244)	0.01	5	120	43	▲	X		▲		▲	X	X	X	X	X	▲	X	
HP-2401C (pg 246)	0.01	5	300	1**	±	X		±		*	X	X	X	X	X		X	
Ramp																		
3440 (pg 237)	0.05	4	105	5	●	●	●	●		X	X		X	X	X	●	X	
3439A (pg 236)	0.05	4	105	5	X	X	X	X		X	X			X		●		
3430A (pg 234)	0.1	3	160	2		X			X		X							

*Optional: ±HP-2410B AC/Ohms Converter; +HP 3461A AC/Ohms Converter.
**4 digits/9 readings per sec; 3 digits/50 readings per sec.
▲ plug-in circuit cards. ● plug-in drawer
†Ratio for ac, dc, ohms and limit test.

racy from precision resistance ratios and a stable reference voltage. A block diagram of the Integrating/Potentiometric Digital Voltmeter is shown in Figure 6.

The HP 3460B is a good choice for applications requiring extremely high accuracy (±0.004% of reading) and high speed with high resolution. The 3460B takes up to 15 readings per second with 5-digit resolution (1.20000 full scale). Since the instrument is guarded, all readings can be made in the presence of large common-mode signals. The integration characteristic also allows a maximum reading rate, even with noise superimposed on the signal.

To be useful as the central analog-to-digital converter in an automatic system, a DVM must have several features which are not needed in a bench meter. Among these are binary-coded decimal output and remote controls. If system use is not intended, cost can be reduced by omitting these features.

The HP H04-3460A, which also uses the integrating/potentiometric technique, has a resolution of 1 part in 1,200,000 and a sensitivity of 1 μV on the 1 volt range. Its measurement accuracy is 0.005% of reading.

Dual-Slope Integration Type: this entirely different technique is used in the HP 3450A Multi-Function 5-digit Voltmeter. The 3450A measures dc voltages by the use of an integrator which produces a time interval proportional to the average value of the applied dc voltage. The time interval determines the gate time of the counter, and therefore the number of pulses totalized. Thus, the number of pulses is proportional to the average of the dc voltage measured.

This technique of integrating the input signal over a precise time interval takes care of normal-mode rejection (line frequency, noise and varying signals) without the use of input filters which reduce the speed of readings considerably.

During a precisely controlled time period of 1/10 or 1/60 of a second, selectable for optimum performance, the 3450A integrates the input signal forming an up-slope. This voltage, stored after integration, is proportional to the average of the dc input voltage. To start the down-slope a precise reference voltage of opposite polarity is switched to discharge the integrator. The zero crossing of the output voltage is detected by a zero detect circuit. The counter is enabled to totalize pulses from a crystal oscillator during the discharge time or down-slope of the integrator. As the discharge time is proportional to the stored voltage, the number of pulses totalized is proportional to the input voltage.

After completion of the integration cycle, the input amplifier is disconnected and automatically zeroed before the next measurement is taken. This autozeroing

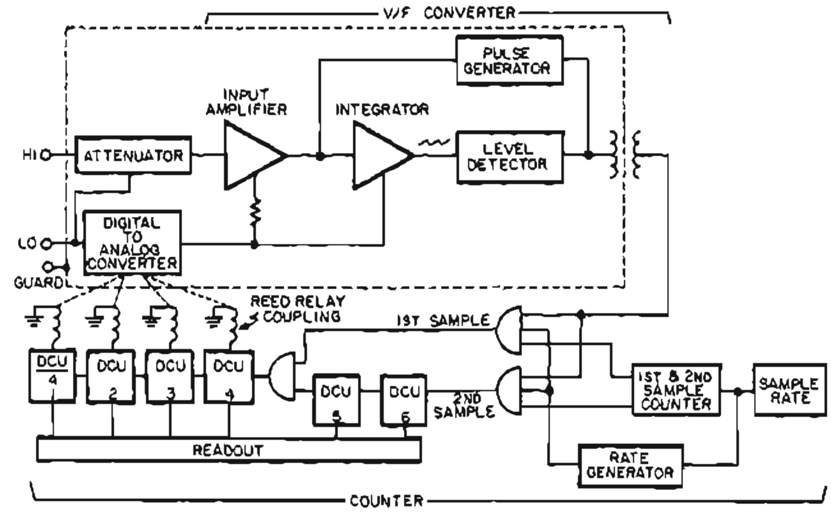


Figure 6. Block diagram of HP 3460B DVM.

effectively compensates for dc drift and eliminates the need for a chopper amplifier and front panel zero controls.

For dc voltage measurement the input is connected to the X input terminals (refer to Figure 7). For dc ratio measurement the ratio is the voltage applied to the X terminals over the voltage applied to the Y terminals (X/Y). The ratio measurement is performed in the same manner as a dc voltage measurement except the down-slope is not determined by the reference voltage but by the Y input voltage. The measurement sequence is as follows: 1) The Y input is measured to determine the proper range for Y. 2) This information is stored. The Y ranging is always performed automatically even if the instrument is switched to manual ranging. 3) The X input is applied to the integrator and the proper range determined. (The range for X must be equal to or higher than that of Y.)

4) After the ranges for both inputs are determined, the X input will be enabled to charge the integrator. 5) Then, the Y input will be enabled (on the proper range) to discharge the integrator. The front panel digital display is the ratio of X/Y.

The X and the Y inputs are measured sequentially. The inputs are switched off and on in sequence. By switching both the high and the low of each input, complete isolation of X and Y and identical input impedances are achieved.

True rms ac to dc converter: ac voltage and ac ratio is a true rms responding measurement for frequencies from 45 Hz to 1 MHz. The input circuitry (shown in the block diagram Figure 8) consists of an operational amplifier whose gain is accurately controlled to achieve attenuation of the input signal. An ac output from the input amplifier is sent to the modulator, and a second output is used as a trigger for the sync generator (nominally 5 Hz). The sync square-wave generator is used to synchronize the modulator and demodulator to the input signal.

A 1 kHz oscillator drives the dc-to-square wave converter which converts the dc output of the ac converter into a reference square wave. The amplitude of the square wave is proportional to the dc output. The output of the modulator, at a nominal 5 Hz rate, consists of a composite signal made up of one-half input signal and one-half reference square-wave (refer to waveshape in Figure 8).

The AGC amplifier controls the gain of the sampling amplifier and the integrator. This keeps the rms value of the signal applied to the thermocouple constant and holds the gain of the system constant regardless of the level of the input signal. The output of the thermocouple varies between two levels, reflecting a difference in the rms value of the input and the reference signal. This error signal is amplified, and two signals 180° out of phase are sent to the demodulator. The demodulator acts as a full-wave rectifier. The output pulses are amplified

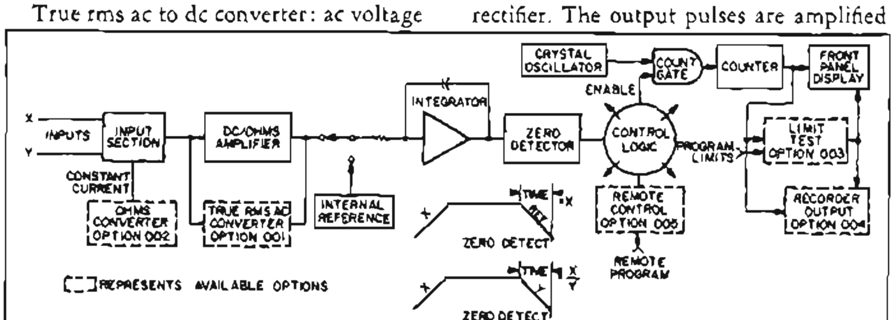


Figure 7. Block diagram of the 3450A Multi-Function Meter.

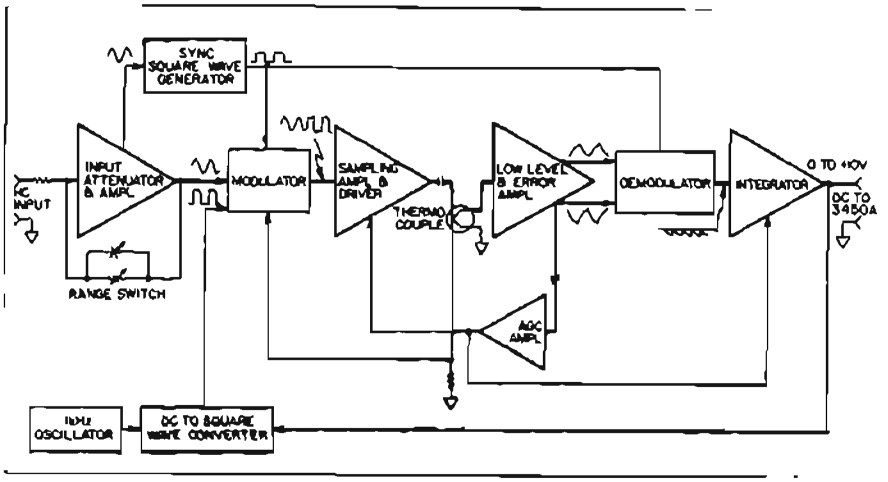


Figure 8. Ac-dc converter for the 3450A.

and integrated to develop the positive dc voltage output. This dc voltage is continuously corrected at nominally 5 times per second to insure a dc voltage output proportional to the rms value of the input signal. From this true rms converter the 3450A provides ac measurements and ac ratio as described for dc measurements.

Ohms Converter: a 4 wire ohms measurement and a 4 terminal ohms ratio measurement can be made with a maximum current of 1 mA applied to the external resistor on the 10 kΩ range. This minimizes errors caused by self-heating of the unknown resistor.

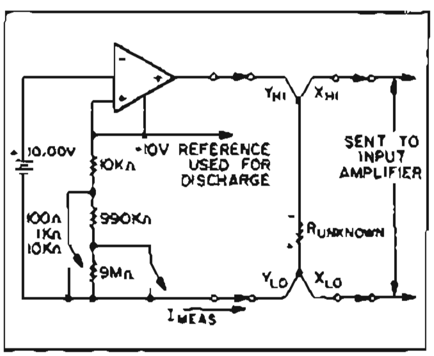


Figure 9. Ohms converter for the 3450A.

A current source supplies three constant currents of 1 mA, 10 μA and 1 μA and an open loop voltage of 17 volts maximum. In ohms operation the X input is the sense terminals, and the Y input is the current terminals. These must be connected for operation (refer to Figure 9), and for optimum accuracy the Hi input for both should be connected to one end of the unknown resistor and the Lo for both to the other end of the unknown resistor. In ohms ratio the four terminals are used as in any other ratio operation with complete isolation between the X and Y inputs.

The resistance measurements are made by feeding a constant current through the unknown resistor and measuring the resultant voltage across the resistor. This current source is similar to an emitter follower with a constant ten volts across the emitter resistor. To increase measurement accuracy, the 3450A reference voltage is disabled, and the ohms reference voltage is used to discharge the integrator.

Limit Test: This operation provides Hi, Go or Lo indication according to two preset limits. If the front panel digit readout is between the two preset limits, the Go indicator will light. If the reading is above the higher limit, the Hi indicator will light, and if the readout is lower than either limit, the Lo indicator will light. This function may also be used for ratio measurements.

Options for remote operation, BCD output and rear input terminals can be obtained. Any combination of options can be purchased, or plug-in modules can be inserted at a later date. Refer to pages 241 through 243 for additional information and specifications.

Selecting a Digital Voltmeter: If the DVM is to be used in a data acquisition system, binary-coded decimal (BCD) output and remote programming ability are necessities. Compatibility with related equipment (see page 118) should be determined.

When selecting a digital voltmeter to make accurate measurements in the presence of noise, the DVM must discriminate the real signal from the noise appearing at its input terminals. Noise rejection by integration permits high accuracy in the presence of severe noise.

The integrating digital voltmeter reads the average value of the input signal over a fixed sample interval and fits into an attractive price class.

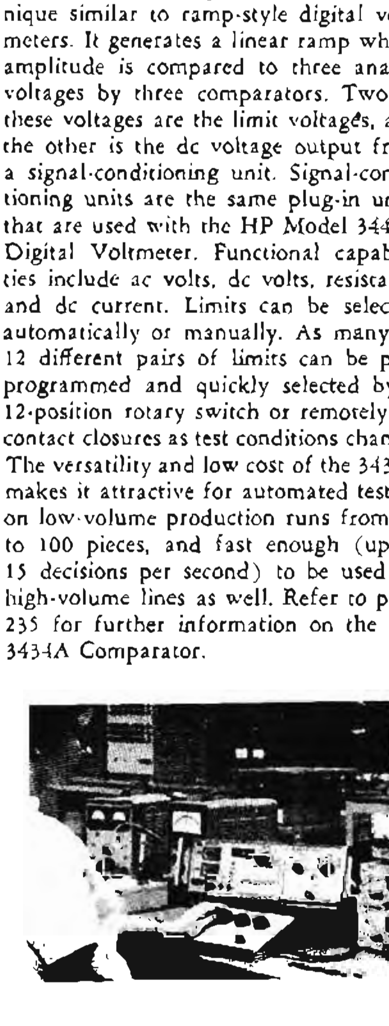
Noise on the signal may be inexpensively reduced by equipping the digital voltmeter with a passive input filter. Filtering need not degrade voltmeter accuracy, but it reduces measurement speed. Consideration of speed must be made if the digital voltmeter is to be used in data acquisition systems.

Common-mode pickup, emf's common to both high and low-terminals, is frequently a severe measurement problem. Guarding, which virtually eliminates the effects of common-mode noise, can be important. The ability to measure signals around zero may be needed, in which case inclusion of a bi-directional counter (HP 2401C, HP 2402A and HP 3460B) is desirable. Refer to Table 1—a Hewlett-Packard DVM is available to meet most application requirements.

High-Go-Low Comparator: Often with the use of a digital voltmeter, an operator must decide whether the number displayed during each measurement lies between two limits. Typical applications include assembly-line tests, system check-out procedures, inspection, instrument calibration, circuit parameter testing, sorting, batching and matching components including integrated circuits.

A moderately-priced Hi, Go, Lo semi-automatic system used in place of a manual arrangement can reduce operator fatigue, result in fewer measurement errors, reduce test time and permit operation by less experienced operators.

Designed to bridge this gap, the HP Model 3434A Comparator uses a technique similar to ramp-style digital voltmeters. It generates a linear ramp whose amplitude is compared to three analog voltages by three comparators. Two of these voltages are the limit voltages, and the other is the dc voltage output from a signal-conditioning unit. Signal-conditioning units are the same plug-in units that are used with the HP Model 3440A Digital Voltmeter. Functional capabilities include ac volts, dc volts, resistance and dc current. Limits can be selected automatically or manually. As many as 12 different pairs of limits can be preprogrammed and quickly selected by a 12-position rotary switch or remotely by contact closures as test conditions change. The versatility and low cost of the 3434A makes it attractive for automated testing on low-volume production runs from 50 to 100 pieces, and fast enough (up to 15 decisions per second) to be used on high-volume lines as well. Refer to page 235 for further information on the HP 3434A Comparator.



HP 3434A used for production line testing of integrated circuits.

AC/DC Converters: the ac-to-dc converter (Figure 10) typically produces a dc output voltage between 0 and 1 V dc proportional to the average value of the applied ac voltage calibrated in rms.

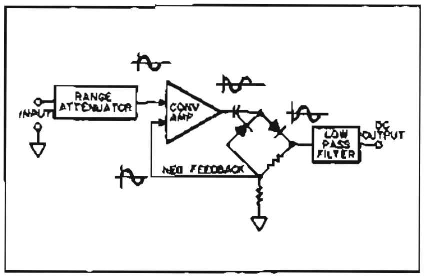


Figure 10. Typical ac/dc converter.

Ohms-to-Dc Converter: the ohms-to-dc converter, frequently an additional function of ac-to-dc converters, produces a dc output voltage between 0 and 1 V dc proportional to the value of the unknown resistance applied. Most ohms-to-dc converters require a high input impedance dc preamplifier.

The HP 3461AC/Ohms Converter DC Preamplifier has total compatibility with the 3460B, and can measure ac voltages up to 1200 V rms, and resistances up to 12 megohms. It is fully guarded, automatic ranging on all functions, and is remotely programmable.

The compatible AC-ohms converter for the 2401C is the HP Model 2410B.

Plug-in AC/DC Converters: the HP 3445A and 3446A Plug-ins are companions to the HP 3439A and 3440A Digital Voltmeters.

Analog Voltmeters used as AC/DC Converters: connect any dc DVM with a 1 V dc range to the dc output of an analog voltmeter, such as the HP 400E/EL.

True rms measurements from 10 Hz to 10 MHz can similarly be made by combining any dc digital voltmeter having a 1-volt range with the HP 3400A RMS Voltmeter.

Typical specifications of Hewlett-Packard ac-to-dc and ohms-to-dc converters are listed in Table 2.

Table 2. Hewlett-Packard AC/Ohms Converters/Preamplifiers.

Converter type (refer to page)	Companion HP DVM	Ranges	Auto ranging	Floating	Guarded	Plug-ins	Remote ranging	Remote triggering	Systems application	Calibration period (days)	Accuracy of measurement at full scale 20°C to 30°C	Can be used with other 1 V range DVM's
AC to DC												
3450A Option 001 True rms (pg. 242)	Part of 3450A	1 to 1000 V 4 ranges	X	X	X	**	X	X	X	30	True rms (45 Hz to 1 MHz) ±0.05 to 2.1%	No
2402A Option 02 (pg 244)	Part of 2402A	1 to 1000 V 4 ranges	X	X	X	**	X	X	X	180♠	(50 Hz to 100 kHz) ±0.12 to ±0.31%	No
3461A (pg 249)	3460B	1 to 1000 V 4 ranges	X	X	X		X	X	X	90	(50 Hz to 100 kHz) ±0.07% to ±0.15%	Yes
2410B (pg 246)	2401C	0.1 to 1000 V 5 ranges	‡	X			X	X	X	90♠	(50 Hz to 100 kHz) ±0.175% to 0.5%	Yes
3445A/3446A (pg 240)	3439A/3440A	10 to 1000 V 3 ranges	X	X		X	X	X	X	90♠	(50 Hz to 100 kHz) ±0.1% to ±0.3%	No
457A* (pg 252)		1 mV to 1000 V 4 ranges		X							(50 Hz to 500 kHz) ±1.05%	Yes
3400A* (true rms) (pg 212)	3439A/3440A	1 mV to 300 V 12 ranges									(10 Hz to 10 MHz) ±0.75% to ±5.0%	Yes
400E/EL* (avg) (pg 209)	3439A/3440A	1 mV to 300 V 12 ranges								365	(10Hz to 10 MHz) ±0.5% to ±5.0%	Yes
OHMS to DC												
3450A Option 002 (pg 242)	Part of 3450A	100Ω to 10MΩ 6 ranges	X	X	X	**	X	X	X	30	±0.012 to 0.102%	No
2402A Option 03 (pg 244)	Part of 2402A	1 kΩ to 10 MΩ 5 ranges	X	X	X	**	X	X	X	180♠	±0.055%	No
3461A (pg 249)	3460B	1 kΩ to 10 MΩ 5 ranges	X	X	X		X	X	X	90	0.016% to ±0.02%	Yes
2410B (pg 246)	2401C	100Ω to 10 MΩ 6 ranges	‡	X	X		X	X	X	90♠	±0.089%	Yes
3444A (pg 239)	3439A/3440A	1 kΩ to 10 MΩ 5 ranges		X		X			X	90♠	±0.3% to ±1.0%	No
DC AMPLIFIERS												
3461A (pg 249)	3460B	0.1 V dc to 1 kV dc 5 ranges	X	X	X		X	X	X	90	±0.008% to ±0.011%	Yes
2411A (pg 246)	2401C	+1, +10 gain		X	X		X	X	X	180♠	±0.03%	No
3443A (pg 238)	3439A/3440A	100 mV to 1 kV 5 ranges	X	X		X	X	X	X	90♠	±0.05% to ±0.1%	No
3444A (pg 239)	3439A/3440A	100 mV to 1 kV 5 ranges		X		X		X	X	90♠	±0.05% to ±0.1%	No

‡Standard 2401B autoranges with 2401C option 31.

*Accuracy of converter only. Accuracy of readout device should be added to determine accuracy of measurement.

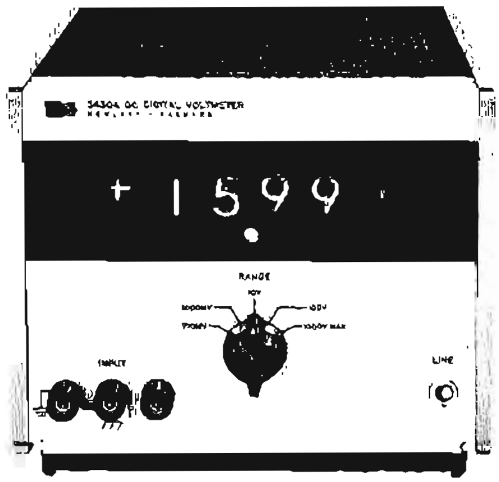
**Options added by plug-in circuit modules and boards.

♠Assumes daily calibration of basic instrument against internal calibration standard after 30 minute warm-up.

DC DIGITAL VOLTMETER

3 Digit DVM at the price of analog voltmeters

Model 3430A



3430A

Description

The Hewlett-Packard 3430A DC Digital Voltmeter offers precision performance at an economical price. The 3430A may be used in the laboratory or for continuous service under rigorous operating conditions in the production area.

Designed for easy operation, the 3430A may be used by inexperienced personnel. The input voltage is indicated by a large, easy-to-read display with the proper units shown by an annunciator. Polarity and decimal point are automatic.

The 3430A is able to make full-scale dc voltage measurements from ±100.0 mV to ±1000 V with up to 60% overranging. To save costly frequent calibration, the 3430A maintains its ± (0.1% of reading +0.1% of range) accuracy for 90 days. This digital voltmeter has a 3-digit display with 60% overranging indicated by a 4th digit. The chance of circuit loading is reduced by the 10 MΩ input resistance.

DC amplifier

A precision (±0.1%) analog dc output is available on the rear panel. This permits the 3430A to be used as a dc amplifier with a non-inverting voltage gain up to 100.

Voltage ratio option

Three-terminal ratio measurements may be made with the option 01. A rear-panel switch permits either normal or ratio mode of operation. In the ratio mode, the voltmeter indication is proportional to the ratio of the input voltage (front terminals) to the reference voltage (rear terminals).

Specifications

Ranges

Voltage: ±100.0 mV, ±1000 mV, ±10.00 V, ±100.0 and ±1 kV f.s.

Overranging: 60% on all ranges except the 1 kV range. (indicated by the 4th digit).

Range selection: manual.

Performance rating

Accuracy: ±(0.1% of reading +0.1% of range) for 90 days, 15°C to 35°C.
Accuracy over the temperature ranges of 0°C to 15°C and 35°C to 50°C is ±(0.25% of reading +0.1% of range).

Reading rate: fixed at 2 readings/s by internal trigger.

Input characteristics

Inputs: floated binding posts on front panel may be operated up to ±500 V dc (350 V rms) above chassis ground.

Input Resistance: 10 mΩ ±3.0% on all ranges.

Effective common-mode rejection (EMCR): ECMR is the ratio of the common-mode signal to the resultant error in the reading.

DC to 60 Hz: >90 dB on the 100 mV range, decreasing 20 dB per range.

AC normal-mode rejection (ACNMR): ACNMR is the ratio of the ac normal-mode signal to the resultant error in the reading.

60 Hz: 40 dB increasing 12 dB/octave.

Overload protection: ±1050 V may be applied on any range except the 100 mV range, where the limit is ±700 V. Overload is indicated by a flashing display.

DC amplifier

Gain (non-inverting): X100 on the 100 mV range, X10 on 1000 mV range, X1 on 10 V range, X0.1 on 100 V range, and X0.01 on 1000 V range.

Output: ±16 V dc maximum at 1 mA-maximum current.

Accuracy: ±0.1% from 15°C to 35°C.

Response time: <0.5 s to 99.9% of final value.

Ratio option (option 01)

Ratio: 0.1:1, 1:1, 10:1, 100:1, and 1000:1.

Overrange: 60% for reference voltage inputs <1 V, decreasing to 33% at 1.2 V.

Range selection: manual by front panel range switch.

Ratio mode selection: manual by rear panel switch.

Accuracy: ±(0.15% of reading +0.1% of range) for 90 days from 15°C to 35°C.
Accuracy over the temperature ranges of 0°C to 15°C and 35°C to 50°C is ±(0.30% of reading +0.1% of range).

Input: 3 terminal with circuit ground common.

Front terminals: ±100.0 mV, ±1000 mV, ±10 V, ±100 V and ±1000 V ranges.

Rear terminals (reference voltage): 0.8 V to 1.2 V. Polarity selected manually by rear panel switch.

Displayed voltage ratio: $\frac{\text{front terminal voltage}}{|\text{rear terminal voltage}|}$

Input resistance: front terminals: 10 MΩ ±3%.

Rear terminals: positive polarity, 50 kΩ ±2%. Negative polarity, 511 kΩ ±2%.

General

Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <20 W.

Dimensions: 7¾" wide, 6¼" high (without removable feet), 11" deep (197 x 159 x 279 mm).

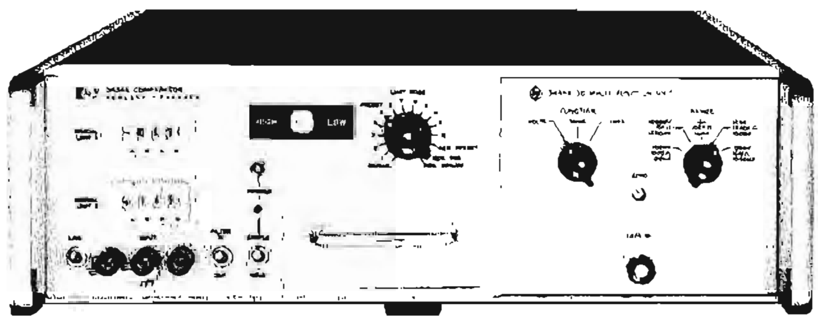
Weight: net 9.75 lb (4,4 kg), shipping 12 lb (5,4 kg).

Price: HP 3430A, $595.
HP 3430A (option 01), voltage ratio, add $80.

HIGH-GO-LOW COMPARATOR

Production time saver for repetitive tests

Model 3434A



3434A with 11084A and 3444A plug-in

High-go-low

This versatile comparator compares the unknown quantity to preset limit pairs. If its value exceeds (more positive) the high preset limit, the HIGH or red light will glow. If its value is smaller (less positive) than the low preset limit, the LOW or yellow light will glow. If its value is between the preset limits, the GO or green light will glow. Contact closures which operate simultaneously with the corresponding (HIGH-GO-LOW) lights are available at an output connector. This information is presented until a new comparison has been completed.

If the main test control switch is replaced by a stepping switch or a scanner, the High-Go-Low outputs may be used as control signals to automate a system. The functions and ranges available depend on the plug-in utilized. (See Table page 236.) Refer to pages 238 through 240 for usable plug-ins. Refer to page 232 for applications of the 3434A in production lines and for other applications including integrated circuit tests.

Specifications*

Functions: provides HIGH-GO-LOW testing for dc volts, ac volts, dc current and ohms with the appropriate plug-in (Table 1, page 236. The 3434A does not have auto-ranging).

Ranges:

DC voltage: 100 mV, 1000 mV, 10 V, 100 V and 1000 V.

AC voltage: 10 V, 100 V and 1000V.

Resistance: 1000Ω, 10 kΩ, 100 kΩ, 1000 kΩ and 10 MΩ.

DC current: 100 μA, 1000 μA, 10 mA, 100 mA and 1000 mA.

Note: Ranges and functions depend on the plug-in.

Performance rating

Accuracy: (all accuracy specifications apply for 90 days from +15°C to +40°C). Limits selected by manual thumbwheels, Preset Programmer (11084A) remote preset or remote BCD.

DC voltages: 10 V, 100 V and 1000 V ranges: ±(0.02% of setting +0.03% of range).

100 mV and 1000 mV ranges: ±(0.05% of setting +0.03% of range).

AC voltages: 10 V, 100 V and 1000 V ranges 50 Hz to 20 kHz: ±(0.08% of setting +0.06% of range). 20 kHz to 50 kHz: ±(0.12% of range). 50 kHz to 100 kHz: linearly derated from ±0.12% of range at 50 kHz to ±0.3% of range at 100 kHz.

Resistance: 1000Ω, 10 kΩ, 100 kΩ and 1000 kΩ ranges: ±(0.2% of reading +0.03% of full scale). 10 MΩ range: ±(0.8% of reading +0.03% of full scale).

Current: 100 μA, 1000 μA, 10 mA, 100 mA and 1000 mA ranges: ±(0.15% of reading +0.04% of full scale).

Limits selected by remote analog are improved as follows:

DC voltage ranges: accuracy improved by ±0.01% of range.

AC voltage ranges: accuracy improved by ±0.02% of range (50 Hz to 20 kHz).

Resistance ranges: accuracy improved by ±0.01% of range.

DC current ranges: accuracy improved by ±0.01% of range.

Input characteristics

Inputs: 3 terminals permit floating measurements up to ±500 V dc (350 V rms) with respect to chassis ground. Rear terminals in parallel are provided.

DC resistance: 10.2 MΩ on all dc ranges.

AC impedance: 3445A (plug-in input only) 10 MΩ/20 pF 3446A (plug-in input), 10 MΩ/35 pF; main frame input, 10 MΩ/175 pF.

Response time: (limit change) 200 ms; (range or function change) 40 ms; (after trigger) 32 ms + 150 ms to 6 s dependent on function and range.

Effective common mode rejection: at dc for all ranges, 90 dB; at 60 Hz for all ranges, (filter in) 56 dB; (filter out) 41 dB.

AC normal mode rejection: 100 mV and 1000 mV ranges (filter in or out) 30 dB at 60 Hz increasing at 6 dB/octave; 10 V, 100 V and 1000 V ranges (filter in) 30 dB at 60 Hz increasing 12 dB/octave; (filter out) 15 dB at 60 Hz increasing 6 dB/octave.

Input signals

Limit selection modes: manual, preset, remote preset, remote BCD, remote analog.

General

Power: 115 or 230 V ±10%, 50 to 400 Hz, <30 W.

Dimensions: (full module) 16¾" wide, 5" high (without removable feet), 18⅜" deep (425 x 127 x 463 mm). Rack mounting kit included (19").

Weight: net 18 lbs (8 kg); shipping 29 lbs (13 kg).

Price: HP 3434A, basic unit, with the 11084A programmer $1800. HP 3434A optional basic unit alone $1575.

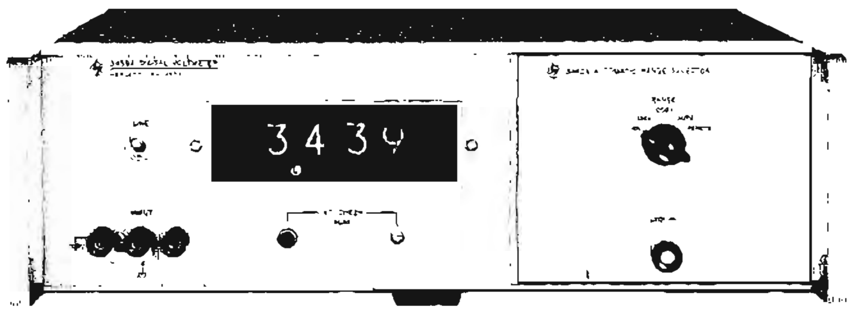
Plug-ins: HP 11084A Programmer, $225; HP 3441A Range Selector, $40; HP 3442A Automatic Range Selector, $150; HP 3443A High Gain/Auto Range Unit, $500; HP 3444A DC Multi-Function Unit, $575; HP 3445A AC/DC Range Unit, $575; HP 3446A AC/DC Remote Unit, $600.

*Refer to data sheet for complete specifications.

DIGITAL VOLTMETERS

Interchangeable Plug-ins Increase Versatility

Models 3439A, 3440A



3439A with 3442A plug-in

Interchangeable Plug-ins Increase Voltmeter Versatility

The HP Models 3439A and 3440A are compact, accurate, rapid and multiple-function digital voltmeters. The choice of automatic ranging, remote and manual operation is obtained by using the 3441A, 3442A, 3443A, 3444A, 3445A or 3446A plug-ins, which are interchangeable with any 3439A or 3440A. The basic voltmeter is solid-state with easy-to-service plug-in circuit cards mounted in the Hewlett-Packard modular enclosure.

DC voltages up to 999.9 V of either polarity are displayed in four significant digits with an accuracy of better than ±0.05% of reading ±1 digit and with the polarity of the applied signal indicated automatically. Modes of range selection available for the plug-ins include manual, remote and automatic. Refer to Table 1 for data. The bright, easy-to-read display reduces operator fatigue. Readout storage is another feature of the 3439A and 3440A with large rectangular digital display tubes which display the previous reading, changing only if the input voltage changes. A polarized light filter reduces the reflection of external light so that a good contrast results when the digits are lighted.

Accuracy and Speed

The 3439A and 3440A Digital Voltmeters have a dc accuracy of better than ±0.05% of reading ±1 digit over the ambient temperature of +15°C to +40°C with a line voltage variation of ±10%. In addition, specified accuracy is retained to 5% beyond full scale, a feature that permits 5-digit resolution at the decade range change points. The ac input filter has a rejection of 30 dB at 60 Hz and the response time to a step change is 450 ms to read 99.95% of final value without a range change.

The input signal pair may be floated up to 500 V above chassis ground without affecting accuracy. An additional feature which results in high accuracy is the constant 10.2 megohm impedance. This impedance presents a constant load on all voltage ranges.

Plug-in Units

Figure 1 illustrates the features obtained by using the 3441A, 3442A, 3443A, 3444A, 3445A or 3446A plug-ins with any 3439A or 3440A.

Plug-in function chart						
Plug-in*	3441A	3442A	3443A	3444A	3445A	3446A
AC volts 10 V to 1000 V	**	**	**	**	√	√
DC volts 10 V to 1000 V	√	√	√	√	√	√
DC volts 100 mV to 1000 V			√	√		
DC amps				√		
Ohms				√		
Manual ranging	√	√	√	√	√	√
Auto-ranging		√	√		√	
Floating input	√	√	√	√	√	√
Remote ranging		√	√		√	√
Remote function						√

*3439A and 3440A require a plug-in to operate.
**Average response measurements: 100μV to 300 volts, 50 Hz to 500 kHz use HP 457A; 1 mV to 300 volts, 10 kHz to 10 MHz use HP 400 E/EL. True rms measurements: 1 mV to300 volts, 10 Hz to 10 MHz, use HP 3400A.

Table 1. Plug-in Function Chart.

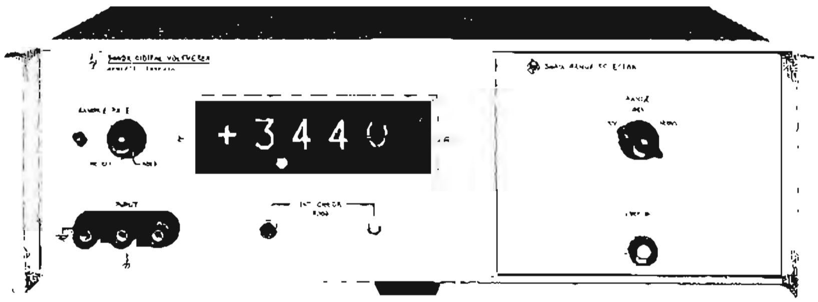
BCD Recorder Output (3440A only)

Each of the four digits, with polarity, function and decimal location, is represented by four-line, binary-coded decimal voltages in the 1-2-2-4 weighted code (1-2-4-8 available on special order). The decimal, polarity and the four digits are in parallel-coded form and are completely compatible with the HP 562A Digital Recorder which will print the information in 6 columns.

Performance

The operator can instantly verify the accuracy of the 3439A and 3440A by pressing a front-panel button. Typical performance on the 3440A internal calibration source is better than 0.002%/°C TC with stability typically better than ±0.05% over a 3 month period. The linearity is approximately ±0.01% for the 10, 100, and 1000 V ranges with 0.03% linearity full scale for the 100 mV and 1000 mV range. The stability of reading is approximately ±1 count.

DIGITAL VOLTMETERS
Interchangeable Plug-Ins Increase Versatility
Models 3439A, 3440A



3440A with 3441A plug-in

Specifications
(Main Frame HP 3439A and 3440A)

Model	HP 3440A	HP 3439A
Sample Rate:	5 samples per second to 1 per 5 seconds with storage during samples and "Hold." In "Hold" a sample may be initiated by applying a +10-V pulse 20 μs wide or greater (ac coupled), or by contact closure.	Fixed at between 2 and 3 per second
DC Isolation:	Signal common may be floated up to 500 V dc from chassis ground.	
Printer Output:	4-line BCD (1-2-2-4) 6 columns consisting of 4 digits of data, polarity, function and decimal. 4-line BCD (1-2-4-8) "1" state positive is H02-3440A*. Impedance: 120 kΩ maximum, each line. "0" state level —24 V, "1" state level—1 V (both voltages are negative).	
Reference Levels:	Positive: approximately −2.5 V, 330 ohms source impedance. Negative: approximately −27 V, 920 ohms source impedance.	
Print Command:	Step from −12 V to −2 V dc from a 100 ohm source.	
Hold-off Requirements:	Anywhere from +6 V to +15 V max. from source impedance less than 2000 ohms (provided by HP 562A Digital Recorder).	
Remote Triggering:	+10 V pulse 20 μs wide or greater, or a contact closure.	
Power:	115 or 230 V ±10%, 50 to 400 Hz, approximately 20 to 30 watts, depending upon plug-in.	
Weight:	Net, 18 lbs (8 kg); Shipping, 23 lbs (10,4 kg).	
Dimensions:	16¾" wide x 5-7/32" high x 11¼" deep (425,5 x 132,5 x 285,6 mm).	
Price:	$1160	$950

*H02-3440A, price: $1220. (requires modified plug-ins).

Accessories Available

HP K01-3440A Plug-in Extender. $65.00. (HP 3440A Only)

HP J74-562A/AR: Digital Recorder for use with HP 3440A accepting 1-2-2-4 BCD code. (Floating Operation to ±500 V dc.) Includes special print-wheel, 6 BCD column boards, input connector assembly with cable. Cabinet, $1693; rack, $1668.

HP J75-562A/AR: Same as J74-562A/AR except for single character function symbol. Cabinet, $1673; rack, $1648.

HP J76-562A/AR: Digital Recorder for use with HP 3440A accepting 1-2-4-8 BCD code. (Floating operation to ±500 V dc). Includes special printwheel, 6 BCD column boards, input connector assembly with cable. Cabinet, $1693; rack, $1668.

HP J77-562A/AR: Same as J76-562A/AR except for single character function symbol. Cabinet, $1673; rack, $1648.

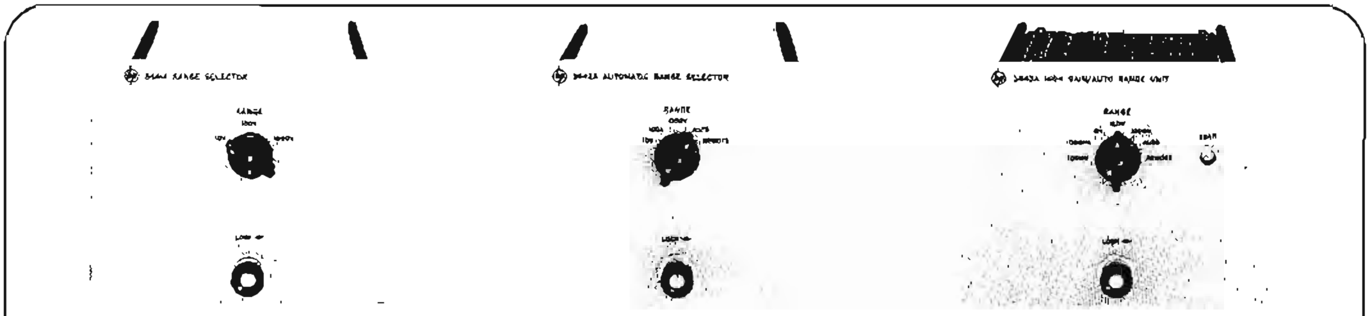
Note:
If the 3440A is used to drive an HP 562A Printer with a 2nd floating input to the 562A, a special 3440A is available. It allows 150 V dc to exist between the 3440A common and the low side of the 2nd input. Up to 500 V dc can exist between the 3440A common and chassis.

				HP 562A Print wheel		
Data	Function	Logic 1-2-2-4	Logic 1-2-4-8	Std.	J75-562A J77-562A	J74-562A J76-562A
0	+ volts	0000	0000	0	+	+V
1	— volts	1000	1000	1	—	—V
2	+ amps	0100	0100	2	A	+A
3	— amps	1100	1100	3	∀	—A
4	ac volts	0110		4	~	AC
5	ohms	1110	1010	5	Ω	Ω
6	ac volts		0110	6	~	AC
7	overrange		1110	7	*	**
8				8		
9	overrange	1111		9	*	**

PLUG-INS FOR 3439A, 3440A

Interchangeable plug-ins used also for 3434A

Plug-in Models 3441A, 3442A, 3443A



3441A 3442A 3443A

3441A Range Selector

The HP 3441A Range Selector is a plug-in unit with a range switch to manually select one of three voltage ranges; 10, 100, or 1000 volts.

3442A Automatic Range Selector

HP Model 3442A Automatic Range Selector is also available for use with the 3439A, 3440A Digital Voltmeters or the 3434A Comparator. The 3442A retains the manual range selection and adds automatic and remote range features. Ten percent hysteresis is built into the automatic ranging function of the 3442A.

3443A High Gain/Auto Range Unit

HP Model 3443A High Gain/Auto Range Unit, available for use with the 3439A or 3440A Digital Voltmeters or the 3434A Comparator, features automatic or remote range selection from 100 mV to 1000 volts full scale. A front-panel, zero offset control enables the operator to obtain a zero indication at the DVM to compensate for the thermal offset voltages of external connections. The 3443A has the same ranging capabilities as the 3442A with the additional features of two added ranges and 10 μV resolution, making it ideal for thermocouple and transducer measurements.

Specifications, 3441A, 3442A

Voltage range: 4-digit presentation of 9.999 V, 99.99 V, and 999.9 V full scale with 5% overrange capability and overrange indicator.

Voltage accuracy: ±0.05% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.1% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

Range selection: with 3441A, manual. With 3442A: manual, automatic and remote range change. Speed: automatic (max.) achieves accurate reading in less than 1 second after new voltage is applied; remote (max.) will change range within 40 ms.

Voltmeter input impedance: constant 10.2 megohms (to dc) all ranges.

Polarity: automatic indication.

Input filter characteristics: response time; less than 450 ms to a step function to within 99.95% of final value (without a range change).

Input filter ac rejection: 10, 100 and 1000 volt ranges: 30 dB at 60 Hz, increasing at 12 dB/octave.

Weight:

3441A: net 1 lb (0,45 kg); shipping 4 lbs (1,8 kg).

3442A: net 1.5 lbs (0,7 kg); shipping 4 lbs (1,8 kg).

Price: HP 3441, $40; HP 3442A, $150.

HP H01-3441A (plug-in for H02-3440A), $65.

HP H02-3442A (plug-in for H02-3440A), $175.

Specifications, 3443A

Voltage range: 4-digit presentation of 99.99 mV, 999.9 mV, 9.999 volts 99.99 volts, and 999.9 volts full scale with 5% overrange capability and overrange indicator.

Voltage accuracy:

9.999 V to 999.9 V full scale: ±0.05% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.1% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

99.99 mV and 999.9 mV full scale: ±0.1% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.15% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

Range selection: Manual, Automatic and Remote Range Change Speed: Automatic (max.) achieves accurate reading within 1.5 seconds after new voltage is applied; Remote (max.) will change range within 40 ms.

Voltmeter input impedance: constant 10.2 megohms (to dc) all ranges.

Polarity: automatic indication.

Input filter characteristics: (to a step function to within 99.95% of final value without a range change) 10, 100, 1000 V dc ranges; response time <450 ms. 100, 1000 mV ranges; <1 second.

Input filter ac rejection: 10, 100, and 1000 volt ranges: 30 dB at 60 Hz increasing at 12 dB/octave. 100 and 1000 mV ranges: maximum of 40 mV and 400 mV p-p respectively at 60 Hz for less than 0.1% of full-scale error; allowable ac increasing at 6 dB per octave.

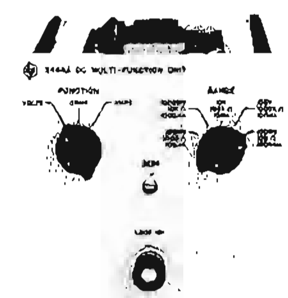
Weight: net 3 lbs (1,35 kg); shipping 5 lbs (2,3 kg).

Price: HP 3443A, $500.

HP H02-3443A (plug-in for H02-3440A), $525.

PLUG-INS FOR 3439A, 3440A
Interchangeable plug-ins used also for 3434A
Plug-in Model 3444A

VOLTAGE, CURRENT, RESISTANCE



3444A

3444A DC Multi-Function Unit

The HP 3444A DC Multi-Function Unit, available for use with the 3439A, 3440A Digital Voltmeters and 3434A Comparator, features voltage, current and resistance-measurement capabilities in one plug-in module.

This plug-in offers manual-ranging dc voltage, dc current and resistance measuring capabilities. Full-scale ranges of 100 mV to 1000 V with 10 μV resolution make this plug-in ideal for thermocouple and transducer measurements. Full-scale current ranges of 100 μA, 1, 10, 100 and 1000 mA are available with a maximum sensitivity of 10 nA. Five resistance ranges of 1000 ohms to 10 megohms are provided.

Specifications, 3444A

Voltage range: 4-digit presentation of 99.99 mV, 999.9 mV, 9.999 volts, 99.99 volts, and 999.9 volts full scale with 5% overrange capability and overrange indicator.

Current range: 4-digit presentation of 99.99 μA, 999.9 μA, 9.999 mA, 99.99 mA and 999.9 mA with 5% overrange capability and overrange indicator.

Resistance range: 4-digit presentation of 999.9 ohms, 9.999 k ohms, 99.99 k ohms, 999.9 k ohms and 9.999 megohms with 5% overrange capability and overrange indicator.

Voltage accuracy:

9.999 V to 999.9 V full scale: ±0.05% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.1% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

99.99 mV and 999.9 mV full scale: ±0.1% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.15% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

Current accuracy: ±0.2% of reading ±1 digit with line variations of ±10% from nominal.

Resistance accuracy: ±0.3% of reading ±1 digit for all ranges up to the 10 megohm range with line variations of ±10% from nominal. ±1% of reading ±1 digit on the 10 megohm range with line variations of ±10% from nominal.

Ohmmeter current:

Range	Short circuit current
1 k	1 mA
10 k	100 μA
100 k	10 μA
1 M	1 μA
10 M	0.1 μA

Range selection: manual.

Voltmeter input impedance: constant 10.2 megohms (to dc) all ranges.

Ammeter input resistance:

Range	Input resistance
100 μA	1000 ohms
1000 μA	100 ohms
10 mA	10 ohms
100 mA	1.3 ohms
1000 mA	0.4 ohms

Polarity: automatic indication.

Input filter characteristics:

Voltage: less than 450 ms to 99.95% of final value for full-scale step function on 10, 100 and 1000 volt ranges. Less than one sec to within 99.95% of final value for a full-scale step function on 100 and 1000 mV ranges.

Current: less than one sec to 99.95% of final value for a full-scale step function on all current ranges.

Resistance: 1000 ohms to 1 megohm; less than 1.0 sec to 99.95% of final value. 10 megohms; less than 5.0 sec to 99.95% of final value.

Input filter ac rejection:

Voltage: 10, 100 and 1000 volt ranges; 30 dB at 60 Hz, increasing 12 dB/octave. 100 and 1000 mV ranges; maximum of 40 mV and 400 mV p-p respectively at 60 Hz for less than 0.1% of full-scale error; allowable ac increasing at 6 dB/octave.

Current: p-p ripple current may be up to 40% of full-scale range at 60 Hz for less than 0.1% of full-scale error; allowable ac increasing at 6 dB/octave.

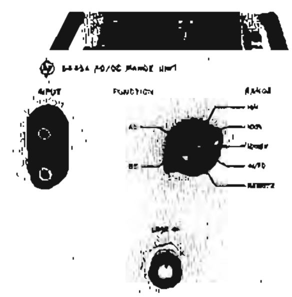
Weight: net 3 lbs (1,35 kg); shipping 5 lbs (2,3 kg).

Price: HP 3444A, $575.
HP H02-3444A (plug-in for H02-3440A), $600.

PLUG-INS FOR 3439A, 3440A

Interchangeable plug-ins used also for 3434A

Plug-in Models 3445A, 3446A



3445A

3446A

3445A AC/DC Range Unit

3446A AC/DC Remote Unit

The HP Model 3445A AC/DC Range Unit or the HP Model 3446A AC/DC Remote Unit may be used with the 3439A, 3440A Digital Voltmeters or the 3434A Comparator for ac or dc measurements. These solid-state units have three full-scale ranges for both ac and dc from 10 to 1000 volts. The ac conversion circuit of the 3445A and 3446A produces a dc output voltage proportional to the average value of the applied ac voltage and is calibrated in rms. The table in the specifications illustrates the differences between the 3445A and 3446A Plug-ins.

Combining the HP 463A Precision Amplifier with the 3445A or 3446A increases the sensitivity of either plug-in from 10 volts full scale to as low as 10 mV full scale over a frequency range of 50 Hz to 100 kHz. Because the HP 463A is a direct-coupled amplifier it can be used to increase the dc sensitivity with any 3441A, 3442A, 3445A or 3446A Plug-in with any 3439A or 3440A Digital Voltmeter. For further information refer to the 463A Data Sheet.

Specifications, 3445A, 3446A

Voltage range (ac & dc): 4-digit presentation of 9.999, 99.99, and 999.9 volts full scale with 5% overrange capability and overrange indicator.

Voltage accuracy (ac): from 20°C to 30°C including line voltage variations of ±10% from nominal.

% Reading % Full Scale Chart (±2 counts)

	60 Hz	20 kHz	50 kHz	100 kHz
10 V to 1 kV Full Scale	±0.1 rdg	±0.1 f.s.	±0.1 to ±0.3 linearly derated f.s.	

±0.005%/°C T.C. applies from 0°C to +20°C (use +20°C as zero T.C. reference point) and from +30°C to +50°C (use +30°C as zero T.C. reference point).

Voltage accuracy (dc): ±0.05% of reading ±1 digit including line voltage variations of ±10% from nominal. A front-panel adjustment on the 3440A insures accuracy over the temperature range between +15°C and +40°C and ±0.1% ±1 digit over the temperature range of 0°C to +15°C and +40°C to +50°C.

Response speed (ac): achieves specified accuracy within 3 sec when on proper range. Allow an extra second for recovery if overloaded.

Floating measurements: signal common may be floated up to 500 V dc above chassis ground.

Input impedance:
10 megohms shunted by 20 pF nominal on all ac ranges; 10.2 megohms on all dc ranges.

Input filter characteristics (dc):
Response time: <450 ms to 99.95% of final value for a step function.
AC rejection: 30 dB at 60 Hz, increasing 12 dB/octave.

Remote selection: remote selection is made by contact closure to ground through <100 ohms. Change will be completed <40 ms. (Refer to table for modes available.)

Table of modes

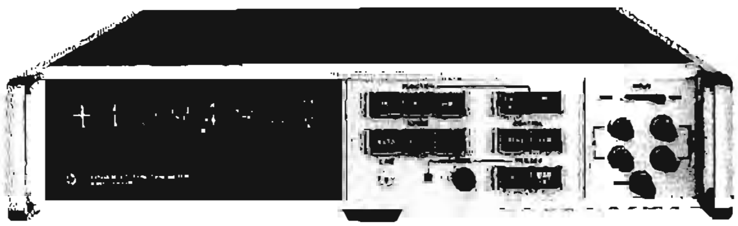
	3445A	3446A
Input Terminals	Plug-In only	Plug-in & Main Frame selected by Front Panel Switch
Range Selection	Manual, Automatic, Remote	Manual, Remote
Function Selection	Manual	Manual, Remote
Input Impedance (nominal)	10 megohms /20 pF	Plug-in Input: 10 megohms/35 pF Main-Frame Input: 10 megohms/175 pF

Polarity: automatic indication.

Weight: net 2.75 lbs (1,24 kg); shipping 5 lbs (2,3 kg).

Price: HP 3445A, $575; HP 3446A, $600. HP H02-3445A (plug-in for H02-3440A), $600.

MULTI-FUNCTION METER
DC, AC voltage, ohms, limit test, all with ratio
3450A



3450A

The Hewlett-Packard Model 3450A Multi-Function Meter is a five digit integrating digital voltmeter. The basic instrument measures dc voltage and dc voltage ratios. Added measurement capability is achieved by the addition of plug-in options, all of which can be easily installed in the field.

The 3450A uses a dual-slope integration technique and is fully guarded. All of its capabilities are contained in 3⅜ inches of rack height and require no cooling fan. Refer to pages 231 and 232 for technical information.

Specifications
DC voltage

Full range display: ±100.000 mV, ±1.00000 V, ±10.0000 V, ±100.000 V, ±1000.00 V. Overranging: 20% on all ranges.

Range selection: manual or automatic. Remote optional.

Performance

Accuracy: 24 hr (23°C ±1°C, <50% RH. This accuracy is referenced to the calibrating source).

Range	Specification
1 V thru 1000 V	±(0.003% of reading +0.001% of range)
100 mV	±(0.003% of reading +0.004% of range)

30 Day (25°C ±5°C):

Range	Specification
1 V thru 1000 V	±(0.008% of reading +0.002% of range)
100 mV	±(0.008% of reading +0.01% of range)

Temperature coefficient (0°C to 50°C): ±(0.0004% of reading +0.0003% of range) per °C.

Measuring speed:

Integration Period	Reading Period (without range change)	Autorange Time (per range change)
1/10s	380 ms	380 ms
1/60s	65 ms	65 ms

Instrument reads within specified accuracy when triggered coincident with step input voltage.

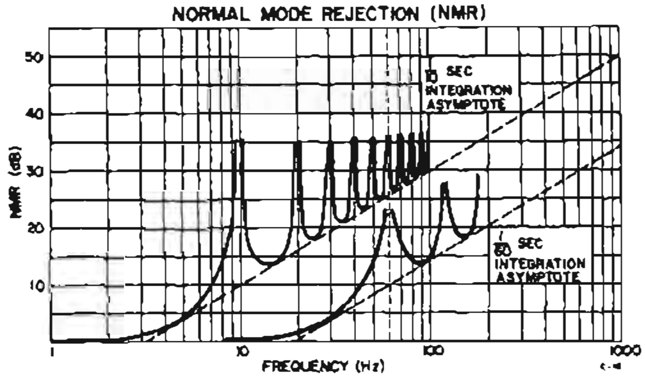
Input characteristics

Input resistance:

Range	Specification
100 mV, 1 V and 10 V	>10¹⁰Ω (10 MΩ ±0.1% selectable by external closure to ground)
100 V and 1000 V	10 MΩ ±0.1%

Common-mode rejection (CMR): CMR is the ratio of the peak common-mode voltage to the resultant peak normal-mode voltage with 1 kΩ unbalance in either lead.
DC: >140 dB, **AC** (at 60 Hz): >120 dB.

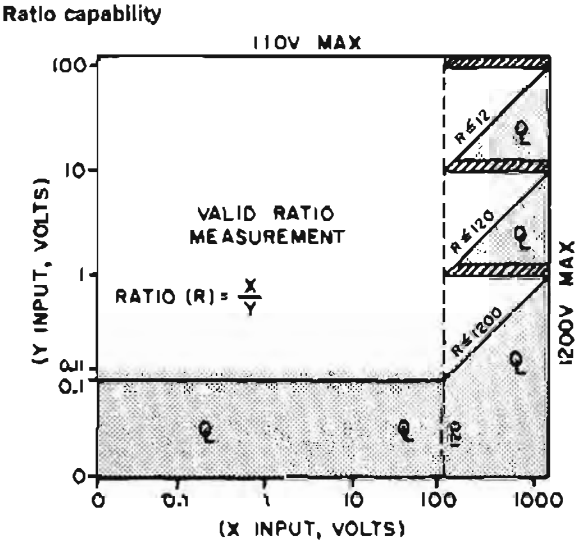
Normal-mode rejection (NMR): NMR is the ratio of the peak normal-mode signal to the resultant error in reading. Sum of dc input and peak normal-mode signal must not exceed 140% of range.



DC ratio

Full range display: ±1.00000, ±10.0000, ±100.000, ±1000.00.

Ratio capability



Ratio measurement possible only if Y input is in overrange condition

Overload condition

Overranging: 20% on all ranges.

Range selection: manual or automatic for X input. Remote optional for X input. Automatic for Y input.

Performance

Accuracy (30 day, 25°C ±5°C): ±(0.01% of reading $+0.002\%$ of range $+ \frac{\text{Y range}}{\text{Y voltage}} \times 0.002\%$ of range)

Temperature coefficient (0°C to 50°C): ±(0.0006% of reading +0.0003% of range) per °C.

Measuring speed:

Integration Period	Reading Period (without range change)	Autorange Time (per range change) Y input	X input
1/10 s	840 ms	380 ms	840 ms
1/60 s	210 ms	65 ms	210 ms

Input characteristics

Input configuration: isolated 4-terminal, guarded. No common ground necessary between signals.

Input resistance: same as DC VOLTAGE for both X and Y inputs.

Common-mode rejection (CMR): same as DC VOLTAGE for both X and Y inputs.

Normal-mode rejection: same as DC VOLTAGE for X input.

AC voltage (Option 001)

True RMS-responding (45 Hz to 1 MHz)

Full range display: 1.00000 V, 10.0000 V, 100.000 V, 1000.00

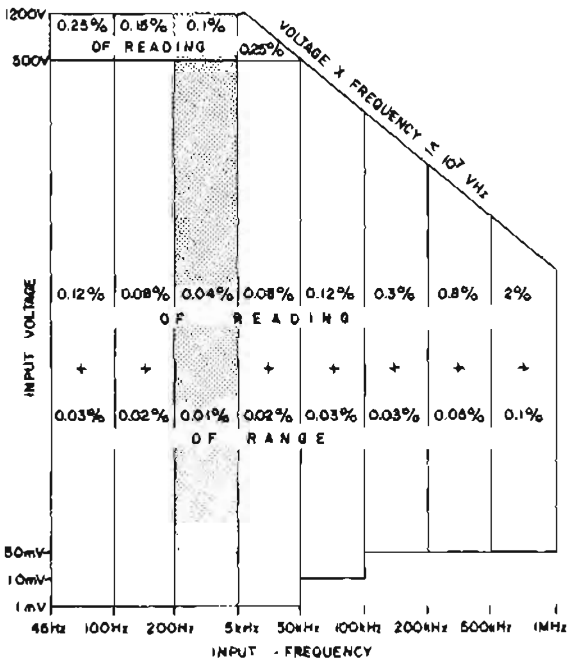
Overranging: 20% on all ranges (1500 V peak on 1000 V range).

Range selection: manual or automatic. Remote optional.

Performance

Accuracy (30 day, 25°C ±5°C):

Max. 1500 V peak.



Stability (24 hr, 23°C ±1°C, 10 mV to 500 V):

Frequency Range	Specification
45 Hz to 200 Hz	±(0.03% of reading +0.003% of range)
200 Hz to 5 kHz	±(0.01% of reading +0.002% of range)
5 kHz to 100 kHz	±(0.03% of reading +0.003% of range)

Measuring speed:

Integration Period	Reading Period (without range change)	Autorange Time (per range change)
1/10 s	2.7 s	2.7 s

Instrument reads within specified accuracy in one reading from 10% to 100% of range for crest factors up to 4:1.

Temperature coefficient (0°C to 50°C):

Frequency Range	Coefficient ±(% of reading	+% of range) per °C
45 Hz to 100 Hz	0.003%	0.001%
100 Hz to 200 Hz	0.002%	0.0005%
200 Hz to 5 kHz	0.001%	0.0004%
5 kHz to 50 kHz	0.002%	0.0005%
50 kHz to 200 kHz	0.003%	0.001%
200 kHz to 500 kHz	0.01%	0.001%
500 kHz to 1 MHz	0.02%	0.002%

Input characteristics

Input impedance

Front terminals: 2 MΩ shunted by 90 ±10 pF in series with 0.1 μF.

Rear terminals: 2 MΩ shunted by 135 ±15 pF in series with 0.1 μF.

Crest factor: 7:1 (1500 V peak max).

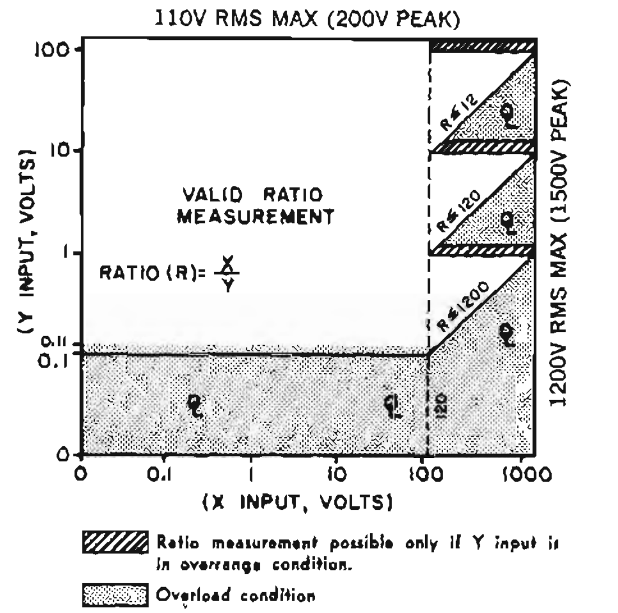
Common-mode rejection (CMR): same as DC VOLTAGE.

AC ratio (Option 001)

True RMS-responding

Full range display: 1.00000, 10.0000, 100.000, 1000.00.

Ratio capability: overranging: 20% on all ranges.



Range selection: manual or automatic for X input. Remote optional for X input. Automatic for Y input.

Performance

Accuracy (30 day, 25°C ±5°C): ±(0.02% of reading +0.01% of range + sum of measurement accuracy of each input).

Temperature coefficient (0°C to 50°C): 200 Hz to 5 kHz: ±(0.002% of reading +0.001% of range) per °C.

Measuring speed:

Integration Period	Reading Period (without range change)	Autorange Time (per range change) Y Input	X Input
1/10 s	8.1 s	2.7 s	8.1 s

Input characteristics

Input configuration: isolated 4-terminal, guarded. No common ground necessary between signals.

Input impedance: same as AC VOLTAGE for both X and Y inputs.

Crest factor: 5:1.

Common-mode rejection (CMR): same as DC VOLTAGE for both X and Y inputs.

Ohms (Option 002)

Full range display: 100.000Ω, 1.00000 kΩ, 10.0000 kΩ, 100.000 kΩ, 1000.00 kΩ, 10000.0 kΩ.

Overranging: 20% on all ranges.

Range selection: manual or automatic. Remote optional.

Performance

Accuracy (30 day, 25°C ±5°C):

Range	Specification
100 Ω	±(0.01% of reading +0.01% of range)
1 kΩ, 10 kΩ, 100 kΩ	±(0.01% of reading +0.002% of range)
1000 kΩ	±(0.02% of reading +0.002% of range)
10000 kΩ	±(0.1% of reading +0.002% of range)

Stability (24 hr, 23°C ±1°C):

Range	Specification
100 Ω	±(0.004% of reading +0.004% of range)
1 kΩ through 10000 kΩ	±(0.004% of reading +0.001% of range)

Temperature coefficient (0°C to 50°C):
±(0.0006% of reading +0.0003% of range) per °C.

Measuring speed:

Integration Period	Reading Period (without range change)	Autorange Time (per range change)
1/10 s	380 ms	380 ms
1/60 s	65 ms (165 ms on 10 MΩ range)	65 ms (165 ms on 10 MΩ range)

Instrument reads within specified accuracy when triggered coincident with step input resistance at terminals.

Input characteristics

Input configuration: 4-wire, guarded.

Current through resistance:

Range	Signal Current
100 Ω, 1 kΩ, 10 kΩ	1 mA
100 kΩ, 1000 kΩ	10 μA
10000 kΩ	1 μA

Common-mode rejection (CMR): same as DC VOLTAGE.

Normal-mode rejection: same as DC VOLTAGE.

Overload protection: ±200 V peak for X or Y input.

Ohms ratio (Option 002)

Full range display: 1.00000, 10.0000, 100.000, 1000.00. (For ohms ratio specifications refer to Data Sheet.)

Limit test (Option 003)

Applicable to: DC, DC RATIO, AC, AC RATIO, OHMS and OHMS RATIO. No degradation in performance of above six functions.

Limit selection

Two 4-digit limits (with 20% overranging), including polarity, are selectable in 1-2-4-8 BCD form with external closure to ground through <3 kΩ (2.8 mA max) or application of −0.5 V to +2.5 V for the "0" state as shown below.

State	Voltage
"0"	−0.5 V to +2.5 V
"1"	+5.5 V to +12 V

Limits must be on same range and same polarity.

Output signals

Limit indications: HI, GO, LO front-panel lights defined as follows:
High Limit ≤HI
Lower Limit ≤GO <High Limit
LO <Lower-Limit

Digital display: 5 digits plus overrange.

Digital output: 9 columns of information including HI, GO, LO decisions are available in 4-line 1-2-4-8 "1" state positive BCD form with DIGITAL OUTPUT (Option 004).

Digital output (Option 004)

Print command: dc coupled. Print level: 0 V, 12 mA max current. Print hold-off level: −0.5 V to +2.5 V, 9 mA max current.

BCD outputs: 4-line BCD (1-2-4-8) "1" state positive, 9 columns of information, as follows: 2 columns for function and polarity, 1 column for range, 6 columns for digital data.

BCD levels:

State	Voltage	Output Characteristics
"0"	−0.5 V to +2.5 V	12 mA max sink current
"1"	5.5 V to +12 V	12 kΩ source resistance

BCD reference levels:

Ref Level	Voltage	Source Resistance
Negative	+1 V	3 kΩ
Positive	+6 V	10 kΩ

Storage: BCD signal levels for previous reading are held until print command of next reading is initiated.

Scanner advance: −12 V pulse, 20 ms minimum before start of next reading.

Remote control (Option 005)

All remote control lines are selected by an external closure to ground through <3 kΩ (2.8 mA max) or application of −0.5 V to +2.5 V for the "0" state as shown below.

State	Voltage
"0"	−0.5 V to +2.5 V
"1"	+5.5 V to +12 V

Remote controls

Program external trigger: selects external trigger in remote operation (normal trigger is selected if this line is not programmed).

***External trigger:** actuated by external contact closure or application of "0" state as shown above for a duration of 1 μs minimum with at least 20 ms in "1" state before "0" state.

***1/60 s integration period:** (normal integration period is 1/10 s).

***100 ms delay:** adds 100 ms delay between trigger and start of measurement for source settling time.

***10 MΩ input resistance:** selects 10 MΩ input resistance on dc 100 mV, 1 V, and 10 V ranges (normal input resistance on these dc ranges is $>10^{10}\Omega$).

Program function: 4 line code selects desired function.

Program remote: disables all front-panel controls except INT and MANUAL/EXTERNAL trigger.

Front-panel lockout: disables all front-panel controls.

Remote range: 4-line code selects desired range.

Remote ratio range: 3-line code selects desired ratio range.

Remote decimal: 4-line code selects desired decimal location independent of actual range.

General

Operating temperature: 0°C to 50°C, unless otherwise specified.

Power: 115 V or 23 V ±10%, 50 Hz to 400 Hz <75 W including all options under normal environmental conditions.

Dimensions: 16¾" wide, 3⅜" high (without removable feet), 19⅜" deep (425 x 86 x 491 mm).

Weight: basic instrument: net 31 lb (14,1 kg). Including all options: net 36 lb (16,3 kg). *Shipping:* 50 lb (22,7 kg).

Accessories furnished: rack mounting kit for 19" rack.

Accessories available: HP 11133A rear input cable assembly, $30; HP 11112A Limit Selector, $150.

Price: HP 3450A (includes DC and DC RATIO) $3150.
Option 001 AC Converter (adds AC, AC RATIO) add $1250.
Option 002 OHMS Converter (adds OHMS, OHMS RATIO) add $ 400.
Option 003 LIMIT TEST (adds Limit Test Capability) add $ 350.
Option 004 DIGITAL OUTPUT (BCD 1-2-4-8 code) add $ 175.
Option 005 REMOTE CONTROL add $ 225.
Option 006 REAR INPUT TERMINALS (add Front/Rear selector switch, rear terminals and 11133A Cable Assembly) add $ 50.

*These remote capabilities are included in the basic 3450A and do not require the addition of Option 005.

INTEGRATING DVM

Measurements to 1 μV at rates to 43 per second

Model 2402A

The 2402A Integrating Digital Voltmeter combines 43 measurement per second sampling rate and the precision and measurement flexibility expected from a laboratory instrument with the programming and electrical output features necessary for data acquisition systems use. It achieves high speed and high accuracy at low levels, without preamplifiers.

Instrument design virtually eliminates errors caused by extraneous noise without imposing any restrictions on the grounding of the signal source, recording device, or programmer, or upon the measuring speed of the instrument. The controls and input/output features of the 2402A permit maximum versatility of application, yet the instrument is straightforward to use.

High accuracy in a DVM is of little practical value unless this accuracy can be maintained in the presence of noise and under the far from ideal conditions of everyday use. The 2402A is average-reading, which greatly reduces the effects of superimposed noise. A floated and guarded input circuit eliminates common mode noise error. Combined, these techniques yield effective common mode noise rejection greater than 126 dB (2 million to 1) at any frequency, including dc.

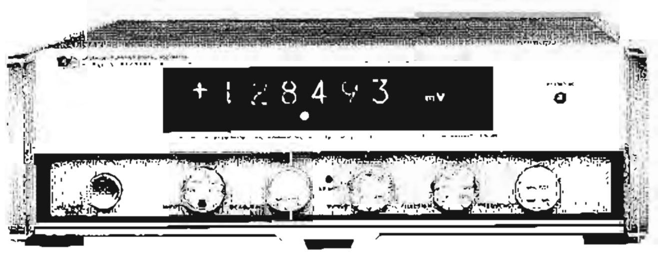
The 2402A reads the average value of the applied voltage over a 1/60 second sample period, and provides maximum rejection of superimposed noise at 60 Hz (1/50 second optional). Since no input filters are employed, it provides both noise rejection capability and rapid accurate response to step input required for data acquisition system applications. Superimposed noise rejection holds for combined signal plus noise amplitudes to 130% of full scale.

The 2402A features a guard that completely isolates the floating measuring circuit from the chassis, breaking the common mode loop. To take a practical example of the 2402A noise rejection, the combined effect of guarding and averaging at 60 Hz is such that a 100 V peak-to-peak common mode potential will not cause a discernible error in reading on any range.

AC voltages to 750V peak can be measured on four ranges from 1V to 1000V when the 2402A is equipped for optional ac voltage measurement. It is adapted for ac voltage measurement by installation of plug-in ac-to-dc converter and control boards. The converter is average-reading and is calibrated in rms with respect to sinusoidal input. The dc voltage input connectors are also used for ac input. The same guard provides common mode rejection for ac and dc voltage measurements. The overload detection circuit of the basic 2402A protects the ac converter.

Resistance measurements to 13 megohms can be made on five ranges from 1k Ω to 10M Ω when the 2402A is equipped with this option. It is adapted for resistance measurement by installation of plug-in ohms-to-dc converter and control boards and a 4-wire guarded rear panel connector. The converter is installed inside the guard, assuring freedom from common mode effects.

The 2402A may be equipped for frequency measurements to 199.99 kHz. Frequency measurement is a plug-in option.



2402A Integrating Digital Voltmeter

Cover flips up to protect controls in systems use.

Specifications

(For ±10% line voltage variation and 6 months operation, assuming daily calibration against internal standard after 30-minute warm-up.)

DC voltage measurement

Noise rejection: overall effective common mode rejection: (ratio of common mode signal to its effect upon readings): 160 dB at dc, decreasing to 126 dB above 30 Hz (infinite rejection cusp gives 168 dB effective cmr at 60 Hz ±.15%). Overall rejection combines common mode rejection and superimposed noise rejection.

Input circuit: type: floated and guarded signal pair. Signal low and guard may be floated up to 500 V above chassis ground with up to 1000 V input signal (maximum low-to-guard voltage is 50 V).

Ranges: 100 mV and 1, 10, 100, and 1000 V full scale selected by front panel switch, external programming or autoranger.

Overranging: to 130% of full scale, except on 1000 V range. Self protected on any range against input voltage to 1000 V. Protective circuits reset automatically for each new reading.

Input impedance: greater than 1000 MΩ on 100 mV, 1 V and 10 V ranges; 10 MΩ on 100 and 1000 V ranges.

Internal calibration standard: (independent of measuring circuit). Derived from stabilized reference diode operating in a constant temperature oven; maintain specified accuracy for 6 months.

Accuracy: (source impedance 10 kΩ, 43 measurements per sec. ±10% line voltage variation.)

	1 V, 10 V, 100 V, 1000 V	100 mV
Short term (24 hour) Accuracy (at 25 ± 1°C)	.003% rdg ± .003% fs (.006% rdg in overrange)	.003% rdg ± .005% fs (.008% rdg in overrange) Below 30 mV accuracy improves to 3μV± .009% rdg.
Long term (6 months) Accuracy (at 25 ± 1°C)	.01% rdg ± .003% fs (.013% rdg in overrange)	.01% rdg ± .005% fs (.015% rdg in overrange) Below 30 mV accuracy improves to 3μV ± .015% rdg.

TEMP EFFECT	Per °C change from Calibrate temperature	
15 to 40°C	.0015% rdg ± .0006% fs	.0015% rdg ± .00015% fs
10 to 15°C or 40 to 50°C	.002% rdg ± .0006% fs	.002% rdg ± .00015% fs

Measurement speed: to 43 measurements per second when triggered externally. Self-triggers at speeds continuously adjustable from 1 measurement every 10 seconds to 10 per second.

Resolution: 1 part in 130,000 on 6-digit display: 100 mV range displays readings to 1 μV.

AC voltage measurement option

Common mode rejection: 160 dB at dc, decreasing to 120 dB at 60 Hz and 6 dB per octave for noise frequencies above 60 Hz, with 1 KΩ between low side of source and low side of input.

Input circuit: floated and guarded signal pair. Signal low and guard may be floated up to 500 V above chassis ground with maximum input voltage applied.

Input voltage limitations: 240 V peak on 1 V range 750 V peak on all other ranges.

Input impedance: 1 MΩ ±1% shunted by 200 pF (maximum).

AC only operation: frequency range: 50 Hz to 100 kHz.

Ranges: 1, 10, 100, and 1000 V full scale, selected by front panel switch, external programming or autoranger.

Overranging: to 130% of full scale, except 750 V peak, on 1000 V range.

Accuracy (with respect to standard used for calibration):

SIGNAL FREQUENCY ①	50 Hz		100 Hz		10 kHz		30 kHz		100 kHz	
	%rdg	% fs	%rdg	% fs	%rdg	% fs	%rdg	% fs	%rdg	% fs
Accuracy (at 25 ± 1°C)	.09	.05	.06	.03	.06	.03	.09	.05	.3	.09
Response error ①	.1	–	.05	–	.02	–	.02	–	.02	–
Ripple error ③	.03	–	.02	–	–	–	–	–	–	–
Temperature effect ④ (Per °C change in ambient from 25°C, over 10 to 50°C range)	.004	.003	.004	.003	.004	.003	.007	.003	.013	.003

① Straight line interpolation holds for frequencies between points.

② Applicable only to step input (received from data system signal scanner) or autorange operation.

③ Ripple error decreases 18 dB per octave above 85 Hz, is zero at 60 Hz because of superimposed noise rejection of basic instrument.

④ Assumes calibration of 2402A against internal standard at 25°C ambient. Calibration of 2402A at operating temperature decreases % rdg temperature effect .0009%.

AC on DC operation: maximum dc component: ±200 V on any range.

Ranging: must start from 1000 V range, proceeds to lower range as required.

Peak input: ac plus dc to 100% of full scale, except 750 V peak maximum on 1000 V range.

Measurement speed: to 1.9 externally-triggered measurements per second. Self-triggered measurement rate adjustable from 1 measurement every 10 seconds to 1.6 per second.

Resolution: 1 part in 130,000 on 6-digit display; 10 μV on 1 V range.

Resistance measurement option

Noise rejection: measurement circuit enclosed in same guard as dc circuit, reducing effect of ac common mode noise when guard is connected to low side of test resistance. Double-shielded cable extends guard to test resistance.

Input circuit: guarded, modified four-terminal circuit; unknown resistor can be either grounded or floating.

Ranges: 1 kΩ, 10 kΩ, 100 kΩ, 1 MΩ, and 10 MΩ full scale, selected by front panel switch, external programming or optional autoranger.

Overranging: to 130% of full scale. Self-protected on all ranges against up to 50 V across resistance input.

Absolute accuracy:

Resistance range	1 kΩ		10 kΩ	100 kΩ	1 MΩ	10 MΩ	
Measurement current	1 mA		1 mA	100 μA	10 μA	1 μA	
Accuracy at 25°C	% rdg ± % fs		.013% rdg ± .003% fs			% rdg ± % fs	
	.016	.003				.025	.005
Temperature ① effect	.004% rdg ± .003% fs per °C difference of ambient with respect to 25°C over 10 to 50°C range						

① Calibration of 2402A against internal standard at operating temperature decreases % rdg temperature effect .0015% per °C. to 0025% rdg per °C.

Measurement speed: to 8 externally triggered readings per second. Self-triggered measurement rate is adjustable from 1 measurement every 10 seconds to 4.5 per second.

Resolution: 1 part in 130,000; .01Ω on 1 kΩ range.

Frequency measurement option

Frequency range: 5 Hz at 199,999 kHz.

Gate time: 1 second; provides 1 Hz resolution.

Accuracy: (±1 count ±1 time base stability); time base aging rate: 2 ppm per week over 20 to 30°C; time base temperature effect: 100 ppm over range 10 to 50°C.

Input

Amplitude range: .1 to 100 V rms.

Pulse or square wave input: negative 1 to 100 V amplitude, 2 μs minimum duration, 50% maximum duty cycle.

Impedance: 1 MΩ shunted by 150 pF.

Maximum voltage: 150 V peak dc plus ac or pulse.

Autorange option

Range selection: DC voltage ranges; each time autoranger is programmed, it starts on 1 V range to take advantage of fast up-ranging. While autoranging is continuously programmed, autoranger starts at range selected for previous reading, sequences to higher or lower range as required. AC voltage ranges; autoranger starts at 1000 V range, sequences to lower range as required. Up-ranges at 110% of full scale, down-ranges at 10.2%.

General

Display and system interface: 6-digit display, BCD output and program inputs. Polarity, decimal, measurement units, calibration, and overload conditions indicated automatically and included in output as function and decimal digits.

Operating conditions: specifications apply for ambient temperatures 10 to 50°C, relative humidity to 90% at 40°C, altitude to 15,000 feet.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 150 W.

Dimensions: 16¾" wide, 5¼" high, 19½" deep behind panel (425 x 133 x 494 mm); hardware furnished for 19" wide rack mount.

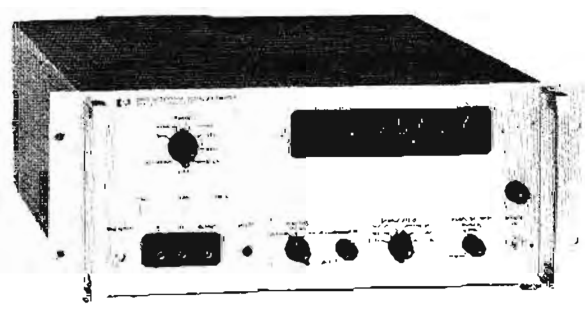
Weight: net 49 lbs (22,2 kg); shipping 56 lbs (25,4 kg).

Price: 2402A for DC measurements, $4800; AC adds $450; resistance adds $750; frequency adds $350; autoranging adds $250.

INTEGRATING DVM

Precise measurements despite severe noise

Model 2401C



2401C

The 2401C Integrating Digital Voltmeter combines the precision and measurement flexibility of a laboratory instrument with system programming and electrical output.

Design features virtually eliminate measurement errors due, to extraneous noise superimposed on the signal, without restriction on grounding of the signal source, recorder, or programming device. Signals as small as a few per cent of full scale can be accurately measured even in the presence of noise approaching three times full scale.

The 2401C measures the average value of the applied voltage over one of three fixed crystal-controlled sample periods. Reversing counter circuits permit signals to be integrated around zero with full instrument accuracy.

Operation of the optional auto-ranger is extremely fast—34 msec maximum range change time. The 2401C with auto-ranging finds excellent application at high sampling rates with varying input signals and at rapid scanning rates when employed in multi-channel systems with widely varying signal levels. The auto-ranger also will select proper range of optional preamp and ac/ohms converter at reduced ranging speeds.

The 2401C is designed for fully automatic operation within a digital data acquisition system. Measurement function, voltage range, sample period, sampling rate and integration interval all can be selected by external circuit closures to ground. While the measurement circuit of the 2401C is guarded, all remote control lines and electrical outputs are referred to chassis ground and do not interfere with the guard.

AC/Ohms measurement

The Model 2410B AC/Ohms Converter enables ac voltages and resistances to be measured with the 2401C Digital Voltmeter. AC voltages up to 750 V peak and resistances up to 10^7 ohms are converted to proportional dc voltages between 0 and 1 volt. Optionally, either the ac voltage or resistance converter section may be omitted from the 2410B.

Guarded data amplifier

The 2411A/2401C combination offers a full scale input range of 10 mV with overranging to 30 mV, ideal for measuring outputs of sources such as thermocouples and strain gages. The low zero drift and noise contributed allow excellent accuracy to be obtained in low-level measurements.

Specifications, 2401C

DC voltage measurements, noise rejection: overall effective common mode rejection: 140 dB at all frequencies 160 dB at dc (0.1 second sample period); superimposed noise rejection: more than 20 dB at 55 Hz for 0.1 second sample period, increases 20 dB per decade increase in frequency, infinite rejection at frequencies evenly divisible by 10.

Input circuit: type: floated and guarded signal pair, may be operated up to 500 V above chassis ground; ranges: 5 from 0.1 to 1000 V f.s., selection by front-panel switch or remote circuit closure to ground, polarity sensed automatically; overranging: to 300% f.s. except 1000 V range; overload: range automatically switched to 1000 V at 310% f.s., reset by next read command; input impedance: 10 MΩ on 10, 100, 1000 V ranges, 1 MΩ on 1 V range, 100 kΩ on 0.1 V range. <150 pF on all ranges.

Absolute accuracy: 0.01% of reading ±0.005% f.s. ±1 digit at 25°C; temperature coefficient 0.001% of reading per °C, 10 to 40°C.

Internal calibration source: ±1 V standard for self-calibration; maintains rated accuracy for 6 months after initial calibration to 0.002% at 25°C.

Measurement speed: fixed sample periods of 0.01, 0.1 or 1 s selected by front-panel switch or remote circuit closure to ground.

Resolution: depends on sample period; max. 1 μV per digit.

Auto-ranger (optional) voltage ranges: automatically selects range from 5 input ranges of standard instrument (0.1 V to 1000 V f.s.). 34 ms max. range change time. Also selects appropriate gain setting (X1 to X10) when 2401C is used with 2411A Amplifier.

DC voltage integration: input signal is integrated over selected sample period; using fixed sample period, integral is average of input.

Frequency measurements: 5 Hz to 300 kHz, optionally to 1.2 MHz; gate time 0.01, 0.1, 1 sec. or manual; accuracy: ±1 count ± time base accuracy; time base: stability at constant temperature (±5°C) is $\pm 2/10^6$/week, temperature effect $\pm 100/10^6$ over range 10 to 50°C, provisions for external time base; display time: variable from 0.2 to 7 sec, or held until reset; input sensitivity: 0.1 to 100 V rms; impedance: 1 MΩ shunted by 150 pF.

Period measurements (optional): 1, 10, and 100 periods; 5 Hz to 10 kHz; display is directly in ms; resolution referred to single period: 1 period, 100 μsec; 10 periods, 10 μs; 100 periods, 1 μsec; accuracy is ±1 count ± time base accuracy ± trigger error divided by number of periods. Sensitivity and impedance same as frequency measurements.

General

Display: 6 digit in-line digital-tube readout; polarity, decimal point, function and overload condition indicated automatically.

Recording outputs: BCD output provided for function and polarity, 1 digit; data, 6 digits; decimal point, 1 digit.

External programming: circuit closures to ground.

Operating conditions: specifications apply for ambient temperatures 10 to 50°C, relative humidity to 95% at 40°C.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 150 W.

Dimensions: 19" wide, 7" high, 18⅜" deep behind front panel (483 x 177 x 467 mm).

Weight: net, 48 lbs (22 kg); shipping, 57 lbs (25,7 kg).

Price: 2401C, $4100.

V-TO-F CONVERTER
Accurate bipolar, low-level dc V-to-F conversion
Model 2212A

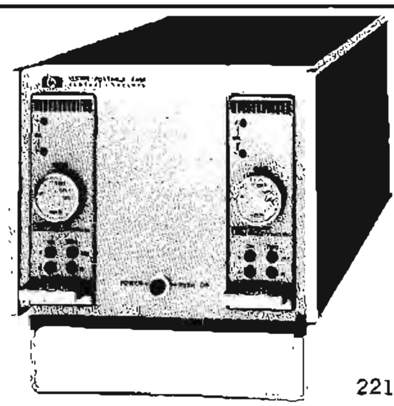
The HP 2212A is a compact Voltage-to-Frequency Converter, well suited to low-level signal applications. Low input drift and high common mode rejection (114 dB at 60 Hz) are achieved without a chopper by differential circuits. The VFC produces an output pulse train with a rate directly proportional to the magnitude of an applied dc voltage. Pulse rate rises linearly and instantaneously from 0 to 100,000 pulses per second as the dc input level is increased from zero to full scale. The 2212A provides outstanding linearity, stability and noise immunity

The output of the HP 2212A, when connected to an electronic counter provides a convenient method of making digital measurements of dc voltages; the converter provides a polarity signal. This converter-counter combination can be connected directly to a digital printer or through an output coupler to other common digital recording devices.

The converter-counter combination integrates dc voltages over any period of time and can therefore be used to read the average of the input over a selected sample period, or over an externally-controlled period. This provides accurate dc measurements in the presence of noise superimposed on the signal. Combining the VFC with a new HP 5321B all-IC Counter, (page 620) provides an Integrating DVM with .01, .1, 1 and 10 sec sample periods.

The modular package with self-contained power supply allows the 2212A to be used in both bench and systems applications. An inexpensive combining case is available to mount 10 instruments side-by-side in only 5¼″ of 19″ rack panel space.

2212A



2212A shown in portable case

Specifications

Specifications include ±10% line voltage variation, hold for 1 kΩ max. source resistance, any unbalance, and assume daily calibration after specified warmup.

DC voltage ranges: 3 ranges; 0 to 10 mV, 100 mV, 1 V. Vernier option, (10-turn potentiometer) extends range to x3.5, for any setting. Overrange: to 250% of full scale, all ranges. Instrument is sensitive to positive and negative inputs; polarity indication and output signal provided.

Accuracy: 'Worst case' accuracy of pulse rate over 1-second sample period with respect to the source used for calibration is as follows:

	.01 V		.1 V		1 V	
	% rdg ±	% fs	% rdg ±	% fs	% rdg ±	% fs
Stability	.07	.06	.05	.015	.02	.011
Linearity		.01		.01		.01
Temp. Coeff.	.004	.017	.004	.0035	.004	.0022

Internal calibration source: 1 V standard for self-calibration. Accurate to within ±0.02% for six months; temp. coeff of ±0.005% per °C (0° to 55°C).

Differential input impedance: 1000 MΩ shunted by 0.001 μF.

Common mode rejection: 120 dB at dc; 114 dB at 60 Hz.

Common mode return: From input common to output common, 1 megohm, max.

Normal mode rejection: More than 40 dB at 55 Hz with 1 second sample period; increases 20 dB per decade increase in noise frequency. Infinite rejection cusp every cycle.

Slewing: 10° V/sec rti (referred to input) with dc offset caused by slew limiting less than 0.1% of peak ac, provided 250% of full scale is not exceeded.

Maximum input signal: ±11 V, signal plus common mode. Combined input up to ±20 V will not damage instrument.

Output (dc coupled): 0 to 100 kHz fs, overranging to 250 kHz; 5 Ma available; short circuit will not damage instrument.

Settling time: 100 μsec to within 0.01% of final pulse rate.

Overload recovery: 200 μsec to 0.01% of final pulse rate for signal to 10 times full scale. Less than 5 ms for signal plus common mode input up to 20 V.

Polarity indication: electrical and visual for + and −.

Operating conditions: Ambient temperatures from 0° to 55°C; relative humidity to 95% at 40°C.

Warmup: operates immediately after turn-on, but requires 1½ hours in free air, 30 minutes in portable case or combining Case (plus 1 hour additional warmup for each 10°C difference between storage temperature and operating ambient) for specified accuracy and zero drift.

Reliability: predicted MTBF (with 90% confidence) is 10,000 hours when operated at 25°C ambient.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 9 W approx.

Dimensions: 1$\frac{9}{16}$″ wide, 4⅞″ high, 15″ deep (39.7 x 123.8 x 381 mm).

Weight: net 4 lb (1,8 kg), shipping 6½ lb (2,9 kg).

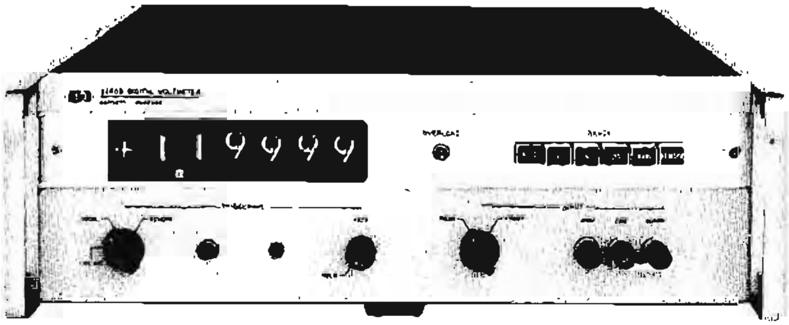
Accessories available: mating rear connector, mating rear connector with power cord, input/output cable; combining case: contains up to 10 instruments in 5¼″ of 19″ rack space (mating connectors furnished), includes power cord and fan; portable case: holds two VFC's (mating connectors furnished) and includes power switch, pilot light, power cord and fan.

Price: HP 2212A Voltage-to-Frequency Converter, $1100.

DIGITAL VOLTMETER

±0.004% accuracy, lab precision, systems speed

Model 3460B



3460B

The Hewlett-Packard Model 3460B is a full five-digit digital voltmeter which combines in one instrument the benefits of high accuracy, high speed, and high noise rejection. The unique method by which the potentiometric and integrating techniques are combined in this instrument is primarily responsible for this combination of outstanding features. A unique two-sample system enables 15 independent readings to be made in one second at this accuracy. Integration during the second of these two samples plus guarding results in excellent effective common-mode rejection and ac normal-mode rejection characteristics. Voltage ranges and integration periods can be selected by contact closures to ground.

DC Voltage Specifications*

Ranges

Full range display: ±1.00000 V; ±10.0000 V; ±100.000 V; ±1000.00 V.

Overranging: 20% on all ranges.

Range selection: manual, automatic or remote.

Performance rating

Accuracy (accuracy applies over a temperature range of 25°C ±5°C):

90 day calibration cycle: ±(0.004% of reading +0.002% of range).

180 day calibration cycle: ±(0.007% of reading +0.003% of range).

Stability: ±(0.002% of reading +0.001% of range) 24 hr, constant temperature ±1°C.

Temperature coefficient: ±(0.0002% of reading +0.0001% of range) per °C (from 0°C to 20°C and 30°C to 50°C).

Reading period

10, 100, 1000 V ranges: <66 ms; **1 V range:** <150 ms.

Integration period: 1/10 s (1/60 second selectable by external contact closure to ground on 10, 100 and 1000 V ranges).

Response time: reads within specified accuracy when triggered coincident with step input voltage.

Autorange time: 33 ms per range change. Remote ranging time: 8 ms.

Input characteristics

Input resistance: 1 V and 10 V ranges, >10^{10}Ω within ±5% of null, otherwise 10 MΩ ±0.03%; 100 V and 1000 V range, 10 MΩ ±0.03%.

Isolation parameters: floated and guarded input terminals; guard can be operated up to ±500 V peak with respect to chassis ground, low can be operated up to ±50 V peak with respect to guard.

Noise rejection: overall effective common-mode rejection (ratio of indicated error voltage to common-mode voltage) 145 dB at all frequencies (0.1 s sample period); common-mode rejection 160 dB at dc, 120 dB at 60 Hz with 1000Ω between low side of input and the point where the guard is connected; superimposed noise rejection; >20 dB at 55 Hz for 0.1 s sample period increased 20 dB per decade of frequency; infinite rejection at frequencies divisible by 10 (0.1 s sample period) or 60 (1/60 s sample period).

*For complete specifications refer to Data Sheet.

Remote control

Range selection: remote: all ranges can be selected by a contact closure to ground with impedance of <100Ω for a period >100 μs. Automatic: automatic mode of range selection can be programmed by a contact closure to ground with impedance <100Ω.

D/A converter reset: contact closure to ground of <100Ω.

Trigger hold-off: hold-off voltage is +3 to +10 V with a maximum current of 6.3 mA (provided by an external device).

Input resistance: 10 MΩ ±0.03% can be programmed by contact closure to ground of <100Ω.

Recorder data

BCD outputs: 4-line BCD (1-2-4-8) "1" state positive, 9 columns of information: function, decimal, overload, and 6 digit data.

General

Operating temperature: instrument will operate within specifications from 0°C to 50°C unless otherwise specified.

Storage temperature: −40°C to +75°C.

RFI: conducted and radiated leakage limits are below those specified in Mil-I-6181D.

Power: 115 V or 230 V ±10%, 50 Hz to 60 Hz, 60 W.

HP 3460B is available on special order for operation with power-line frequencies between 50 Hz and 400 Hz.

Dimensions: 16¾" wide, 5" high (without removable feet), 19⅜" deep (425 x 127 x 492 mm).

Weight: net 38 lbs (17,6 kg); shipping, 52 lbs (23,5 kg).

Accessories furnished

HP 11065A 6-ft rear input cable, guarding preserved; $15.

HP 11085A remote control cable, $30; rack mount kit for 19" rack.

Accessories available: HP 3461A AC/Ohms Converter-DC Preamplifier; HP 562A/AR Digital Recorder (refer to page 237 for special versions); HP 5050A Digital Recorder.

Optional Filter

An optional programmable filter can be added (as indicated in the table below) to increase the ac normal-mode rejection by 26 dB at 60 Hz (24 dB at 50 Hz). With this added rejection the 3460B accommodates ac normal-mode signals up to 100% of range (peak value).

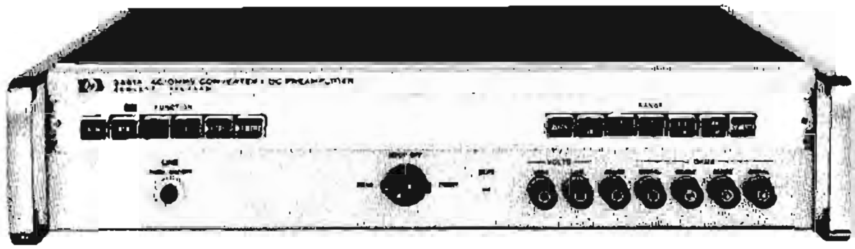
When using the filter, 725 ms is added to the reading period and 363 ms is added to the auto-range time listed in the 3460B specifications.

Price: HP 3460B, 1-2-4-8 BCD "1" state positive. $3800.

Options	BCD Code ("1" state positive)		3461A Compatibility	Filter	Additional Price
	1-2-4-8	1-2-2-4			
001		X			N/C
002	X		X		$150
003		X	X		$150
004	X			X	$250
005		X		X	$250
006	X		X	X	$400
007		X	X	X	$400

HP H50-3460B, optimum noise rejection for 50 Hz line frequency (3560B Options apply), $3860.

AC/OHMS CONVERTER/PREAMP
Automatic ranging in all functions
Model 3461A



3461A

The Model 3460B Digital Voltmeter and 3461B AC/Ohms Converter dc Preamplifier combine to provide a multiple-function instrument system capable of making high-accuracy dc voltage, ac voltage (average responding) and resistance measurements.

The 3460B/3461A combination is a fully programmable multi-function digital voltmeter. These features make the 3460B/3461A multi-function package an ideal choice for systems applications.

Combined Specifications
(3460B option 02 or 03 and 3461A)

DC voltage

The 3461A provides a 0.1 V range and can be used on the 1 V and 10 V ranges when 10^{10} Ω input impedance is required (accuracy is slightly demoted). The 3461A Bypass mode can be selected when dc accuracy of the 3460B alone is desired.

AC voltage

Ranges: full range, 1.00000 V, 10.0000 V, 100.000 V, 1000.00 V.
Overranging: 20% all ranges from 50 Hz to 100 kHz.
Range selection: manual, automatic or remote.
Performance rating
Accuracy, 90 day calibration cycle; temp range of 25°C ±5°C.

Frequency	Specification
50 Hz to 100 Hz	±(0.08% of reading +0.02% of range)
100 Hz to 10 kHz	±(0.07% of reading +0.01% of range)
10 kHz to 20 kHz	±(0.08% of reading +0.02% of range)
20 kHz to 100 kHz	±(0.15% of reading or 0.1% of range)

Stability: ±(0.012% of reading +0.006% of range) 24 hr. C.T. ±1°C.
Temperature coefficient: ±(0.0022% of reading +0.0006% of range) per°C for temps of 0°C to 20°C and 30°C to 50°C.
Reading period: ACF (above 200 Hz), <550 ms; ACN, <1.2 s.
Autorange time: ACF, <445 ms; ACN, <1.1 s (per range change).
Input characteristics
Input: floated and guarded input terminals.
Impedance: front panel, 5 MΩ ±0.1% shunted by <50 pF.

Ohms

Ranges: full range display of 1.00000 kΩ, 10.0000 kΩ, 100.000 kΩ, 1.00000 MΩ, 10.0000 MΩ; 20% overranging, all ranges.
Range selection: manual, automatic or remote.
Performance rating
Accuracy (applies for 25°C±5°C) 90 days calibration cycle:

Range	Specification
1 kΩ to 100 kΩ	±(0.012% of reading +0.004% of range)
1 MΩ and 10 MΩ	±(0.016% of reading +0.004% of range)

Stability: (24 hr. constant temperature ±1°C).

Range	Specification
1 kΩ to 100 kΩ	±(0.004% of reading +0.002% of range)
1 MΩ and 10MΩ	±(0.005% of reading +0.002% of range)

Temperature coefficient:

Range	Coefficient per °C
1 kΩ to 100 kΩ	±(0.0007% of reading +0.0002% of range)
1 MΩ and 10 MΩ	±(0.0012% of reading +0.0002% of range)

Derate the above specifications by these temperature coefficients for operation in temp range of 0°C to 20°C and 30°C to 50°C.
Reading period: 1 kΩ to 1 MΩ range, <150 ms; 10 MΩ range <66 ms.
Input characteristics
Input configuration: resistance measurements are made by a 4-terminal guarded system.
Current through unknown resistance: short-circuit current is from 1 mA on the 1 kΩ range to 1 μA on the 10 MΩ range.
Remote control
Function and range selection
Remote: selected by contact closure to ground, <100Ω.
Automatic: programmed by closure to ground, <100Ω.
Recorder data
Print command and BCD outputs: provided by the 3460B.

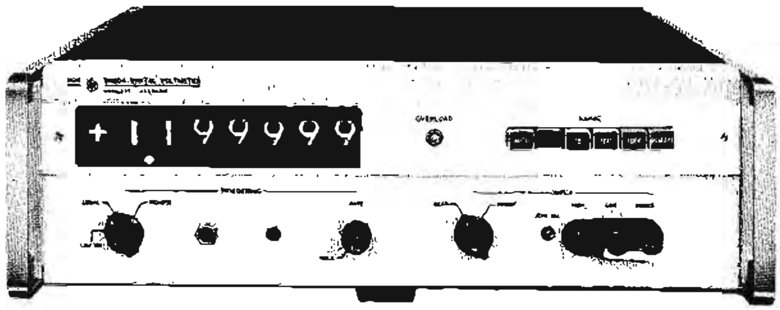
General

Effective common-mode rejection and normal-mode rejection: dc >160 dB (all functions); ac >139 dB (dc and ohm functions).
Operating temperature: 0°C to 50°C unless otherwise specified.
RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D.
Power: 115 V or 230 V ±10%, 50 Hz to 60 Hz, 95 W (3460B and 3461A with all functions). Available on special order for operation with power-line frequencies between 50 Hz and 400 Hz.
Dimensions: 16¾" wide, 3⅜" high (without removable feet), 18⅜" deep (425 x 86 x 467 mm).
Weight (3461A): net 24 lbs (11,2 kg); shipping 33 lbs (14,9 kg).
3460B Option 02 or Option 03 accessories furnished: refer to 3460B specifications.
3461A accessories furnished
HP 11065A volts rear input cable assembly; $15.
HP 11090A ohms rear input cable assembly (only with standard 3461A and 3461A Option 03); $30.
HP 11091A output cable assembly; $30.
HP 11092A interface logic cable assembly; $30.
HP 11093A remote control cable assembly; $15.
Rack mounting kit for 19" rack.
Accessories available
HP Part No. 5060-6026 joining bracket kit for combining 3460B and 3461A.
Refer to 3460B specifications for other accessories.
Price: HP 3460B Option 02 or Option 03, $3950.
HP 3461A, AC/Ohms Converter-DC Preamp, $2400.
HP 3461A Option 02 AC/DC Converter, $1700.
HP 3461A Option 03 Ohms/DC Converter-DC Preamp, $1950.

DIGITAL VOLTMETER

DVM resolution, 1 μV in 1 V, 1 mV in 1000 V

Model H04-3460A



H04-3460A

Features

- Resolution: 1 part in 1.2x10⁶
- Sensitivity: 1 μV
- Accuracy: 0.005% of reading
- Guarding reduces the effects of common-mode noise (CMR) by 160 dB at dc
- Four ranges to ±1000 volts full scale, selected by pushbuttons, automatically or remotely
- 20% overrange capability on all ranges - offering full-scale display within specified accuracy (measures up to 1200 V dc).

Description

The HP Model H04-3460A Potentiometric Integrating Digital Voltmeter is an integrating, guarded digital voltmeter offering high accuracy, resolution, and stability in the presence of noisy signals while retaining a constant input impedance. It offers a resolution of 1 part in 1,200,000—four times more resolution than any other digital voltmeter in its price range. Additionally, the H04-3460A DVM has a sensitivity of 1 μV and an accuracy of 0.005% of reading or ±0.0005% of full scale. The potentiometric-integrating technique used so successfully in the HP 3460B is also used in the H04-3460A. Using this DVM, measurements from 100 millivolts to 1200 V can be made with better than 0.005% of reading accuracy.

The H04-3460's combination of 1 ppm resolution, high accuracy, constant input impedance, and 20% overranging provide new measurement capabilities. A front-panel zero adjust is provided to compensate for any thermals in connections to external circuitry.

Typical examples where 1 ppm resolution and high accuracy can be used are in semiconductor research and testing and calibration of dc standard power supplies and transfer standards.

Null measurements can be performed wth 1 μV resolution. BCD output capability permits recording of data and remote programmability permits system applications. Transducers and load cell performance can be monitored for incremental changes in their outputs. Accurate determination of Zener diode breakdown voltages as a function of temperature can be made by utilizing the excellent short-term stability of the H04-3460A.

The H04-3460A offers a maximum reading rate of 1.1 seconds/reading on all ranges. The 20% overranging capability on all ranges offers full-scale display within specified accuracy; up to 1200 volts on the 1000 volt range.

Another feature is the constant 10 megohms impedance on all ranges. Four input ranges of 1.000000, 10.00000, 100.0000, and 1000.000 may be selected by front-panel pushbuttons with automatic or remote control left to the option of the operator. The front-panel input terminals are gold-flashed binding posts to reduce thermal electric effects. The guarded front or rear input terminals may be selected by a front-panel switch. A decimal point is automatically positioned so that the display reads directly in volts. The H04-3460A is fully programmable. Permanent test records of all readings including polarity, decimal location and overload are available by using HP Model 562A printer. The H04-3460A is designed for fully automatic operation with digital acquisition systems.

Programming the H04-3460A

The HP H04-3460A is designed for fully automatic operation within a digital data acquisition system. Voltage range can be selected by external circuit closures to ground.

To simplify system cabling, input connections can also be made at the rear of the instrument. All remote control lines and electrical outputs are referred to chassis ground and do not interfere with the guard.

Recording Output

1-2-4-8* binary-coded decimal voltages (ground referenced) are produced for each measurement and for indication of measurement function, voltage range and polarity. A complete printed record of the HP H04-3460A output information can be obtained by using an HP Model 562A/AR or 5050A Digital Recorder.

Specifications

Ranges:

Automatic or manual full-scale presentation of ±1.000000, ±10.00000, ±100.0000, and ±1000.000 (up to 20% overrange indicated with 7th digit). Range selection may be made automatically, remotely or manually.

*1-2-2-4 available with HP H04-3460A Option 01.

Performance rating:

Absolute voltage accuracy.* ±0.005% of reading or ±0.0005% of full scale whichever is greater over a temperature range from +20°C to +30°C for a period of 90 days.

Voltage accuracy temperature coefficient: ±(0.0002% of reading/°C +0.0001% of full scale/°C) over a temperature range of 0°C to +20°C and +30°C to +50°C.

Short term stability: ±0.002% of reading or ±0.0004% of full scale, whichever is greater at 23°C ±1°C and relative humidity up to 50% for a period of 24 hours.

Long term stability: ±0.008% of reading or ±0.001% of full scale, whichever is greater at 23°C ±1°C and relative humidity up to 50% for a period of 6 months.

Response time:

On Fixed Range—reads within specified accuracy when triggered coincident with step input voltage.

Reading Period—1.1 s minimum on 1, 10, 100, 1000 volt ranges.

Polarity Selection—No delay.

Automatic Range Selection—60 ms per range change (180 ms maximum).

Remote Range Selection—8 ms.

Isolation parameters:

Inputs: floated and guarded signal pair (special gold-plated binding post on front panel or connector on rear panel are selected by front-panel switch). Guard may be operated up to ±500 V dc with respect to chassis ground (350 volts rms). Low may be operated up to ±50 V dc with respect to guard.

Common mode rejection: ratio of common mode signal to resultant superimposed signal: 160 dB at dc with 1 k ohm between the low side of the input and the point where the guard is connected, 120 dB at 60 Hz under the same conditions.

More than 160 dB effective common mode rejection at all frequencies.

Input characteristics:

Input resistance: constant 10 megohms ±0.03% all ranges.

Input impedance: 40 pF in parallel with 10 megohms at front panel.

Superimposed noise rejection:

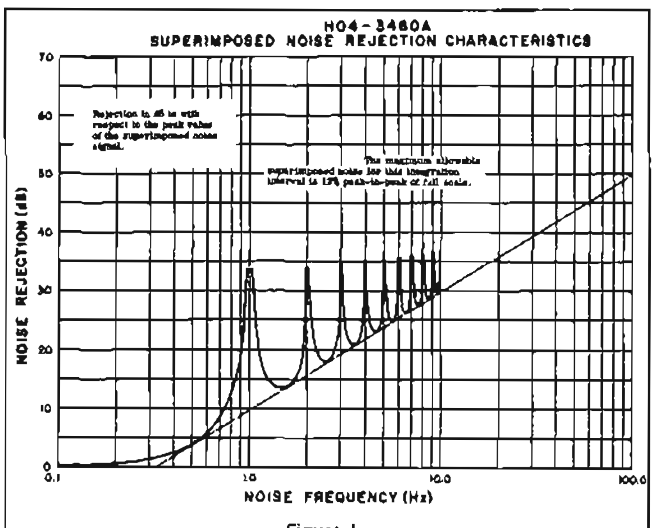


Figure I.

Input:

Range selection:

Automatic: pushbutton selector or a switch closure to ground with impedance <100 ohms provides auto-range operation. 60 ms is required per range change (180 ms max).

Remote: a switch closure to ground with impedance <100 ohms for a period >100 μsec selects range desired.

Manual: pushbutton selector.

External read command:

Trigger	Open Ckt Voltage	Trigger Level	Duration	Load
Positive going Direct coupled	−10 V	+10 to +30 Vdc	>100 μs <10 ms	2.5 mA at +10 V 6 mA at +30 V
Negative going Direct coupled	+10 V	Vdc −10 to −30	>100 μs	2 mA at −10 V, 5 mA at −30 V
AC coupled		20 V p-p with rise	>100 μs <10 ms	6k ohms in parallel
(Either Polarity)		time 10 μs		with 25 pF 0.01 μF coupling capacitor used)

Voltmeter reset: switch closure to ground through <100Ω assures minimum reading period.

Trigger hold off: hold off level is +3 to +10 volts with a maximum current of 6.3 mA. (Provided by HP Model 562A Digital Recorder.)

Output:

Print command: dc coupled.

BCD outputs: 4-line BCD (1-2-4-8) 9 columns consisting of polarity, overload and decimal location, and 7 digits of data (HP H04-3460A Option 01 is available for 1-2-2-4 BCD).

Operational features:

Input terminals-binding posts on front panel or connector on rear panel (high, low and guard). Selectable by front-panel switch.

Trigger selection: front-panel selection of local or remote.

Overload indicator: indicates when input voltage is higher than 120% of range selected.

Sample indicator: indicates when instrument is digitizing.

General

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 60 watts. The HP H04-3460A is available on special order for operation with power line frequencies between 50 and 400 Hz.

Dimensions: 16¾″ wide, 5″ high (without removable feet), 21⅜″ deep (425 x 127 x 543 mm).

Weight: net 38 lbs (16 kg); shipping 43 lbs (19.6 kg).

Accessories furnished:

Rack Mounting Kit includes 3 printed circuit extender boards.

HP 11065A: 6′ rear input cable, guarding preserved, terminated end mates with H04-3460A. $15.

HP 11069A: Remote Control Cable. $20.

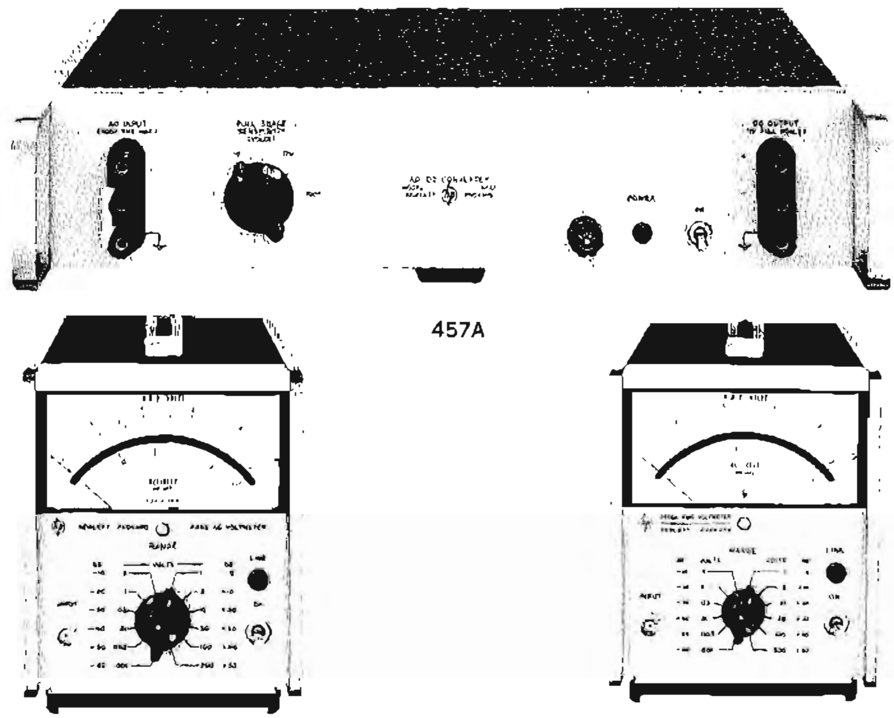
Price: HP H04-3460A, $4800; Option 01 (1-2-2-4 BCD output), no additional charge.

*Relative to the National Bureau of Standards.

AC TO DC CONVERTERS

Economical AC to DC converters

Models 457A, 400E, 3400A



Model 457A is an average-responding, rms calibrated ac-to-dc converter. Thus, a one-volt rms sine wave input provides a one-volt dc output.

A frequency range from 50 Hz to 500 kHz is covered with conversion accuracy of ±1 mV ±0.75% of full scale; from 50 Hz to 50 kHz, accuracy is ±1 mV ±0.3% of full scale.

Specifications, 457A

Input range: 100μV to 300 V rms, in 4 decade ranges corresponding to 1, 10, 100 and 1000 V rms full scale; overranging to 200% of full scale, all ranges except 1000 V.

Frequency range: 50 Hz to 500 kHz.

Accuracy: ±0.3% ±1 mV from 50 Hz to 50 kHz; ±0.75% ±1 mV from 50 kHz to 500 kHz.

Floating Input: permits measurement of ac voltages at dc potentials of ±500 V above power-line ground.

Output: 0 to 1 Vdc, responding to average value of ac input, with output calibrated as rms value of sine wave; input step attenuation of 1, 10, 100 or 1000.

Output impedance: 10,000 ohms.

Input impedance: 1 megohm, shunted by 30 pF.

Power: 115 or 230 V ±10%, 50 to 400 Hz, approx. 31 W.

Dimensions: 16¾" wide, 3¾" high, 13¾" deep (426 x 95 x 324 mm).

Weight: net 12 lbs (5,4 kg); shipping 20 lbs (9 kg).

Accessories available: 1110A Current Probe, $100; 10100B Feed-Through Termination (100Ω), $18; 11000A Cable, $5; 11001A Cable, $6.

Price: HP 457A, $500.

Two Hewlett-Packard analog voltmeters provide a dc output voltage that is directly proportional to the meter current and may be used as ac-to-dc converters. By connecting a dc digital voltmeter to the dc output of these instruments, an economical ac digital voltmeter is available. The output voltage of the HP 400E/EL and 3400A is 1 V dc for full-scale deflection.

The HP 3400A may be used as a true rms ac/dc converter. Typical dc output accuracy is ±0.75% of full scale from 50 Hz to 1 MHz. For additional information, refer to page 212.

The 400E/EL may be used with 0.5% accuracy as an ac/dc converter in its frequency range from 100 Hz to 500 kHz. For complete specifications, refer to page 209.

AC/DC Converter Output

400E/EL output: 1 V dc at full-scale deflection, proportional to meter deflection (linear output for Models 400E/EL).

Output resistance: 1000 ohms.

Response time: 2 seconds to within 1% of value.

Price: HP 400E, $325; HP 400EL, $335.

3400A output: —1 V dc at full-scale deflection, proportional to meter deflection (from 10 - 100% of full scale).

Output resistance: 1000 ohms.

Price: HP 3400A, $525.

IMPEDANCE AND PHASE MEASUREMENTS

Impedance measurements are concerned with the magnitude and the nature of the opposition of a component or network to the flow of ac current. Not only is a measure of the total opposition to current flow desired, but it is also important to determine the ratio of reactance to resistance and whether the reactance is inductive or capacitive.

At frequencies below 100 MHz, these qualities are most easily determined by measuring the voltage resulting from the flow of a known ac current into the component or network under test. The voltage amplitude indicates the absolute value of the impedance.

The nature of the reactance can be determined by comparing the phase difference between the current and voltage waveforms at the point of measurement. With the magnitude and phase angle θ thus determined, the ratio of reactance X to resistance R and whether the reactance is inductive or capacitive can be determined (see diagram Fig. 1).

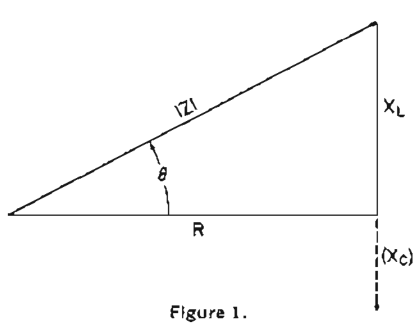


Figure 1.

Such measurements must be made at several frequencies if the component or network is to be fully characterized.

In the past, measurements of impedance at RF frequencies and above required several pieces of test equipment and were time-consuming, requiring many steps to acquire the desired information at each discrete frequency. Recently developed instruments from Hewlett-Packard, however, have greatly simplified the measurement of impedance over a broad range of frequencies. With these instruments, it is possible to make sweep frequency plots of the absolute value of impedance |Z| and phase angle (θ) vs. frequency and in so doing acquire complete coverage within the frequency band of interest.

Vector impedance meters

Direct readout of |Z| and θ are presented on adjacent meters by the remarkable new HP 4800A Vector Impedance Meter and the HP 4815A RF Vector Impedance Meter.

The 4800A (Fig. 2) which operates in a frequency range from 5 Hz to 500 kHz, requires only that frequency (and range) be selected; the unknown is connected across front-panel terminals. The magnitude of Z is read in ohms directly on one meter, while the second meter, centered on zero, indicates phase angle and, by needle deflection, whether the reactance is capacitive or inductive.

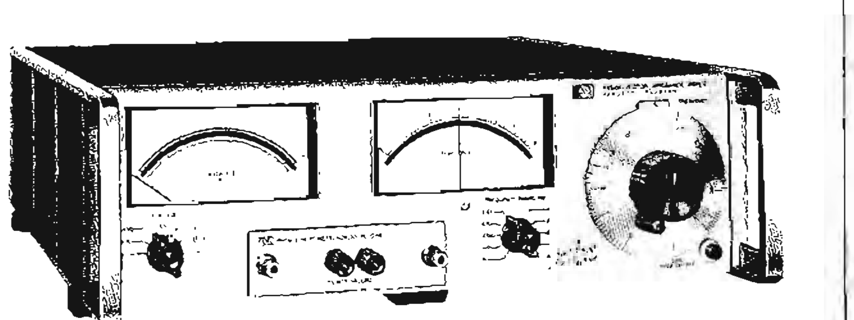


Figure 2.

Outputs at the rear provide dc analog signals proportional to meter deflections for Z, θ, and frequency for convenient recording. The operating range of the Model 4800A is 1 ohm to 10 megohms, ±90° phase angle.

In the Model 4815A RF Vector Impedance Meter, an internal LC oscillator supplies a low-level excitation signal to the circuit under test through a convenient probe attached to a 5-foot cable. A sampling AGC loop maintains the excitation constant at 4 microamps. At the same time, the voltage response of the test circuit is sensed and converted by a second sampling channel, located within the same probe, to read out directly in impedance. A phase detector monitors the difference between the voltage and current channels to yield the phase angle of the impedance vector. One probe, both excites the test circuit and measures its impedance and phase angle.

Operating range of the 4815A is 500 kHz to 108 MHz, 1 to 100,000 ohms, 0 to 360° phase angle.

The 4815A provides all of the convenience of "probe and read" measurements. In use, the probe is connected directly into the circuit to be evaluated, frequency is selected, and complex impedance is read. This method allows a straightforward adaptation to various jigs and fixtures for special measurements.

Where only component values are to be determined, a quick-mount adapter is provided to allow rapid measurements. For critical component applications, the unit to be evaluated may be mounted directly in its working circuit and its value determined in its actual environment, at the frequency of interest.

Analog output of frequency, magnitude, and phase angle are provided so that these values may be recorded on an X-Y recorder.

VECTOR IMPEDANCE METER

Quickly, easily measure Z & θ, 5 Hz to 500 kHz

Model 4800A

Advantages:

- Reads impedance and phase angle directly
- Easy to operate, no balancing or nulling
- Versatile, plug-in measuring terminals
- Reliable, solid-state circuits

The HP 4800A Vector Impedance Meter will make fast measurements of impedance to 10 megohms and phase to ±90° of unknown two-terminal networks. Measurement can be made at a particular frequency or over a continuous range from 5 Hz to 500 kHz. The instrument may be mechanically swept to produce continuous measurements over its full frequency range. Analog outputs of frequency, impedance, and phase are available for X-Y recording. The instrument provides the design engineer with an easy-to-use, one-instrument method for checking components and circuits.

Specifications

Frequency characteristics

Range: 5 Hz to 500 kHz in five bands: 5 to 50 Hz, 50 to 500 Hz, 0.5 to 5 kHz, 5 to 50 kHz, 50 to 500 kHz.

Accuracy: ±2% from 50 Hz to 500 kHz, ±4% from 5 to 50 Hz, ±1% at 15.92 on frequency dial from 159.2 Hz to 159.2 kHz, ±2% at 15.92 Hz.

Monitor output: level: .2 volt rms minimum; source impedance: 600 ohms nominal in series with 50 μF.

Impedance measurement characteristics

Range: 1 ohm to 10 megohms in seven ranges: 10 ohms, 100 ohms, 1000 ohms, 10 k ohms, 100 k ohms, 1 megohm, 10 megohms full scale.

Accuracy: ±5% of reading.

Phase angle measurement characteristics

Range: 0° ±90°; **Accuracy:** ±6°; **Calibration:** increments of 5°.

Direct inductance measurement capabilities

Range: 1 μH to 100,000 H, direct reading at decade multiples of 15.92 Hz.

Accuracy: ±7% of reading for Q greater than 10 from 159.2 Hz to 159.2 kHz; ±8% of reading for Q greater than 10 at 15.92 Hz.

Direct capacitance measurement capabilities

Range: 0.1 pF to 10,000 μF, direct reading at decade multiples of 15.92 Hz.

Accuracy: ±7% of reading for D less than 0.1 from 159.2 Hz to 159.2 kHz, ±8% of reading for D less than 0.1 at 15.92 Hz.

Measuring Terminal Characteristics

Configuration: electrical: both terminals above ground, ground terminals provided for shielding convenience; mechanical: binding posts spaced 3/4" at centers.

Waveshape: sinusoidal.

External Oscillator Requirements: 0.9 V ±20 % into 20 k ohms.

Recorder outputs:

Frequency: level, 0 to 1 volt nominal; source impedance, 0 to 1000 ohms nominal; proportional to frequency dial rotation.

Impedance: level, 0 to 1 volt nominal; source impedance, 1000 ohms nominal.

Phase angle: level, 0 ±.9 volt nominal; source impedance, 1000 ohms nominal.

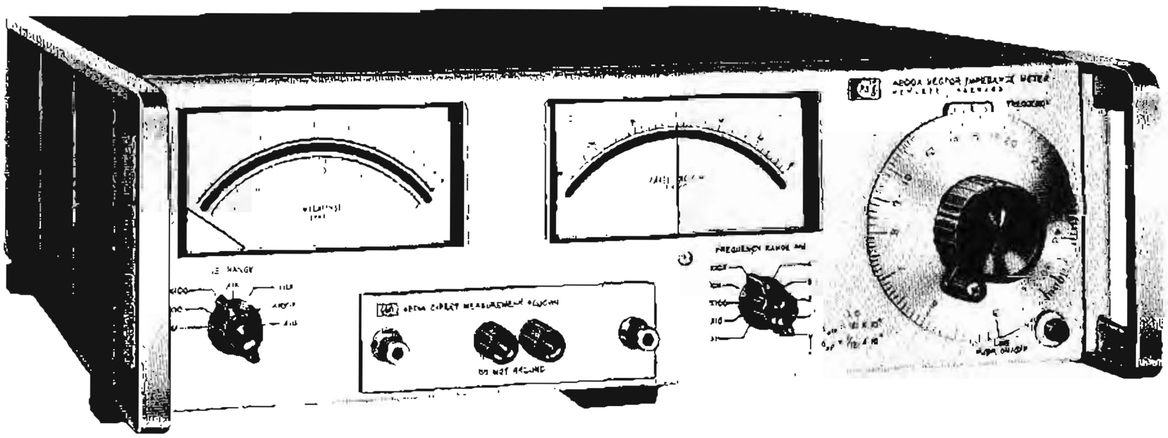
Accessories furnished: 13525A Calibration Resistor, 00610A Terminal Shield.

Dimensions: 16¾" wide, 5¼" high, 18⅜" deep (426 x 133 x 467 mm).

Weight: net 24 lbs (10,8 kg), shipping 30 lbs (13,5 kg).

Power: 105 to 125 V or 210 to 250 V, 50 to 400 Hz, 27 W.

Price: HP 4800A, $1,650.



4800A

RF VECTOR IMPEDANCE METER
Quickly, easily measure Z & θ, .5 to 108 MHz
Model 4815A

Advantages:

- Direct reading of impedance and phase
- Convenient probe for in-circuit measurements
- Self calibration check provides measurement confidence
- Analog outputs for data recording
- Low-level test signal minimizes circuit disturbance

The HP 4815A RF Vector Impedance Meter provides all of the convenience of "probe and read" measurements. In use, the probe is connected directly into the circuit to be evaluated, frequency is selected, and complex impedance is read. This type measurement allows a straightforward adaptation to various jigs and fixtures for special measurements. Where only component values are to be determined, a quick-mount adapter is provided to allow rapid measurements. For critical component applications, the unit to be evaluated may be mounted directly in its working circuit and its value determined in its actual environment, at the frequency of interest.

Specifications

Frequency

Range: 500 kHz to 108 MHz in five bands: 500 kHz to 1.5 MHz, 1.5 to 4.5 MHz, 4.5 to 14 MHz, 14 to 35 MHz, 35 to 108 MHz.

Accuracy: ±2% of reading, ±1% of reading at 1.592 and 15.92 MHz.

RF monitor output: 150 mV minimum into 50 ohms.

Impedance magnitude measurement

Range: 1 ohm to 100 k ohms; full-scale ranges: 10, 30, 100, 300, 1 k, 3 k, 10 k, 30 k, 100 k ohms.

Accuracy: ±4% of full scale $\pm \left(\frac{f}{30\text{ MHz}} + \frac{Z}{25\text{ k ohms}}\right)$ % of reading, where f = frequency in MHz and Z is in ohms; reading includes probe residual impedance.

Calibration: linear meter scale with increments 2% of full scale.

Phase angle measurement

Range: 0 to 360° in two ranges: 0 ± 90°, 180° ± 90°.

Accuracy: $\pm \left(3 + \frac{f}{30\text{ MHz}} + \frac{Z}{50\text{ k ohms}}\right)$ degrees; where f = frequency in MHz and Z is in ohms.

Calibration: increments of 2°.

Adjustments: front panel screwdriver adjustments for Magnitude and Phase Zero.

Recorder outputs

Frequency: 0 to 1 volt from 0 to 1 k ohm source, proportional to dial rotation.

Impedance magnitude: 0 to 1 volt from 1 k ohm source.

Phase angle: 0 ± 0.9 volt from 1 k ohm source.

Dimensions: 16¾" wide, 7¼" high, 18¾" deep (426 x 185 x 476 mm).

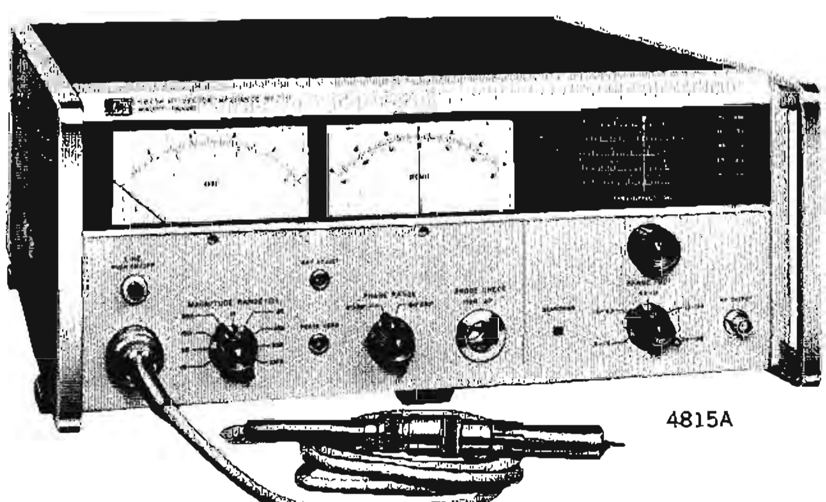
Weight: net 39 lbs (17,6 kg), shipping 55 lbs (24,8 kg).

Power: 105 to 125 V or 210 to 250 V, 50 to 400 Hz, 50 W.

Accessories furnished:

1. 00600A Probe Accessory Kit: contains BNC Type "N" adapter, Probe Socket, 00601A Component Mounting Adapter, 2 probe center pins, probe ground assembly.
2. Rack Mount Kit.

Price: HP 4815A, $2650.



4815A

Impedance bridge

Analysis of capacitors, inductors, and resistors for low-frequency applications is commonly made with a universal bridge. Universal bridges have considerable versatility, being able to measure not only resistance, capacitance, and inductance over wide ranges, but also the Q of inductances and the dissipation factor $(\frac{1}{Q})$ of capacitors.

The HP Model 4260A bridge measures resistance values from 10 milliohms to 10 megohms, inductances from 1 microhenry to 1000 henry, and capacitances from 1 pF to 1000 μF.

Q is measured, in the series configuration, from 0.02 to 20; Q of R in parallel with L is measurable in a range from 8 to 1000. The dissipation factor (D) of capacitors is measured from 0.001 to 0.12 for series C and R, and from 0.05 to 50.0 with parallel C and R. The accuracy of D and Q measurements is $\pm$5%, or better.

Inside the bridge is a driving oscillator, operating at 1 kHz. Other frequencies within a range of 20 Hz to 20 kHz may be used to drive the bridge.

A generalized ac impedance bridge is shown in Fig. 1. The bridge is driven by an ac source across the corners OQ. When the voltage across arm OP equals the voltage across arm OS, the output voltage, expressed across the detector connected to P and S, is zero. The bridge is balanced, or nulled; the product of the impedance across OS and that across PQ is equal to the product of the impedance across SQ and that across OP.

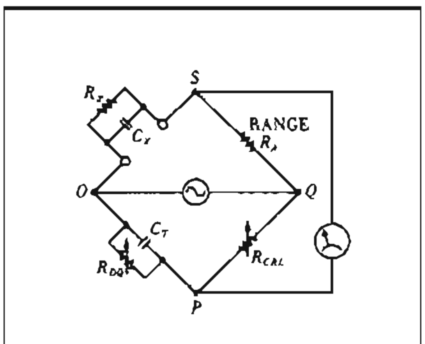


Figure 1. Generalized ac bridge configuration. OQ is bridge driving voltage. OS is fixed by value of unknown component and setting of RANGE switch. OP is determined by R_{CAL} and R_{DQ} controls and C_T. When balanced, voltage across PC is zero.

Now the value of any of the four impedances can be calculated if the other three are known.

An internal dc supply is used for measurements of resistance and an internal 1-kHz oscillator drives the bridge for measurements on capacitors and inductors.

Null procedure in Hewlett-Packard's new Model 4260A Universal Bridge uses a feedback control system to make one of the bridge adjustments automatically. C or L can be read directly, after balancing the bridge with only one adjustment of the CRL control.

The dissipation factor for capacitors (D) or quality factor for inductors (Q) is found with only two adjustments; there is no "chasing" of the null through further alternate adjustments of any interacting controls.

Q meters

The Q of a resonant circuit, comprising a variable known capacitor (C_q) contained in the Q meter and an external inductor (L_x), is measured by impressing a signal of known voltage (E_i) and variable known frequency in series in the circuit, and measuring the voltage (E_q)

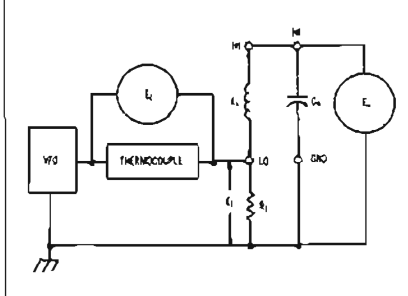


Figure 2. Q Meter.

across the capacitor when the circuit is resonated to the chosen frequency of the impressed voltage. Q of the circuit is the ratio E_q/E_i. With E_i known, the voltmeter measuring E_q can be calibrated directly in Q. By inserting low impedances in series with the inductor L_x, or high impedances in parallel with the capacitor C_q, the constants of unknown circuits or components may be measured in terms of their effect on the original circuit Q and tuning capacitance.

To calibrate these meters, Hewlett-Packard provides Q standards which are standard inductors of calibrated Q.

There are two Q meters in the HP family. Model 260A is for the frequency range 50 kHz to 50 MHz which may be extended down to 1 kHz by using a suitable external oscillator with a Model 00564A Coupling Unit. Model 190A serves the range 20 MHz to 260 MHz.

RX meter

The HP Model 250B RX Meter directly presents the parallel resistive and reactive constituents of Z, for two-terminal networks, in the range from 0.5 to 250 MHz.

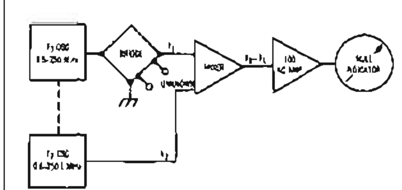


Figure 3. RX Meter.

The output of the 0.5 to 250 MHz test oscillator (F_1) is fed into a Schering bridge. When the impedance to be measured is connected across one arm of the bridge, the equivalent parallel resistance and reactance unbalance the bridge, and the resulting voltage is fed to the mixer. The output of the 0.6 to 250.1 MHz oscillator (F_2), tracking 100 kHz above F_1, also is fed to the mixer, resulting in a 100 kHz difference frequency proportional in level to the bridge unbalance. This is amplified selectively to provide desired balance sensitivity. When the bridge R and C controls are nulled, their respective dials accurately indicate the parallel impedance components of the test sample.

The instrument's range of measurement is 15 to 100,000 ohms for parallel resistance (0 to 15 ohms by indirect means) for C, and 0.001 μH to 100 mH for L.

UNIVERSAL BRIDGE
Simplified, easy to read impedance measurement
Model 4260A

Advantages:

Electronic AUTOBALANCE — single control null
Digital Readout for C, R, L
Direction Indicators for fast range selection and balance

Measurements of C, R, L, D (dissipation factor of capacitors), and Q are easily made with the new Model 4260A Universal Impedance Bridge.

The readout for C, R and L is digital with the decimal point automatically positioned. Units of measurement and the equivalent circuit automatically appear with a twist of the function switch. There are no multipliers or confusing non-linear dials which need interpolation.

Operation is simple. Set the function knob for the parameter to be measured, adjust the range switch for an on-scale indication, and obtain a null with the CRL control. There are no interacting controls to adjust and readjust. There are no false nulls. A unique electronic AUTOBALANCE circuit solves all these problems. Components with low Q or high Q are as easy to measure as those without loss.

For D or Q measurements, switch out of AUTO and turn the DQ control until another null is obtained. Only one adjustment is needed for each measurement.

Five bridge circuits are incorporated in the 4260A; each is composed of stable, high-quality components for good accuracy and linearity. An internal 1 kHz drives the bridge.

Nulling is easy. Illuminated pointers (< CRL >) automatically tell whether a null is up- or down-scale. Both range and CRL controls can be set watching these pointers.

Components may be biased by connecting a battery to the rear terminals. An external oscillator and detector can be used for measurements in the 20 Hz - 20 kHz range.

The compact modular cabinet is ideal for bench use; and it may be rack mounted using accessory hardware. A tilt stand is provided to raise the viewing angle; it also serves as a convenient carrying handle.

4260A

Specifications

Capacitance measurement

Capacitance

Range: 1 pF to 1000 μF, in 7 ranges.

Accuracy:
± (1% + 1 digit), from 1 nF to 100 μF.
± (2% + 1 digit), from 1 pF to 1 nF and 100 μF. to 1000 μF.

Dissipation factor

Range:
LOW D—(of series C): 0.001 to 0.12.
HIGH D—(of parallel C): 0.05 to 50.

Accuracy: for C >100 pF.
LOW D—(of series C): ±(5% + 0.002) or ± ONE DIAL DIVISION, whichever is greater.
HIGH D—1/D (of parallel C): ±(5% + 0.05) or ± ONE DIAL DIVISION of LOW Q dial, whichever is greater.

Inductance measurement

Inductance

Range: 1 μH to 1000 H, in 7 ranges.

Accuracy:
±(1% + 1 Digit), from 1 mH to 100 H.
±(2% + 1 Digit), from 1 μH to 1 mH and 100 H to 1000 H.

Quality factor

Range:
LOW Q—(of series L): 0.02 to 20.
HIGH Q—(of parallel L): 8 to 1000.

Auto-balance

Eliminates need for DQ adjustments in parallel C and series L measurements at 1 kHz.

Accuracy: for D <1 and Q >1 add ±0.5% to C and L accuracy specifications.

Resistance measurement

Range: 10 milliohms to 10 megohms, in 7 ranges.

Accuracy:
± (1% + 1 digit), from 10 ohms to 1 megohm.
± (2% + 1 digit), from 10 milliohms to 10 ohms and 1 megohm to 10 megohms; for greater accuracy in this high range, Model 419A is recommended.

Oscillator and detector

Internal oscillator: 1 kHz ± 2%, 100 mV rms ± 20%.

Internal detector: tuned amplifier at 1 kHz; functions as a broadband amplifier for measurements with external oscillator.

General

Power: 115 or 230 volts ± 10%, 50-60 Hz, approx. 7 watts.

Dimensions: 7-25/32" wide, 6-17/32" high, 11" deep (190 x 166 x 279 mm).

Weight: net, 11 lbs (5 kg); shipping, 15 lbs (6,8 kg).

Optional accessories:
HP 419A for accurate R measurements <10 ohms and >1 M ohms.
HP 204B for measurements 20 Hz - 20 kHz.
HP 140A/1400A or external tuned null detector with 90 dB gain and Z_{in} >10 k ohms for measurements 20 Hz - 20 kHz.

Price: Model 4260A Universal Bridge, $550.00.

Manufactured by Yokogawa Hewlett-Packard Ltd., Tokyo.

RX METER

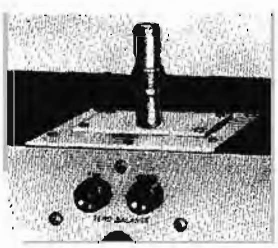
Self-contained rf bridge, 500 kHz to 250 MHz

Model 250B

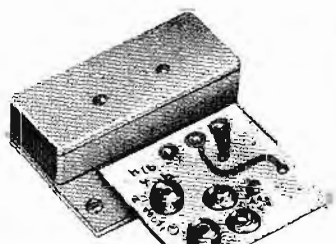
The HP 250B RX Meter is a completely self-contained instrument for use in measuring the equivalent parallel resistance and capacitance or inductance of two-terminal networks. The instrument's design includes an accurate, continuously tuned oscillator, high-frequency bridge, amplifier detector and null/RF level indicator.

The oscillator, which is carefully designed to minimize temperature effects, is mounted inside a rigid casting in order to obtain a high degree of accuracy, stability and low leakage. A long-life sub-miniature triode is used, and the unit is carefully shielded to avoid any leakage of signal to the amplifier-detector by any path other than through the bridge. The high-frequency bridge is also mounted inside a casting and is specially designed to minimize the effects of coupling between arms.

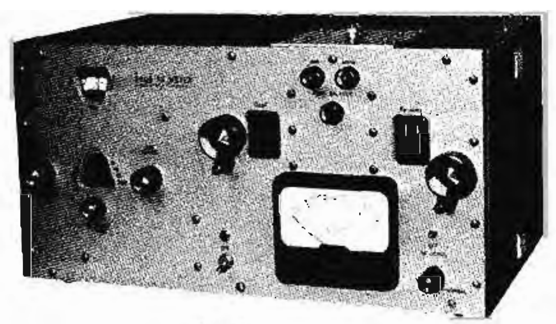
Connections to the unknown impedance are arranged for almost zero lead length. Convenient, easily adjusted bridge balance controls are provided on the front panel. Controls are also provided for adjustment and indication of the relative RF signal level at the test terminals. A connector on the rear panel provides an IF output for a sensitive tuned voltmeter for improved resolution when nulling during reduced signal level operation.



00515A



13510A



250B

Specifications

Radio frequency characteristics

RF range: total range: 500 kHz to 250 MHz; number bands: 8; band ranges: 0.5 to 1 MHz, 1 to 2 MHz, 2 to 4 MHz, 4 to 9 MHz, 9 to 21 MHz, 21 to 48 MHz, 48 to 110 MHz, 110 to 250 MHz.

RF accuracy: $\pm 2\%$.

RF calibration: increments of approximately 1%.

Resistance measurement characteristics

Resistance range: 15 to 100,000 ohms.

Resistance accuracy: $\pm\left[2+\frac{F}{200}+\frac{R}{5000}+\frac{Q}{20}\right]\%$ ± 0.2 ohm; F = frequency (MHz), R = RX Meter R_p reading (ohms), $Q = \omega CR \times 10^{-12}$, where C = RX Meter C_p reading (pF).

Resistance calibration: increments of approximately 3% throughout most of range.

Capacitance measurement characteristics

Capacitance range: 0 to 20 pF (may be extended through use of auxiliary coils).

Capacitance accuracy: $\pm(0.5 + 0.5\ F^2\ C \times 10^{-5})\ \%$ ± 0.15 pF; F = frequency (MHz), C = RX Meter C_p reading (pF).

Capacitor calibration: 0.1 pF increments.

Inductance measurement characteristics

Inductance range: 0.001 μh to 100 mh (actual range depends upon frequency; auxiliary resistors employed).

Inductance accuracy: basic accuracy is capacitance accuracy given above.

Measurement voltage level

RF: 0.05 to 0.75 V approx, depending on frequency, with SET RF LEVEL control in NORMAL position. RF level adjustable to below 20 mV; relative level indicated when SET RF LEVEL switch is depressed.

DC: 0 V; (external dc current up to a 50 mA, may be passed through RX meter terminals).

Accessories available: 00515A Coax Adapter Kit (designed to permit connection to the RX meter bridge circuit of any coaxial transmission line or fixture fitted with a Type "N male connector), $50; 13510A Transistor Test Jig (provides a convenient means for measuring Y parameters Y_{11b}, Y_{11e}, and Y_{22e} of transistors on the RX meter over the frequency range of 500 kHz to 250 MHz), $195.

Physical characteristics

Dimensions: 20" wide, 10⅜" high, 13½" deep (508 x 264 x 343 mm).

Weight: net 40 lbs (18 kg); shipping 50 lbs (22,5 kg).

Power: 105 to 125 volts or 210 to 250 volts, 50 to 400 Hz, 60 watts.

Price: HP 250B, $2050.

Q METER
Expanded scale for Q measurements
Model 260A

The direct-reading expanded scale of the HP 260A Q Meter permits measurement of Q down to 10 and also permits reading of very small changes in Q resulting from the variation of the test parameter.

The Q meter was first designed and introduced as a means of measuring the Q or "figure of merit" of coils. Improved models and broadened applications have kept pace with new measuring needs, and today the Q meter is recognized as a flexible general-purpose device with a large number of uses.

Circuit technique

The Q meter consists of a self-contained, continuously variable, stable oscillator, whose controlled and measured output is applied in series with a series-tuned, resonant circuit. A vacuum tube voltmeter with high input impedance is connected across the internal variable capacitor portion of the tuned circuit to measure the reactive voltage in terms of circuit Q. The coil portion of the tuned circuit is connected externally and represents the unknown to be measured. By inserting low impedances in series with the coil or high impedances in parallel with the capacitor, the parameters of unknown circuits or components can be measured in terms of their effect on the circuit Q and resonant frequency.

Usefulness, special features of the 260A

The 260A is typical of these instruments. It is useful for direct reading of circuit Q on its parallax-free meter. From such measurements, the distributed capacitance, effective inductance and self-resonant frequency can be determined. On capacitors, capacitance from 0.1 pF to 100 μF and Q from 10 to 10,000 can be evaluated from measurements made with and without the component connected. Capacitor self-resonant frequency also can be determined.

Effective RF resistance, inductance or capacitance, and Q of resistors also may be determined, and, used on IF and RF transformers, the 260A will measure effective impedance, Q, coefficient of coupling, mutual inductance and frequency response. The Q meter also is useful for making measurements of dielectric constant and dissipation factor on insulating materials.

The HP 260A utilizes a rugged thermocouple operating at half rated power; oscillator output is factory-adjusted to avoid overload. Both these features guard against accidental thermocouple overload. Through the use of an internal regulating transformer and an electronically regulated power supply, the operation of the instrument is not affected by normal power line fluctuations.

Teflon insulation has been provided for 260A terminals, providing mechanical stability and low electrical loss The oscillator output is controlled by varying the screen grid voltage of the oscillator tube to obtain smooth operation, as well as good waveshape. A 0.02-ohm annular insertion resistor is used to improve 260A accuracy. Provision is made for use of an external oscillator to supply the Q meter through a matching transformer (HP 00564A) to provide operation below 50 kHz down to 1000 Hz. A scale also is provided to read inductance directly at selected frequencies.

260A

Specifications

Radio frequency characteristics

RF range: total range: 50 kHz to 50 MHz, 1 kHz to 50 kHz (with external oscillator); number bands: 8; band ranges: 50 to 120 kHz, 120 to 300 kHz, 300 to 700 kHz, 700 to 1700 kHz, 1.7 to 4.2 MHz, 4.2 to 10 MHz, 10 to 23 MHz, 23 to 50 MHz.

RF accuracy: ±2%.

RF calibration: increments of approximately 1%.

Q measurement characteristics

Q range: total range: 10 to 625; low range: 10 to 60; Δ range: 0 to 50.

Q accuracy: ±5%, 50 kHz to 30 MHz; ±10%, 30 MHz to 50 MHz (for circuit Q of 250 read directly on indicating meter).

Q calibration: main scale: increments of 5 from 40 to 250; low scale: increments of 1 from 10 to 60; Δ scale: increments of 1 from 0 to 50; XQ scale: increments of 0.1 from 1 to 1.5 and increments of 0.5 from 1.5 to 2.5.

Inductance measurement characteristics

L range: 0.09 μH to 130 mH, (effective inductance), direct reading at six specific frequencies.

L accuracy: ±3% (for resonating capacitance >100 pF and inductance >5 μH).

Resonating capacitor characteristics

Capacitor range: main: 30 to 460 pF; vernier: −3 to +3 pF.

Capacitor accuracy: main: ±1% or 1 pF, whichever is greater; vernier: ±0.1 pF.

Capacitor calibration: main: 1 pF increments 30 to 100 pF, 5 pF increments 100 to 460 pF; vernier: 0.1 pF increments.

Physical characteristics

Mounting: sloping front cabinet, for bench use.

Finish: gray wrinkle, engraved panel (other finishes available on special order).

Dimensions: 21¼" wide, 11¾" high, 10" deep (540 x 298 x 254 mm).

Weight: net 40 lbs (18 kg); shipping 55 lbs (24,8 kg).

Power: 260A: 95 to 130 V, 60 Hz, 65 W; 260AP: 95 to 130 V, 50 Hz, 65 W.

Accessories available: 00103A Inductors, 00513/00518A Q Standards, 00564A Coupling Unit.

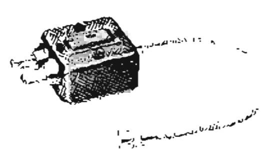
Price: HP 260A,AP, $1350.

Q METER ACCESSORIES

Q standards, inductors, coupling transformer

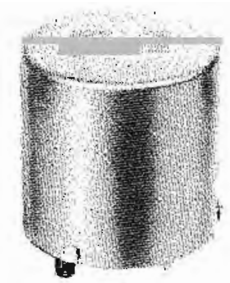
Models 00513A, 00518A, 00103A, 00564A

00518A



00564A

00513A



00103A

00103A Inductors

The HP 00103A Inductors are designed specifically for use in the Q circuit of the 160A and 260A Q Meters, for measuring the RF characteristics of capacitors, insulating materials, resistors, etc. Price: HP 00103A, $25 each; HP 00127A, set of 16 inductors for 260A, $360; HP 00128A, set of 17 inductors for 160A, $380.

Specifications, 00103A

HP model	Inductance	Approx. resonant frequency for tuning capacitance of: 400 pF	100 pF	60 pF	Approx. Q	Capacitance pF
00103-A1	1 μH	8	16	20 MHz	180	6
00103-A2	2.5 μH	5	10	14 MHz	200	6
00103-A5	5 μH	3.5	7	10 MHz	200	6
00103-A11	10 μH	2.5	5	7 MHz	200	6
00103-A12	25 μH	1.5	3	4.5 MHz	200	6
00103-A15	50 μH	1.1	2.2	3 MHz	200	6
00103-A21	100 μH	800	1600	2000 kHz	200	6
00103-A22	250 μH	500	1000	1400 kHz	200	6
00103-A25	500 μH	350	700	1000 kHz	170	7
00103-A31	1 mH	250	500	700 kHz	170	7
00103-A32	2.5 mH	150	300	450 kHz	170	8
00103-A35	5 mH	110	220	300 kHz	160	8
00103-A41	10 mH	80	160	200 kHz	140	9
00103-A42	25 mH	50	100	140 kHz	110	9
		100 pF		35 pF		
00103-A50	0.5 μH	20 MHz		35 MHz	225	5.5
00103-A51	0.25 μH	30 MHz		50 MHz	225	5.5
00103-A52	0.1 μH	45 MHz		75 MHz	225	3.5

00513A Q Standards

HP 00513A Q Standards are shielded reference inductors which have accurately measured and highly stable inductance and Q characteristics. Specifically designed for use with the 160A and 260A Q Meters, the Q standards are particularly useful as a means for checking the overall operation and accuracy of these instruments, as well as for providing precisely known supplementary Q circuit inductance desirable for many impedance measurements by the parallel method. Price: HP 00513A, $125 each.

Nominal values for HP 00513A			
L-250 μH		Cd-8 pF	
	0.5 MHz	1 MHz	1.5 MHz
Q_e	190	250	220
Q_i	183	234	200

Actual values of all these quantities are marked on the name plate of the Q standard; with the unit in the Q circuit, approximate resonant frequencies of 500, 1000 and 1500 kHz are obtained with tuning capacitances of 400, 100 and 50 pF, respectively.

00518A Q Standards

HP 00518A Q Standards, used in conjunction with the 00513A Q Standards, provide frequency coverage from 50 kHz to 50 MHz—the entire range of the 260A Q Meter. These units are useful as precision inductors and as a fast, convenient means for checking the overall operating accuracy of Q meters. Price: HP 00518A, $125 each; HP 00538A, set of five 00518A and one 00513A, $675.

Specifications, 00518A

HP model	00518-A1	00518-A2	00518-A3	00518-A4	00518-A5
Inductance	0.25 μH	2.5 μH	25 μH	2.5 mH	25 mH
Low freq. data: Frequency	15 MHz	5 MHz	1.5 MHz	150 kHz	50 kHz
Resonating C	420 pF	395 pF	440 pF	440 pF	400 pF
Indicated Q	175	195	175	170	90
Middle-freq. data: Frequency	30 MHz	10 MHz	3 MHz	300 kHz	100 kHz
Resonating C	100 pF	95 pF	105 pF	100 pF	85 pF
Indicated Q	235	235	225	180	130
High-freq. data: Frequency	45 MHz	15 MHz	4.5 MHz	450 kHz	150 kHz
Resonating C	40 pF	40 pF	45 pF	40 pF	35 pF
Indicated Q	225	205	230	135	125

(Table shows nominal values)

00564A Coupling Transformer

The 00564A Coupling Transformer Unit is designed to couple the output of an external oscillator into the 160A or 260A Q Meter for the purpose of extending the operation range of the Q meter to the low-frequency region. By means of the coupling unit and an auxiliary oscillator, the Q meter may be operated down to a low-frequency limit of 1 kHz. The oscillator should supply a variable voltage of 22 volts maximum into an impedance of 500 ohms. Price: HP 00564A, $50.

Q METER, INDUCTORS

Direct Q measurements, 20 to 260 MHz

Models 190A, 00590A

190A Q Meter

The HP 190A Q Meter finds applications similar to those described for the 260A Q Meter (page 259), but in the VHF range of frequencies. This instrument does not have a thermocouple, but employs a special coupling impedance to introduce voltage across the series-tuned, resonant circuit. This voltage, as well as the reactive voltage developed across the internal Q capacitor, is measured by two high-impedance, low input capacitance vacuum tube voltmeters and indicated on a single front-panel parallax-free meter.

Specifications, 190A

Radio frequency characteristics

RF range: total range: 20 to 260 MHz; number bands: 4; band ranges: 20 to 40 MHz, 40 to 80 MHz, 80 to 160 MHz, 160 to 260 MHz.

RF accuracy: ±1%.

RF calibration: increments of approximately 1%.

Q measurement characteristics

Q range: total range: 5 to 1200; low range: 10 to 100; △ range: 0 to 100.

Q accuracy: ±7% 20 to 100 MHz; ±15% 100 to 260 MHz (for circuit Q of 400 read directly on indicating meter).

Q calibration: main scale: increments of 10 from 50 to 400; low scale: increments of 2 from 10 to 100; △ scale: increments of 2 from 0 to 100; XQ scale: increments of 0.1 from 0.5 to 1.5, increments of 0.5 from 1.5 to 3.

Resonating capacitor characteristics

Capacitor range: 7.5 to 100 pF.

Capacitor accuracy: ±0.2 pF, 7.5 to 20 pF; ±0.3 pF, 20 to 50 pF; ±0.5 pF, 50 to 100 pF.

Capacitor calibration: 0.1 pF increments.

Accessories available: 00590A Inductors.

Physical characteristics

Dimensions: 14¼" wide, 10⅛" high, 10½" deep (362 x 257 x 267 mm).

Weight: net 25 lbs (11,3 kg); shipping 32 lbs (14,4 kg).

Power: 190A: 95 to 130 volts, 60 Hz, 55 watts; 190 AP: 115/230 volts, 50 Hz, 55 watts.

Price: HP 190A,AP, $1475.

00590A Inductors

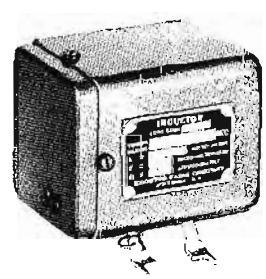
HP 00590A Inductors are designed specifically for use in the Q Circuit of the 190A Q Meter for measuring the radio-frequency characteristics of capacitors, resistors, and insulating materials. They have general usefulness as reference coils and may be used for periodic checks to indicate any considerable change in the performance of the Q meters.

Specifications, 00590A

HP model	Inductance µH	Capacitance pF	Approx. resonant freq. MHz	Approx. Q	Approx. distributed C pF
00590-A1	0.05	95—7.5	70—230	350	1.5
00590-A2	0.1	95—7.5	50—160	320	1.7
00590-A3	0.25	100—7.5	30—100	380	2.3
00590-A4	0.5	80—7.5	25— 70	360	2.3
00590-A5	1.0	60—7.5	20— 50	350	2.9
00590-A6	2.5	15—8.0	20— 30	330	2.9

Price: HP 00590A, $25 each; HP 00591A, complete set of six $130.

190A



00590A

Digital & RF products

Hot Carrier Diodes. Extremely fast turn-on, turn-off times. Excellent forward and reverse characteristics. Especially useful for RF mixer/detector applications. Matched pairs and quads. New low prices.

Step Recovery Diodes. Time domain specified for pulse generation and shaping. Full specs on ramping and rounding parameters. For generation of test waveforms, fast clock pulses, odd numbered harmonics, special drive waveforms, sharp linear triangular waveforms. Glass, metal-ceramic, special packages.

New, Low-cost, Hot Carrier Diode. 100 picosecond switching time. 70-volt breakdown. Low turn-on voltage at 410 mV at 1 mA. Ideal for subnanosecond switching and sampling applications. Has silicon temperature capabilities and turn-on equal to germanium. 55c in 1000 quantities.

Optoelectronic devices

PIN Photodiodes. Ultrafast light detectors for visible and near-infrared radiation. Unusually good response to blue and violet. Excellent dynamic range. Low noise. HP 5082-4200 series.

GaAs Infrared Sources. Radiates high-intensity, narrow band, infrared light. Well suited for use in card and tape readers, encoders and similar applications. HP 5082-4100 series.

Photon Coupled Isolators. A wide bandwidth DC coupling device combining a GaAs emitter and silicon PIN diode. Small, light-weight, rugged, and about half the price of electromagnetic transformers. Isolation up to 200 V dc. HP 5082-4300 series.

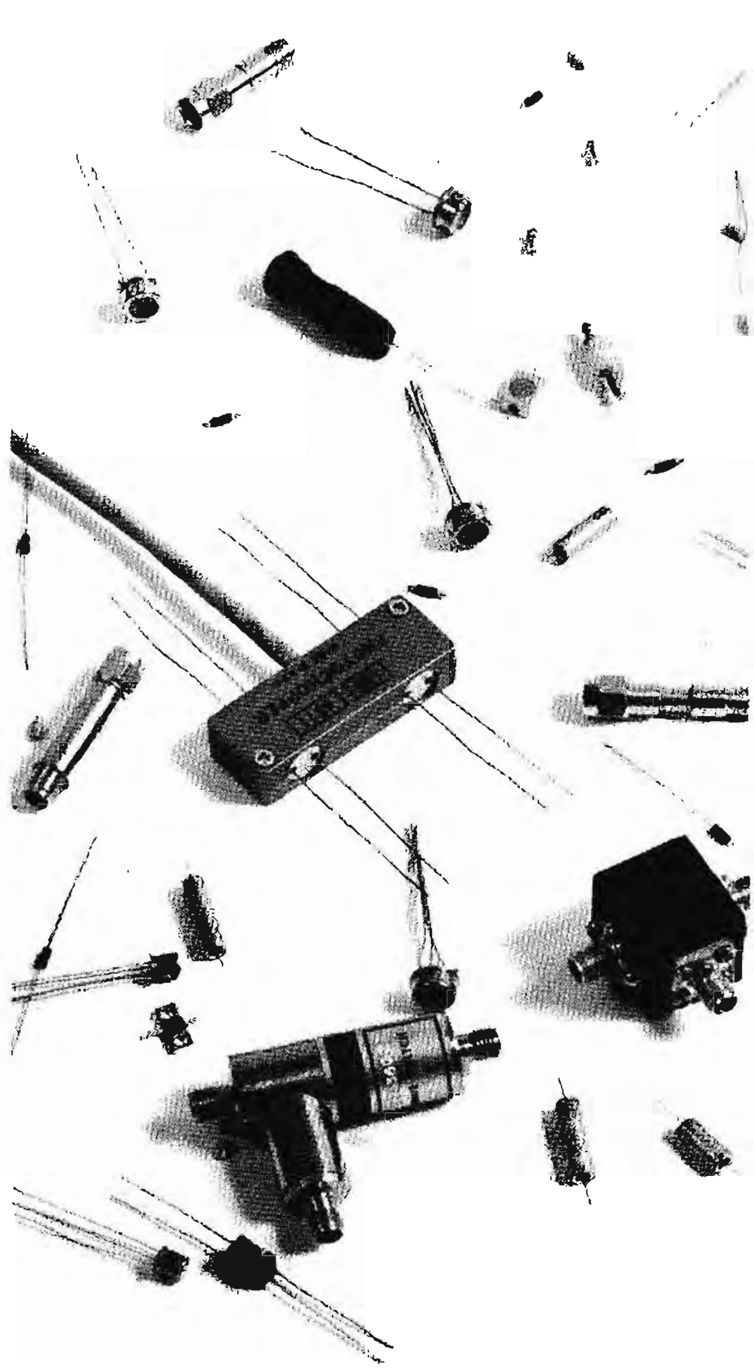
Solid State Visible Light Source. Compatible with integrated circuits. GaAs phosphide diodes offer long life, shock and vibration resistance. Free from catastrophic failure. Wide choice of package styles.

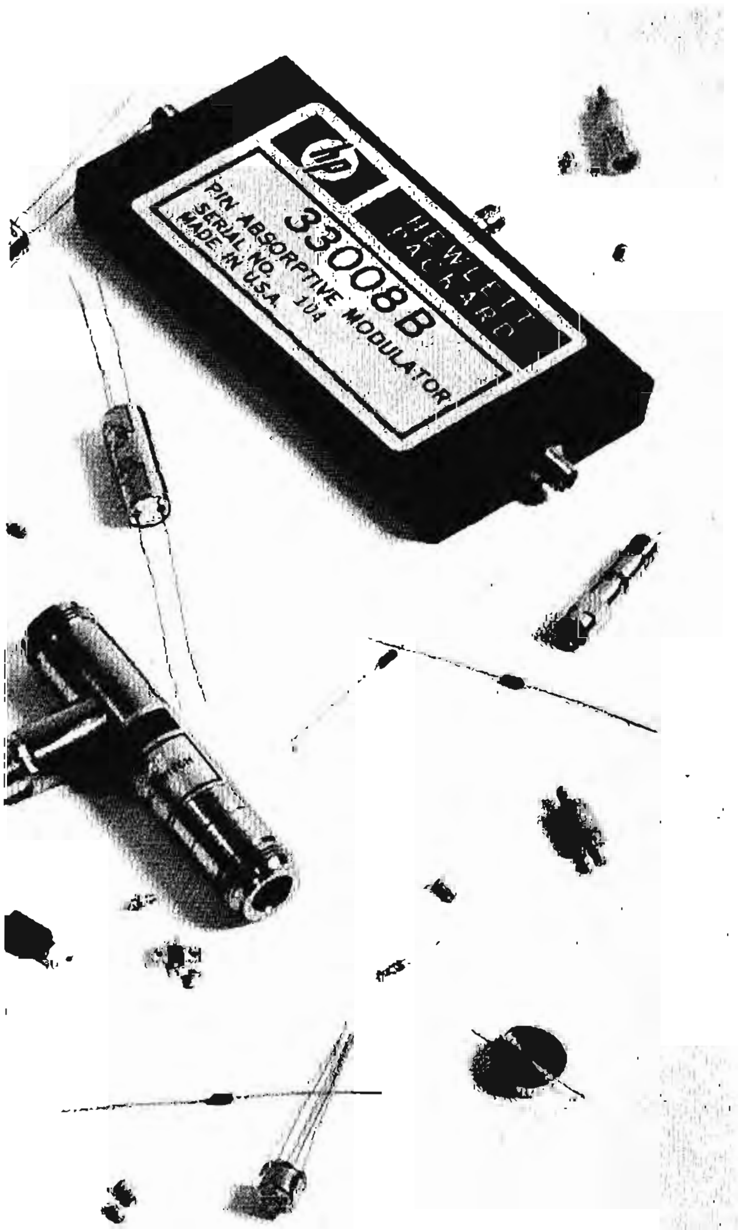
Solid state numeric displays

For information display where space and reliability are critical considerations. Combines advantages of very small size and brightness adequate for full daylight viewing. Switching logic circuit integral with display module. HP 5082-7000.

Ministrips, lids, beamleads, chips

Most of our conventional diode types are available now as chips or in ministrip, beamlead or LID configurations.





Photoconductor devices

Photocells. For switching, chopping and control circuit applications. Hermetically sealed packages. Stabilized and selected for long life, reliability. Several types available. HP 5082-4600 series.

Photocontrolled Resistors. Lamp/photocell combinations ideally suited for applications where single or multi-pole switching is required with high isolation between drive and signal circuits. Or for applications needing electrically controlled resistances.

Photochoppers. Four-cell (modulator/demodulator) and two-cell (modulator only) versions available for use with both high impedance or low impedance signal sources. Low noise and offset with high stability and efficiency. HP 5082-4511 series.

Microwave products

Solid State Switches. All the way from dc to 18 GHz. SPST or SPDT. Positive or negative. Stripline or coaxial. Reflective or absorptive. Fast or slow. MIL Spec. Any connector style. For ECM, Radar, Lab checkout, etc. HP 33500/600 series (SPST); HP 33006/7 (SPDT).

Limiter Modules. Operate between 400 MHz and 12.4 GHz. Typical SWR 1.5:1. Protect sensitive receiver elements against power surges. MIL spec. HP 33701/33711.

Pin Absorptive Modulators. Hybrid integrated. Combine broad bandwidth, wide dynamic range, low VSWR. For sweep generator leveling, receiver AGC, distance measuring systems. Phased array radar. MIL spec. HP 33000A/B; HP 33001A/B; HP 33008A/B.

Step Recovery Diodes & Modules. Complete, modular, shunt mode impulse circuits. Hermetically sealed. Contain all matching elements, driving inductance. Comb output useful for measuring spectral behavior of components, antennas, receivers, filters, etc. Also discrete diodes use tested and design optimized. MIL spec. HP 33002/3/4/5.

Mixer/Detectors, Diodes & Modules. Versatile modules designed as low-pass filters for use with broadband microwave equipment. ECM, reconnaisance receivers, test equipment, missile guidance systems. Discrete diodes from L through Ku Band. MIL spec. HP 33801A/B; 33802A/B; 33803A/B.

PIN Diodes. For modulating and switching microwave signals. High voltage, high speed, low intermodulation products. Surface-passivated for improved stability and reliability. MIL spec. Wide package option. HP 5082-3000 series.

Want more information?

Complete, detailed, product literature, application information and prices are as near as your phone. Call any Hewlett-Packard sales office for information or assistance. Or . . . write or call Hewlett-Packard, 620 Page Mill Road, Palo Alto, California 94304; (415) 321-8510.

. . . Ask for our catalog of solid state devices.

DOUBLE BALANCED MIXERS
High performance simplifies many design tasks
Models 10514A/B, 10534A/B/C

Advantages:

- Wide-band, low-noise, flat response
- Excellent balance of ports
- Low insertion loss
- Low intermodulation products
- Rugged, environmentally type-tested
- Models for printed circuit mounting
- Various connector options available

Uses:

- As a mixer for extracting the sum or difference of two frequencies with a high degree of carrier suppression which greatly reduces filter requirements
- As a phase detector with specified low-noise that permits phase or frequency stability measurements on the highest-quality signal sources
- As a suppressed carrier modulator with 45 dB typical carrier rejection at HF
- As a pulse modulator or spectrum generator with precise turn-on and turn-off characteristics
- As a current-controlled attenuator
- As a frequency doubler for very flat-response, low-noise frequency doubling

The double balanced mixers in this series offer an outstanding combination of high performance, versatility, and economy. These advantages are made possible by using specially developed transformers and carefully selected hot carrier diodes produced by Hewlett-Packard. The main differences between the five models are their frequency range and packaging, as detailed in the specifications.

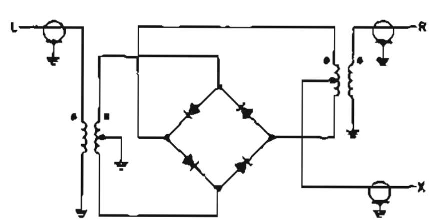
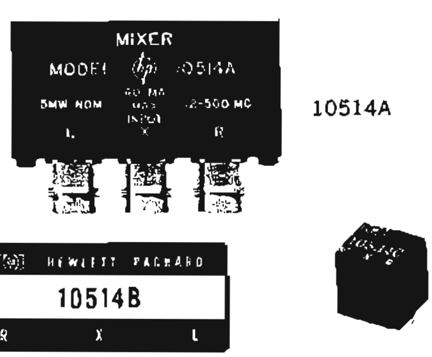


Figure 1. Ring modulator.



10514A

10514B

10534C

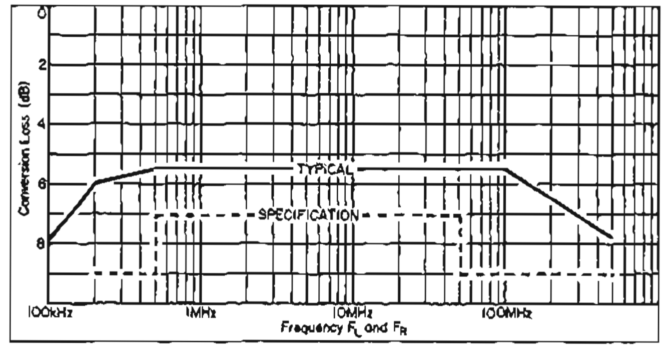


Figure 2. Typical conversion loss at 25°C. The lower frequency input f_L was at +7 dBm, the higher f_R at −3 dBm.

The newest mixer in this group is the 10534C, a miniature version of the 10534B. This tiny device has a base area of only 0.14 square inch to minimize circuit board space and for design and production convenience the leads are arranged the same as on flatpack integrated circuits.

Besides being mixers, these devices may be used as phase detectors, pulse and amplitude modulators, or current controlled attenuators. The function performed is determined by the connections made at the input-output ports (L, R, and X in Figure 1).

When used as a mixer, the inputs are connected at L and R while the output (sum and difference of input frequencies) is available at X. This function is widely used in receivers, tuned voltmeters, and wave analyzers. Figure 2 shows typical and specified values for conversion loss* in the 10514A and B. The noise specifications are identical to the conversion loss curves because excess noise contributed by the diodes is insignificant above 50 kHz.

As a current controlled attenuator the RF input is placed at L, the control signal at X, and the RF output at R. Attenuation is inversely proportional to the control current, as shown in Figure 3. Note the wide range of linear attenuation.

Amplitude and pulse modulation can be produced with almost the same connections as for the attenuator. Again L is the RF input and R the output, but now a modulating signal is inserted at X.

Operation as a phase detector is possible because the X port

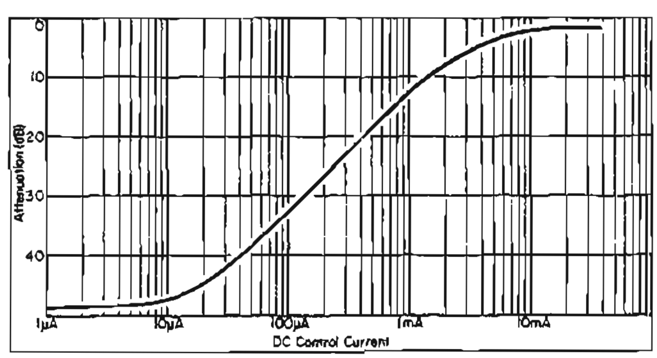


Figure 3. Typical attenuation at 25°C. L to R vs. DC "X" control.

is dc-coupled. With the same frequency at the R and L ports, the output at X will be a dc voltage. This output voltage will go to zero when the input signals are 90° out of phase; it will be a maximum at 0° and 180° phase difference.

Having a dc coupled port also makes possible the use of the mixers as balanced modulators in communication systems. The output modulation product of the L and X ports consists of sidebands displaced plus and minus the modulation frequency from the carrier with the carrier suppressed. Thus, it is possible to make an inexpensive and broadband two tone generator by combining the mixer with an audio and an RF signal source.

Optional connector of four types are available for the 10514A and 10534A for added versatility.

*Conversion loss is the power ratio (in dB) between the available input power at the *R port and one of the output sidebands, with 50Ω source and load impedances and +7 dBm input at L port.

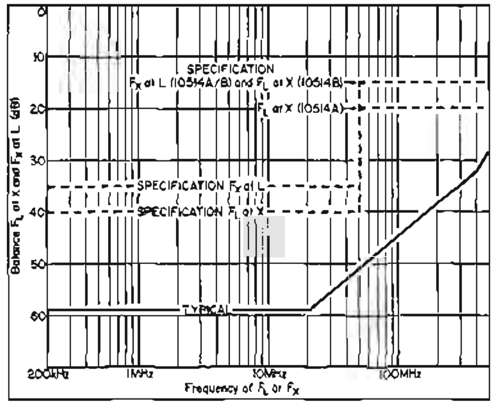


Figure 4. Typical balance at 25°C. f_L at X with f_L references f_R =4 at 0 dBm. f_L level +7 dBm.

Specifications, 10514A/B, 10534A/B/C

	10514A	10514B	10534A	10534B, 10534C
Input/output frequencies:	"L" and "R" ports: 200 kHz to 500 MHz; "X" port: dc to 500 MHz.		"L" and "R" ports: 50 kHz to 150 MHz; "X" port: dc to 150 MHz.	
Maximum input:	40 mA (damage level).		40 mA (damage level).	
Impedance:	Designed for and specified in 50Ω system.		Designed for and specified in a 50Ω system.	
Mixer conversion loss (single sideband):	7 dB max for f_L and f_R in the 500 kHz to 50 MHz range and f_X from dc to 50 MHz. 9 dB max for f_L and f_R in the 200 kHz to 500 MHz range and f_X from dc to 500 MHz.		6.5 dB max for f_L and f_R in the 200 kHz to 35 MHz range and f_X from dc to 35 MHz. 8.0 dB max for f_L and f_R in the 50 kHz to 150 MHz range and f_X from dc to 150 MHz.	
Noise performance (single sideband):	7 dB max noise figure for f_L and f_R in the 500 kHz to 50 MHz range and f_X in the 50 kHz to 50 MHz range. 9 dB max noise figure for f_L and f_R in the 200 kHz to 500 MHz range and f_X in the 50 kHz to 500 MHz range.		6.5 dB max noise figure for f_L and f_R in the 200 kHz to 35 MHz range and f_X in the 50 kHz to 35 MHz range. 8.0 dB max noise figure for f_L and f_R in the 100 kHz to 150 MHz range and f_X in the 50 kHz to 150 MHz range.	
Noise phase detector	Less than 100 nV per root cycle max at output for f_X at 10 Hz.		Less than 100 nV per root cycle max at output for f_X at 10 Hz.	
Typical conversion compression:	By f_R alone: 0.3 dB for 1 mW level. By f_{R2} signal presence interfering with f_{R1} signal: 1 dB for f_{R2} level of 1 mW; 10 dB for f_{R2} level of 10 mW.		By f_R alone: 0.3 dB for 1 mW level. By f_{R2} signal presence interfering with f_{R1} signal: 1 dB for f_{R2} level of 1 mW, 10 dB for f_{R2} level of 10 mW (f_L level at 5 mW).	
Intermodulation:	Typical intermodulation product production with f_L level of 5 mW and f_R at 70 mV.		Typical intermodulation product production with f_L level of 5 mW *and* f_R *at 70 mV.* f_R = *21* MHz and f_R = 20 MHz.	
Typical pulse modulator performance (pulse input "X" port, output at "R"):	**Rise or fall times:** 1 nanosecond. **Pulse width:** no restriction. **On-off ratio:** 35 dB. **Saturation pulse amplitude:** 10 mA with f_L = 5 mW. **Maximum input:** 40 mA (damage level.) **Modulation source:** *either + or − polarity turns switch on;* amplitude between pulses, within 2 mV of 0 V. **Linearity:** output is linear over a 30 dB range at 500 MHz; better at lower frequencies.		**Rise or fall times:** 2 nanoseconds. **Pulse width:** no restriction. **On-off ratio:** 35 dB. **Saturation pulse amplitude:** 10 mA with f_L = 5 mW. **Maximum input:** 40 mA (damage level.) **Modulation source:** *either + or − polarity turns switch on;* amplitude between pulses, within 2 mV of 0 V. **Linearity:** output is linear over a 30 dB input current range at 150 MHz; better at lower frequencies.	

Intermodulation, 10514A/B:

Product	Level*	Product	Level*
$2f_L - f_R$	30 dB	$2f_R - f_L$	65 dB
$3f_L - 2f_R$	70 dB	$3f_R - 2f_L$	65 dB
$4f_L - 3f_R$	70 dB	$4f_R - 3f_L$	85 dB
$5f_L - 4f_R$	90 dB	$5f_R - 4f_L$	90 dB
$6f_L - 5f_R$	95 dB	$6f_R - 5f_L$	100 dB
$7f_L - 6f_R$	100 dB	$7f_R - 6f_L$	100 dB

*Referred to f_X level.

Intermodulation, 10534A/B/C:

Product	Level*	Product	Level*
$2f_L - f_R$	40 dB	$2f_R - f_L$	65 dB
$3f_L - 2f_R$	65 dB	$3f_R - 2f_L$	65 dB
$4f_L - 3f_R$	65 dB	$4f_R - 3f_L$	90 dB
$5f_L - 4f_R$	85 dB	$5f_R - 4f_L$	90 dB
$6f_L - 5f_R$	90 dB	$6f_R - 5f_L$	95 dB
$7f_L - 6f_R$	95 dB	$7f_R - 6f_L$	95 dB

*Referred to f_X level.

High performance simplifies many design tasks
Models 10514A, B; 10534A, B, C

Mixer balance:

10514A

Mixer Balance for	In Frequency Ranges (MHz): f_L, f_R: 0.5–50, f_X: dc–50	In Frequency Ranges (MHz): f_L, f_R: 0.2–500, f_X: dc–500	Referenced to
f_L at R	40 dB	30 dB	f_L
f_L at X	40 dB	20 dB	f_L
f_R at L	45 dB	30 dB	f_R
f_R at X	25 dB	15 dB	f_R
f_X at L	35 dB	15 dB	f_X
f_X at R	25 dB	15 dB	f_X

10534A, B

Mixer Balance for	In Frequency Ranges (MHz): f_L, f_R: 0.05–35, f_X: dc–35	In Frequency Ranges (MHz): f_L, f_R: 0.035–150, f_X: dc–150	Referenced to
f_L at R	40 dB	30 dB	f_L
f_L at X	35 dB	20 dB	f_L
f_R at L	40 dB	30 dB	f_R
f_R at X	20 dB	15 dB	f_R
f_X at L	35 dB	20 dB	f_X
f_X at R	20 dB	12 dB	f_X

10514B

Mixer Balance for	In Frequency Ranges (MHz): f_L, f_R: 0.5–50, f_X: dc–50	In Frequency Ranges (MHz): f_L, f_R: 0.2–500, f_X: dc–500	Referenced to
f_L at R	40 dB	25 dB	f_L
f_L at X	40 dB	15 dB	f_L
f_R at L	45 dB	25 dB	f_R
f_R at X	25 dB	15 dB	f_R
f_X at L	35 dB	15 dB	f_X
f_X at R	25 dB	15 dB	f_X

10534C

Mixer Balance for	In Frequency Ranges (MHz): f_L, f_R: 0.05–35, f_X: dc–35	In Frequency Ranges (MHz): f_L, f_R: 0.035–150, f_X: dc–150	Referenced to
f_L at R	35 dB	25 dB	f_L
f_L at X	35 dB	25 dB	f_L
f_R at L	35 dB	25 dB	f_R
f_R at X	20 dB	15 dB	f_R
f_X at L	35 dB	25 dB	f_X
f_X at R	20 dB	12 dB	f_X

	10514A	10514B	10534A	10534B
Connectors:	Female BNC.	0.040-inch pins for printed circuit board mounting.	Female BNC.	10534B: 0.40 inch pins 10534C: 0.009×0.020 inch leads
Environmental:	Mixer has been type tested to meet its specifications over −20°C to + 65°C and through five cycles of 40°C and 95% humidity. Compliance with the rigid MIL-I-6181D RFI specification has been demonstrated. Non-operating tests include −40°C to + 75°C exposure, 0.060 inch peak-to-peak vibration at 55 Hz, 4-inch bench drop, and altitude to 25,000 feet.	Type tested to meet environmental specifications of MIL-E-16400F Class 1; MIL-T-21200 Class 1; and MIL-5400D Class 2. Conditions include: non-operating temp −54°C to + 75°C; humidity 95% at + 60°C; vibration to 500 Hz = 10 g's; shock simulated hammer test 1500 g's; operating altitude 50,000 feet. The 10514B is not designed to meet RFI requirements since it is intended for use on printed circuits.	Mixer has been type tested to meet its specifications over −20°C to + 65°C and through five cycles of 40°C and 95% humidity. Compliance with the rigid MIL-I-6181D RFI specification has been demonstrated. Non-operating tests include −40°C to + 75°C exposure, 0.060 inch+ peak-to-peak vibration to 55 Hz, 4-inch bench drop, and altitude to 25,000 feet.	Type tested to meet environmental specifications of MIL-E-16400F Class 1; MIL-T-21200 Class 1; and MIL-5400D Class 2. Conditions include: nonoperating temp −62°C to + 85°C; operating temp −54°C to + 75°C; humidity 95% at 65°C; vibration to 500 Hz to 10 g's; shock simulated hammer test 1500 g's; operating altitude 50,000 feet. The 10534B is not designed to meet RFI requirements since its intended use is on printed circuits.
Lead temperature (during soldering):	Does not apply.	265°C (509°F) max at distances greater than 1/32 inch from seating surface for 10 seconds max.	Does not apply.	265°C (509°F) max at distances greater than 1/32 inch from seating surface for 10 seconds max.
Dimensions:	2.3 in x 0.6 in x 1.7 in (59 x 15 x 43 mm).	1.63 in L x 0.70 in W x 0.43 in H seated (0.63 in H with pins).	2.3 in x 0.6 in x 1.7 in (59 x 15 x 43 mm).	10534B: 1.63" long x 0.70" wide x 0.43" high seated (0.63" high with pins). 10534C: 0.40" long x 0.35" wide x 0.40" high.
Weight:	2.1 oz (59 grams).	0.5 oz (14 grams).	2.1 oz (59 grams).	10534B: 0.5 oz (14 grams). 10534C: 0.053 oz (1,5 grams).
Price: *1 - 4 5 - 9 10 - 24	$95 85 78	$65 65 55	$70 63 58	10534B: $50, 50, 40 10534C: $60, 60, 50
Options	Option 01, TNC connectors, add $5. Option 02, OSM No. 211 connectors, add $25. Option 03, Sealectro screw-on No. 50-043-0000, add $5. Option 04, Sealectro snap-on No. 51-043-0000, add $5.		Option 01, TNC connectors, add $5. Option 02, OSM No. 211 connectors, add $25. Option 03, Sealectro screw-on No. 50-043-0000, add $5. Option 04, Sealectro snap-on No. 51-043-0000, add $5.	

*Contact Hewlett-Packard for prices of larger quantities.

TRANSISTOR CHIPS, AMPLIFIERS

Guaranteed high frequency characteristics

35000, 35800 Series

Small, reliable system components

Hewlett-Packard's search for ultra-reliable instrument components has led to the development of the 35800 family of transistor chips and the 35000 series of hybrid integrated circuits. The 35800 devices are planar, NPN transistors optimized for linear high frequency and microwave applications to 6 GHz. The 35000 series of microcircuits includes a family of amplifiers constructed from vacuum-deposited layers of metals and metal oxides and the microwave transistors mentioned above. Transistors and amplifiers utilize materials and processes selected to ensure long life and stable performance characteristics. The result is a new family of components with attractive features for systems where performance, size, and reliability are important considerations.

Technology

In the course of developing ultra-reliable microwave transistors and microcircuits, many new advances in processing techniques were implemented. A gold contact system was developed to provide very reliable connections to the base and emitter regions of the microwave transistors. This contact system also permits high-temperature assembly techniques (400°C) without the detrimental oxidation that occurs with aluminum contacts. The majority of the passive components of the microcircuits use tantalum-based thin films. Unique processing techniques provide both capacitors and resistors that are stable to 400°C for maximum reliability and performance stability.

Transistors with guaranteed high frequency characteristics

For the first time in the history of the solid state components industry, the microwave parameters of unpackaged transistors are guaranteed by complete testing of every device. Measuring the reflection and transmission coefficients that the transistor produces in a 50Ω system (i.e. the microwave scattering parameters, see p. 465) determines the device's performance in any linear circuit. For a slight additional charge, the measured data for each device can be supplied at a variety of bias points and frequencies from 500 MHz to 6 GHz.

High performance microcircuit amplifiers

The 35000 series of hybrid integrated amplifiers covers the frequency range from 10 kHz to 2 GHz, providing gain up to 40 dB and output power levels up to 200 mW. These amplifiers are well-suited to applications such as broadband IF's in radar and telecommunication receivers; RF distribution systems such as community antenna television and studio-transmitter links; and preamplification in radionavigation, telemetry, radar, and radio astronomy receivers. They are also useful for increasing the output of low-power signal generators and frequency synthesizers, as well as increasing the sensitivity of oscilloscopes, voltmeters, and other high frequency measuring instruments. For further information, contact a Hewlett-Packard Sales Office.

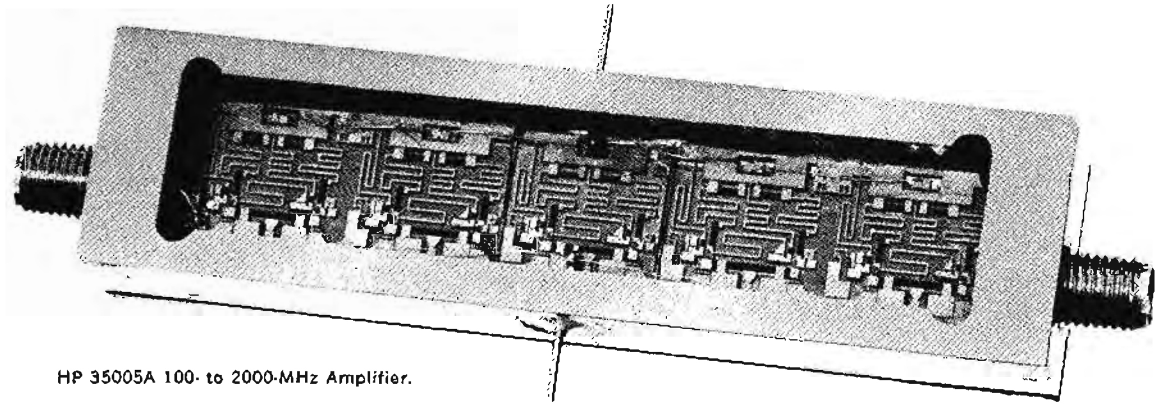
Characteristics

Transistor chips

Device Type	Typical characteristics					Wide Band Applications
			$\lvert S_{fe} \rvert^2$			
	f_{max} (GHz)	f_t (GHz)	1 GHz (dB)	2 GHz (dB)	3 GHz (dB)	
35800A	6.0	4.0	–	5.2	2.0	Osc.–Ampl.
35801A	4.3	3.5	–	3.3	–	Osc.–Ampl.
35802A	3.0	3.0	5.2	–	–	Osc.–Linear Ampl.

Hybrid integrated amplifiers

Device Type	Frequency Range	Gain (dB)	Output Level (1 dB Gain Comp.)	Package/ Connectors
35000A	0.1–100 MHz	30	+5 dBm	Flat Plug-In
35001A	0.1–100 MHz	20	+19 dBm	Flat Plug In
35002A	0.01–400 MHz	20	+7 dBm	OSM
35003A	0.01–400 MHz	20	+23 dBm	OSM
35004A	0.01–1.3 GHz	25	+16 dBm	OSM
35005A	0.1–2.0 GHz	40	+16 dBm	OSM



HP 35005A 100- to 2000-MHz Amplifier.

BASIC INSTRUMENTS FOR MICROWAVE MEASUREMENTS

Hewlett-Packard offers a complete line of microwave test equipment from which systems can be assembled for making accurate reflection, transmission, frequency and power measurements. Measurement techniques and equipment functions are discussed briefly in the following paragraphs. More detailed information is available in Application Notes 64, 65, and 84, complimentary copies of which are available from Hewlett-Packard sales offices.

Impedance measurements

Impedance-matching a load to its source is one of the most important considerations in microwave transmission systems. If the load and source are mis-matched, part of the power is reflected back along the transmission line toward the source. This reflection not only prevents maximum power transfer, but also can be responsible for erroneous measurements of other parameters or even cause circuit damage in high-power applications.

The power reflected from the load interferes with the incident (forward) power, causing standing waves of voltage and current along the line. The ratio of standing-wave maxima to minima is directly related to the impedance mis-match of the load. The standing-wave ratio (SWR), therefore, provides a valuable means of determining impedance and mis-match.

Slotted line techniques

Standing-wave ratio can be measured directly with a slotted line in a setup like the one shown in Figure 1. The slotted

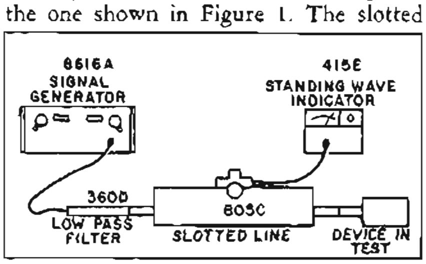


Figure 1. Typical setup for SWR and impedance measurements in coax using HP 805C Slotted Line.

line is placed immediately ahead of the load in test, and the source is adjusted for 1-kHz amplitude modulation at the desired microwave frequency. The slotted line probe is loosely coupled to the RF field in the line, thus sensing relative amplitudes of the standing-wave pattern as the probe is moved along the line. The ratio of maxima to minima (SWR) is displayed directly on the SWR meter.

While this method works very well for single-frequency testing, it is very time-consuming for broadband applications. The number of discrete measurements necessary to ensure complete coverage across a frequency range is determined by the degree of confidence required that a sharp resonance or hole does not exist, and for a high confidence factor, the number of measurements must be very high.

The solution to broadband measurements is the swept-frequency technique. This method provides continuous coverage across the frequency range of interest. Measurements of SWR of coaxial devices operating below about 2 GHz and of waveguide devices is accomplished with the reflectometer (Figure 3). However, the low directivity of coaxial directional couplers operating above 2 GHz seriously limits accuracy in coax at these higher frequencies.

The swept slotted line

A measuring system which combines the speed and convenience of swept-frequency measurements and the inherent accuracy of the slotted line can be built around the 817A Slotted Line System (page 282). The 817A consists of an 816A Coaxial Slotted Line, 809C Carriage and 448A Slotted Line Sweep Adapter and can be used throughout the range from 1.8 to 18 GHz. The signal source is a sweep oscillator and the read-out device is an oscilloscope.

The measurement technique is much the same as for fixed-frequency measurements. A detecting probe is moved along the slotted line a distance of at least one half wavelength at the lowest frequency so that both maximum and minimum voltages of the standing waves are sampled. However, instead of the plot being a single vertical line, which would be the case in a fixed-frequency measurement, it is a smear or envelope as shown in Figure 2. At any given frequency, the ratio of the maximum and minimum amplitude of the envelope is the SWR.

Measurement of low SWR requires sensitive readout devices to resolve the maxima and minima adequately. Therefore, the signal source must be leveled

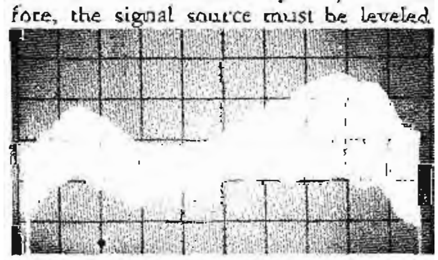


Figure 2. Multi-sweep slotted-line measurement. Vertical scale 0.5 dB/cm (SWR = 1.12/cm).

to keep the entire plot on scale. The 448A, comprising a slotted section and two matched detectors, effectively levels the sweeper output and monitors the standing waves in the 816A Slotted Line. No additional probe is required for the 816A.

A storage oscilloscope such as the HP 141A is ideal for these measurements. A plot of SWR can be generated in a few seconds and retained on the CRT for evaluation or photography. Time-exposure photography and a conventional oscilloscope such as the HP 140A can also be used. The HP 1416A Swept-Frequency Indicator, a plug-in for both the 140A and 141A Oscilloscopes, provides additional convenience with its logarithmic calibration. No zero-level reference is needed, and SWR is indicated directly in dB when the detector is operated in its square-law region. An X-Y recorder such as the Moseley 7035B can also be used to plot measurements.

Accuracy of slotted-line measurements is limited primarily by the residual SWR of the line itself, 1.01 in waveguide and 1.02 to 1.06 in coax depending upon the frequency and type of connector. However, there are other considerations. Penetration of the detector probe into the line should be kept to a minimum to prevent standing waves due to the probe itself. Elimination of harmonics from the signal source is also important. HP 360, 362, and 8430 filters are excellent for this purpose.

Reflectometer techniques

The reflection coefficient (ρ) of a device or system is another useful term in establishing the impedance match of microwave devices. The following relationships of ρ and SWR are frequently used in impedance work:

$$|\rho| = \frac{E_{reflected}}{E_{incident}} = \frac{SWR - 1}{SWR + 1}.$$

The amplitude of reflected voltage with respect to the incident voltage is given in terms of dB *return loss* by the expression: dB = $-20 \log_{10}|\rho|$. For example, if the reflected signal from a test device is 26 dB below the incident signal level, the reflection coefficient of the device is calculated as 0.05. In a like manner, any reflection coefficient from zero to one can be determined by a measure of the return loss.

The reflection coefficient of a load can be measured by separating the incident and reflected waves propagated in the transmission line connecting the source and load. The reflectometer uses directional couplers to accomplish this separation in both waveguide and coaxial systems. Reflectometers permit continuous oscilloscope displays or permanent X-Y recordings of reflection coefficient across complete operating bands.

Incident power in the improved reflectometer is held constant by the leveling action of the sweep oscillator and crystal detector sampling the incident wave from the forward coupler. With incident power held constant, only the relative amplitude of the reflected wave need be measured to determine reflection coefficient. This technique permits better accuracy than older systems, and fast sweep speeds enabling the use of oscilloscope displays. See Figure 3.

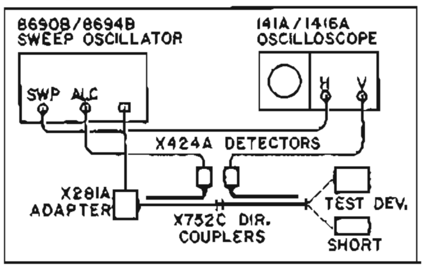


Figure 3. Typical Waveguide Reflectometer.

Reflectometer calibration

To calibrate the reflectometer, a short circuit is placed at the output port, thus reflecting all of the incident power. The detector in the reverse-arm coupler samples the reflected power and provides a proportional dc voltage for readout. By placing a calibrated attenuator ahead of the detector, specific amounts of return loss may be pre-inserted for calibration of the oscilloscope or recorder gain. The attenuator is then returned to zero, the short removed and the test device connected and measured on the pre-calibrated display.

Calibration also is possible without the pre-insertion attenuator if the detector law is known and the vertical response of the readout device is constant. Calibration levels with this technique are established with the RF turned off (corresponding to no reflection), then with all of the power reflected by a sliding short. Reflections falling between these limits are then read from the oscilloscope graticule or directly from calibrated transparent overlays such as furnished with Hewlett-Packard Application Note 65. The HP 140A Oscilloscope with its 1416A plug-in eliminates the need for overlays. With logarithmic calibration, the 140A/1416A provides return loss directly in dB.

Reflectometer calculator

Time-consuming calculations of return loss and conversion of ρ to SWR may be eliminated by using an Hewlett-Packard Reflectometer Calculator. This slide-rule-type aid provides continuous scales of ρ, SWR and return loss, which may be positioned under a cursor for instant conversion of terms. Other useful information such as ambiguity in reflectometer measurements, mismatch loss and phase and amplitude mismatch errors are included on the calculator. It may be obtained from your Hewlett-Packard field engineer upon request.

Reflectometer accuracy

The overall measurement accuracy of leveled reflectometer systems such as described here may be closely approximated by considering the various sources of error separately, then taking the rms average. These errors may be classified as being due to imperfect components comprising the reflectometer as follows:

1) directional couplers
2) detectors
3) attenuator used in calibration
4) display or readout instrument.

One of the primary errors introduced by directional couplers is the directivity signal. Directivity of a coupler refers to its ability to distinguish between forward and reverse power flowing in the main arm. Since reflectometry is based on the separation of incident and reflected power by use of the directional couplers, high directivity is essential to accurate measurements. Any incident power passing to the reverse coupler auxiliary output (because of imperfect directivity) will add in unknown phase with the actual *reflected* signal from the load in test. The result is an ambiguity in the voltage level at the reverse coupler output. The ambiguity caused by reverse coupler directivity can be determined in terms of reflection coefficient by substituting the directivity (in dB) into the return loss equation given earlier. Thus, for a reverse coupler directivity of 40 dB, the ambiguity in ρ is ± 0.01.

The ambiguity caused by the *forward* coupler directivity also must be considered, particularly when measuring large reflections. If directivity is not infinite, part of the signal reflected from the test load will appear at the auxiliary arm output of the forward coupler. This directivity signal adds vectorially with the incident signal, producing an ambiguity in the incident power level. The ambiguity is proportional to the magnitude of load reflection and forward coupler directivity and may be calculated as follows:

$$\Delta \rho = \pm\rho \left(\log^{-1}\frac{dB}{20}\right)$$

where dB = coupler directivity
ρ = reflection coefficient of test load.

Primary factors to be considered in the detectors are frequency response, deviation from square law and mismatch. Using HP 423A or 424A Crystal Detectors, frequency response is typically flat to within ± 0.2 dB per octave and deviation from square law less than ± 0.2 dB over a 20 dB dynamic range. These two errors can be evaluated in terms of reflection coefficient ambiguity by alternately adding and subtracting the dB value to the return loss actually measured. The errors caused by these two factors can be eliminated by using the pre-insertion attenuator for initial system calibration. Error due to mismatch between HP 752 Waveguide Couplers and 424A Detectors is typically less than $\pm 3\%$ of the ρ measured. This includes the total effects of detector mismatch in the incident coupler used for leveling feedback and the reverse arm measuring reflected voltage from the load.

The use of a pre-insertion attenuator for calibration eliminates some detector errors but introduces error of its own. The dial accuracy of the attenuator and mismatch considerations lead to the following expression for the error introduced in the measured reflection coefficient:

$$\Delta \rho = \rho\,(1 - \rho^{\pm 0.02} \pm 0.015)$$

where ρ = reflection coefficient of the test load.

When the attenuator is not used for calibration, the readout or display device causes error in the measured ρ. The effects of nonlinearity, instability and resolution are factors which must be considered. When using HP 130C or 140A Oscilloscopes for measuring small ratios (≈ 1), accuracies of 2% are reasonable. Ratios of 30 dB ($\rho \approx 0.03$) can be determined with about 4% accuracy.

The total effects of these errors can be conservatively estimated with the following equations:

1. Using the 382A attenuator pre-insertion technique, $\Delta\rho = \pm(0.01 + 0.05\rho)$.
2. Using the straightforward oscilloscope technique, $\Delta\rho = \pm(0.011 + 0.04\rho)$.

A more complete discussion and error analysis of reflectometer systems is in-

ATTENUATION MEASUREMENTS

cluded in Hewlett-Packard Application Note 65, "Swept Frequency Techniques."

Attenuation measurements

Attenuation is defined as the decrease in power (at the load) caused by inserting a device between a Z_o source and load. Under this condition, the measured value is a property of the device alone so that this is the "ideal system" in which to make measurements. The term Z_o is used to describe a unity SWR condition where the load and source impedances equal the transmission line impedance.

There are three common methods for measuring RF attenuation: 1) square-law detection with audio substitution, 2) linear detection with IF substitution, and 3) direct RF substitution using attenuators calibrated by either of the first two methods. Accurate square-law measurements over a range of 30 dB in a single step are possible using modern crystal detectors such as the HP 423A coaxial, and 424A waveguide series. With partial RF substitution this range can be extended to about 45 or 50 dB. With direct RF substitution a 45 or 50 dB range is possible using the same detectors without square-law loading. The 423A and 424A detectors are well suited to swept-frequency attenuation tests with either method 1) or method 3) above because of their flat frequency response and low reflection coefficient.

A number of factors affect the range and accuracy of attenuation measurements, each of which must be evaluated for the particular method being used. The measuring system must have low source and load reflections to minimize mismatch error. Pads or isolators can be used to minimize source mismatch, but closed loop leveling is more effective. By leveling the output power of the source at the point of measurement, source impedance is effectively maintained close to Z_o. With this technique, impedance variations in intervening cables, connectors, and adapters are effectively eliminated since they are within the leveling loop.

Low reflection from the readout crystal detector is important for reducing mismatch error at the load in the measurement system. All Hewlett-Packard detectors are swept-frequency tested to assure low reflection through their frequency ranges.

Square-law detection technique

Figure 4 shows a waveguide system for swept attenuation measurements of 30 to 40 dB. Source power is leveled using a

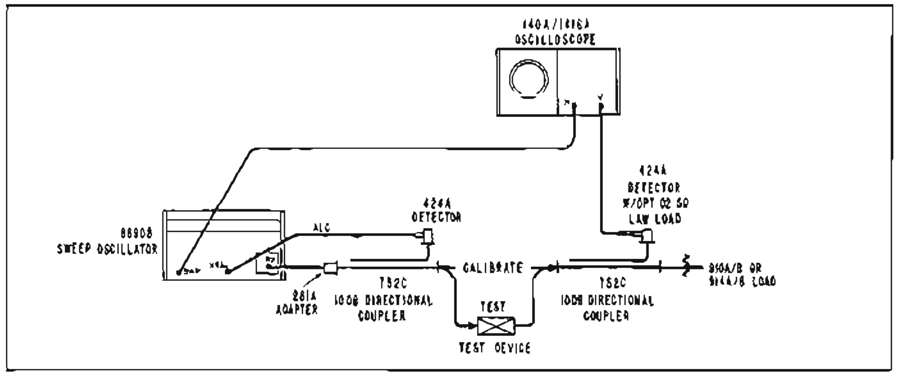


Figure 4. Swept attenuation system for measurements up to 40 dB with oscilloscope.

single 752-series 10-dB directional coupler in the ALC loop. Coupling variation versus frequency in the leveling loop causes leveled power variation of about 1 dB at the point of test device insertion. This power variation is nearly equal to, but opposite, the coupling variation of the readout coupler. The net variation in readout calibration is therefore mutually compensated to within about 0.3 dB in X-band, depending primarily on coupler tracking.

With the 8690B sweeping the frequency range of interest, a zero-dB reference level is established on the oscilloscope without the test device in the system. The device is then inserted as indicated in Figure 4 and its attenuation versus frequency determined by the amplitude decrease from the CRT reference level previously established.

Oscilloscope readout of attenuation measurements is especially useful for viewing broadband performance of test devices while adjustments are being made, or for rapid testing applications.

Figure 5 shows a typical coaxial sys-

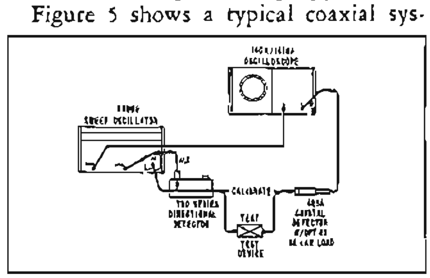


Figure 5. Typical Coaxial Setup for Square-Law Attenuation Measurement.

tem for measuring attenuation by square-law detection. The procedure and dynamic range are the same as for the waveguide system. In the 0.96- to 12.4-GHz range the HP 780 series directional detectors are a convenient means of deriving a leveling signal for the sweep oscillator.

RF substitution technique

Swept attenuation measurements up to 45 or 50 dB can be made using the RF pre-insertion, X-Y recorder system shown in Figure 6. The leveling arrangement is identical to that shown in Figure 4, but coupler tracking and detector errors are eliminated by plotting a calibration grid on the X-Y recorder prior to the actual measurement. In addition to being leveled, the sweeper is internally amplitude-modulated at 1 kHz to drive the 415E SWR Meter. The 415E, after amplifying the 1-kHz signal, feeds a proportional dc voltage to the recorder Y-input. The dc sweep voltage from the 8690B drives the recorder X-input directly.

Calibration lines are plotted by setting in specific values of attenuation on the 382A near the anticipated test device attenuation and triggering single 30-second sweeps. The 382A is then set to 0 dB and the test device inserted as shown in Figure 6. A final sweep is triggered and attenuation of the test device plotted over the calibration grid.

The system does not rely on square-law performance in the readout detector because of the calibration grid plotted with known attenuation levels set by the 382A. For this reason, the option 02 square-law load is not connected to the 424A readout detector and higher sensitivity is obtained.

IF substitution technique

The IF substitution technique of attenuation measurement involves conversion of the microwave frequency to a constant, much lower frequency for which very accurately calibrated attenuators are available. These are the principles used in the HP 8405A Vector Voltmeter and HP 8410A Network Analyzer. With the vector voltmeter, accurate attenuation measurements can be made

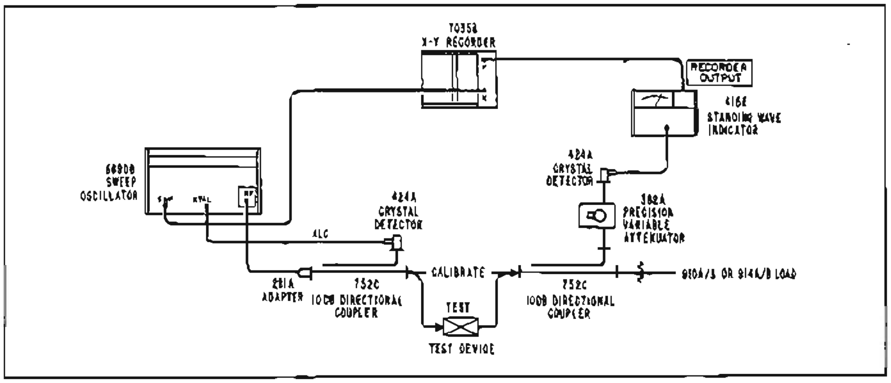


Figure 6. RF pre-insertion technique for swept attenuation measurements.

over more than 90 dB from 1 to 1000 MHz. The 8410A Network Analyzer has a range of more than 60 dB from 0.1 to 12.4 GHz. For more information about these instruments see the Network Analyzer section of this catalog.

Frequency measurements

There are two general classes of frequency measuring devices—active and passive types. Electronic counters, transfer oscillators, and frequency converters are examples of active types. These instruments measure frequency well into the microwave region with accuracies of a few parts in 10^6. More information about active frequency-measuring instruments is contained in the frequency section of this catalog.

Where the accuracy of active devices is not required, passive devices offer direct readout at a considerable saving in cost. Passive transmission-type frequency meters, such as the HP 532, 536A, and 537A, are two-port devices that absorb part of the input power in a tunable cavity. When the cavity is tuned to resonance, a dip occurs in the transmitted power level. This dip can be observed on a meter or oscilloscope display of the detected RF voltage. Frequency is then read from a calibrated dial driven by the cavity tuning mechanism.

The accuracy of cavity frequency meters depends upon the cavity Q, dial calibration, backlash, and effects of temperature and humidity variations. The Hewlett-Packard waveguide and coaxial passive frequency meters achieve accuries of a few parts in 10^4.

Instrumentation

Hewlett-Packard offers a broad line of the coaxial and waveguide accessories required in the measurement of impedance, attenuation, frequency, and other microwave characteristics. Included in the line are directional couplers, thermistor mounts for power meters, frequency meters, slotted lines, detectors, pads, loads, filters, adapters, and other devices and accessories useful in microwave measurements. This instrumentation is tabulated on the following pages for quick and easy reference. Frequency ranges and the page on which each item is described in detail are included in the tables. In the case of waveguide equipment, typical measurement setups are shown with the tables. In general, the setup shown for one band can be duplicated in other bands.

Slotted lines

Slotted lines covering the coaxial and waveguide frequency ranges are available for SWR measurements. Residual SWR is minimal for highest measurement accuracy. Hewlett-Packard SWR meters, probes, and detectors complete the SWR measurement setup.

For coaxial systems, the 817A permits the slotted line technique to be used for swept SWR measurements. This method presents SWR versus frequency directly on an oscilloscope. High measurement accuracy is attainable due to the low residual SWR of the slotted line.

Directional couplers

Hewlett-Packard offers both coaxial and waveguide directional couplers. Coaxial couplers are available in single and dual styles in the 770 and 780 series. The coupler-detector combination of the 780 series gives improved performance to sweep oscillator leveling applications. In the 770 and 780 series, the new 779D and the 778D are high performance, multi-octave couplers that bring convenience and economy to broadband applications.

In waveguide couplers, the 752 series covers the spectrum from 2.6 to 40 GHz in full band models. Available with coupling of 3, 10, or 20 dB, these units are swept-tested for both coupling and directivity. Directivity in most cases exceeds the 40-dB specification by a substantial margin; however, on special order, couplers can be selected to exceed the directivity specification in a particular frequency range. Coupling attenuation is tabulated and supplied with each 752.

Detectors

The 423A, 8470A, and 8472A coaxial crystal detectors, and the 424A series of waveguide detectors, offer the optimum in detectors for swept SWR and attenuation measurements. These detectors are ideal for sweep oscillator leveling applications because of their flat frequency response. Also, the flat frequency response of the individual detector eliminates the need for matched pairs in most applications. Where extremely closely matched frequency response is required, selected pairs can be provided.

Attenuators

Attenuators for a wide variety of functions in microwave measurements are available in both coaxial and waveguide versions. For coaxial systems, the 8490-series provides tested, economical, high-performance fixed attenuators that cover dc to 18 GHz. These attenuators are available in 3-, 6-, 10-, 20-, 30-, 40-, 50-, and 60-dB versions with a choice of Type N, APC-7 and miniature connectors. The 354A is a 0- to 60-dB, dc to 12.4 GHz coaxial step attenuator that uses the simple, effective principles of the fixed attenuators.

Waveguide attenuators are available in the 375 series of utility variable flap attenuators and the 382 series of precision rotary vane attenuators. The 375 series is useful for controlling power applied to a system or for padding source mismatch, and the 382 attenuators with their accurate calibration and wide range are valuable in calibration and for comparative measurements.

Waveguide construction

Many Hewlett-Packard waveguide instruments are made of die-cast aluminum to attain maximum dimensional and production stability. A broaching technique for cutting the internal waveguide dimensions to very close tolerances can be used on die-cast aluminum. A broach is a long cutting bar similar to a file that is pulled through the casting to cut the interior surfaces. The linear cutting stroke of the broach eliminates minor surface irregularities resulting from use of the milling process. Whereas typical tolerance of milled waveguide tubing is

±.003 inch, precision broaching allows internal dimensions to be controlled to ±.001 inch or less.

The broaching process is very important for instruments such as slotted lines, high directivity directional couplers, sliding loads, and sliding shorts. Smaller tolerances on internal waveguide dimensions provide low SWR so maximum accuracy can be obtained in waveguide setups.

Flanges

Each flange of a waveguide instrument is machine lapped after initial sanding belt surface preparation. This process, in addition to ensuring smooth surfaces to obtain the best possible mating, provides a slightly convex surface so that only the innermost area of the mating flanges makes contact. Thus, the tightest possible connection is made between waveguide instruments with the result that leakage is minimized.

Power measurements

Power measurements are basic at microwave frequencies. Unlike voltage and current levels along a transmission line, microwave power remains constant with position of measurement in a lossless line and can easily be related to circuit performance. Newly developed instrumentation for convenient measurement of phase, gain, and impedance at microwave frequencies is also available. See page 461.

Bolometric power meters

Below 10 milliwatts, power is usually measured with bolometers (temperature-sensitive resistive elements) in conjunction with a balanced bridge. There are two general types of bolometers: thermistors, whose resistance decreases with temperature (negative temperature coefficient), and barretters, which have a positive temperature coefficient. Thermistors are most commonly used because they are more rugged, both physically and electrically, than barretters. These bolometer elements are mounted in devices that present an impedance match to microwave transmission lines, either coaxial or waveguide. Such devices are appropriately termed bolometer mounts and allow a bias connection to the bolometer element, as well as a proper entry point for RF. The bolometer is connected as one leg of a Wheatstone bridge through the bias connection, and bridge excitation is applied. The dc or ac bridge excitation biases the bolometer element to balance the bridge. When the unknown microwave power is applied to the bolometer, the resulting temperature rise causes the element's resistance to change, unbalancing the bridge. Withdrawing a like amount of bias power from the element rebalances the bridge. The amount of bias removed is displayed on a meter.

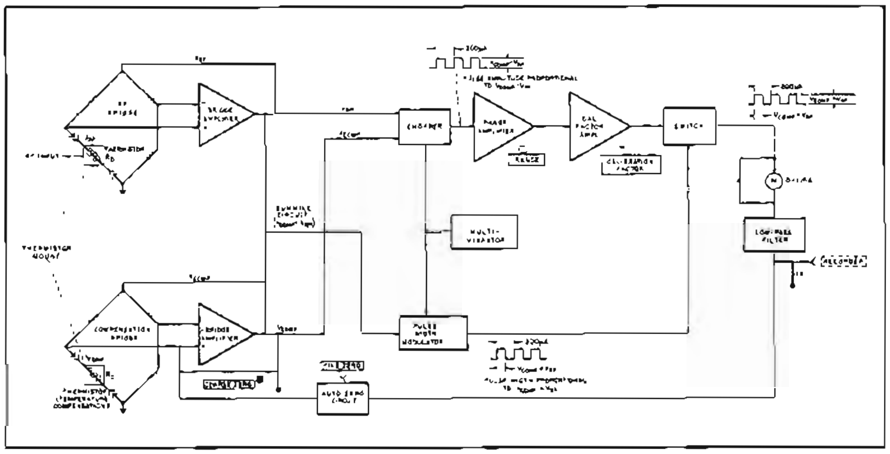


Figure 7. Block diagram of HP 432A Power Meter. Dual bridge provides proper bias to thermistor mount to correct for temperature variation and reduce zero drift.

Automatic bolometer bridges

There are a number of bolometer bridge designs which provide various degrees of accuracy, speed, and convenience.

The Hewlett-Packard Model 432A Power Meter is a temperature-compensated, automatically balanced thermistor bridge of versatile design. Operating with any of the HP temperature-compensated thermistor mounts, the 432A automatically maintains bridge balance and reads substituted bias power to a basic accuracy of ±1% of full scale. The 432A power ranges of 10 microwatts to 10 milliwatts (full scale) encompass virtually all levels involved in small signal microwave power measurement.

Since all bolometer elements are temperature-sensing devices, they are unable to distinguish between applied power level changes and environmental temperature changes. As bolometer bridge sensitivity is increased, even minute temperature variations can unbalance the bridge. This results, if uncompensated, in "zero drift" of the power meter and erroneous power measurements.

A dual bridge arrangement, as shown in Figure 7 is used in the 432A to compensate for variations in temperature at the thermistor mount. The thermistor mounts used with the 432A have two thermistor elements. The two are in close thermal proximity and are affected equally by changes in ambient temperature. Thus R_D responds to both ambient temperature and applied RF power; R_C, isolated from the RF power, responds only to ambient temperature. Each element is connected to its own bridge circuit in the power meter, which automatically controls bias power. This arrangement compensates for temperature changes, thus reducing zero drift in the 432A by a factor of 100 over uncompensated meters. Another advantage of the 432A design is that when zeroed on the most sensitive range, the meter may be switched to any other power range without re-zeroing (zero-carryover is within 1% on all ranges). A dc output proportional to the meter deflection is available for recording purposes or control of external circuits such as power meter leveling of microwave sweep oscillators and signal generators.

Compensated thermistor mounts available for the 432A include the 478A (10 MHz to 10 GHz) and the 8478A (10 MHz to 18 GHz) Coaxial Mounts. The 486A Waveguide Series collectively cover the waveguide bands from 2.6 to 40 GHz. All mounts have low SWR over their frequency ranges without tuning.

Non-temperature-compensated bridges

The HP Model 430C Power Meter operates with a number of non-temperature-compensated barretter or thermistor mounts such as the HP 477B Coaxial and 487 Waveguide Series. The 478A, 8478B, and 486A Thermistor Mounts also can be operated in a non-temperature-compensated mode with the 430C using the 11528A Adapter. This permits utilization of the 430C Power Meter in waveguide bands not covered by the 487 series of mounts. Accuracy of the 430C in measuring substituted power is ±5% of full scale.

Calorimetric power meters

Bolometer elements cannot be used for direct power measurement at levels above 10 to 50 milliwatts because of their physical size. Calibrated directional couplers or attenuators are sometimes used to reduce the power level to the bolometer's range; however, this also reduces overall accuracy because of the additional tolerances on coupling factor or attenuator calibration. Where better accuracy is desired, calorimetric techniques provide a more useful result.

Calorimetric power meters dissipate the unknown power in a resistive termination that is matched to the transmission line or source impedance. The temperature rise caused by the power dissipation is then measured by a temperature sensor which is calibrated against known amounts of dc power. Calorimetric power meters fall into two categories—dry and fluid. Dry calorimeters depend upon a static thermal path between the dissipative load and the temperature sensor. This arrangement often requires several minutes for the termination and sensor to reach equilibrium, making measurements time-consuming and too sluggish for tuning circuit parameters for optimum output.

Fluid calorimeters such as the HP 434A utilize a moving stream of oil to transfer heat quickly to the sensing element. An amplifier-feedback arrangement, in conjunction with the series oil flow system as shown in Figure 8 reduces measurement time in the 434A to less than 5 seconds for full-scale response. The physical size of the termination and the flow rate of liquid passing over the termination are primary factors which determine the maximum power that may be dissipated by a fluid calorimeter. The HP 434A covers the important range of 10 mW to 10 watts.

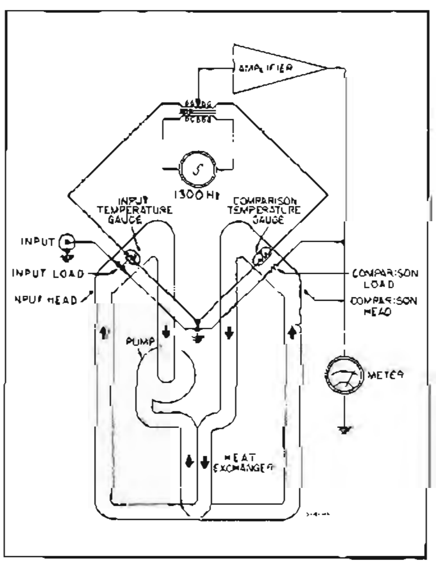


Figure 8. Simplified diagram of HP 434A Calorimetric Power Meter, showing oil flow path.

Peak power measurement

A frequent requirement in microwave work is the measurement of peak power in a periodic pulse. This may be done by various indirect techniques using bolometers or calorimeters. Hewlett-Packard produces a versatile instrument that conveniently measures peak power directly in the 50 MHz to 2 GHz region. This instrument (the 8900B) utilizes a video comparator technique to bring a known dc voltage, supplied by the 8900B, in a known impedance to a level which is equal to the pulse being measured. This allows simple measurements of peak pulse power with a basic accuracy of 1.5 dB even when the waveform is not rectangular. A custom calibration chart increases accuracy to 0.6 dB for critical applications.

Application Note 64

Complete information on the theory and operation of bolometers and bridges, along with other types of power meters, is included in a comprehensive application note available from Hewlett-Packard. Application Note 64 contains up-to-date information on virtually all aspects of microwave power measurement, including detailed descriptions and illustrations of instruments, techniques, error analysis and applications. Sources of measurement error and systematic methods for error-reduction allow selection of the best procedure for a specific application. Application Note 64, entitled "Microwave Power Measurement", is available on request through your HP sales office.

Steps toward better accuracy

The fundamental standards of microwave power lie in dc or low-frequency ac voltage and resistance standards which may be accurately measured and used for comparison or substitution. Other factors, such as impedance matching and efficiency of the sensing device, play an important role in the *overall* measurement accuracy.

The basic accuracy of HP power measuring equipment satisfies the requirements of most applications without complicated set-ups requiring extensive manual operations and calculation. Should greater accuracy be required, the versatility and stability of HP equipment allows easy enhancement of its basic accuracy in a step-by-step manner until the degree of accuracy needed is achieved.

Tuners: Certainly one of the most important steps for higher accuracy is the elimination of mismatch loss with a tuner. Hewlett-Packard bolometer mounts and calorimeter input systems are designed and tested for good broadband impedance match (low SWR) to common microwave transmission lines. However, source SWR must also be considered in any power measurement, and the combination of source and load SWR can produce serious mismatch errors. To eliminate mismatch error, HP 870A Waveguide Series or 872A Coaxial Slide-screw Tuners may be used ahead of the bolometer or calorimeter input.

Effective Efficiency and Calibration Factor: A bolometric power meter can only measure power that is absorbed by the bolometer element, not that which is dissipated elsewhere in the mount or reflected by the mount (SWR). Furthermore, the spatial distribution of current and resistance within the element is slightly different for microwave frequencies and the dc (or low-frequency ac) which is actually measured by the meter. The effects of these sources of error are measured at certain frequencies during the manufacture of the Models 478A and 486A mounts and presented on their nameplates as Calibration Factor and Effective Efficiency. Calibration Factor is the ratio of substituted bias power in the power meter to the microwave power incident on the mount. Effective Efficiency is the ratio of substituted bias power in the power meter to the microwave power absorbed by the mount. Although direct traceability to NBS (National Bureau of Standards) is not yet available in certain bands, the extensive tests and cross-checks conducted by HP on literally thousands of mounts assure a uniformly high level of efficiency in all mounts. The HP E31-8690 Series of power calibration systems provides these data in either coax or waveguide. In addition, the mounts are swept-frequency tested, so the effects of even sharp resonances on efficiency are revealed and eliminated.

Instrumentation: HP 432A power meters provide a basic accuracy of $\pm 1\%$ in substituted power to the thermistor. The DVM output of the HP 432A allows connection of a digital voltmeter (such as the HP 3440A) for high resolution readout of power. Rear panel connectors also allow direct measurement of voltages in the bridges; the computed substituted dc power reduces instrumentation error to less than $\pm 0.2\%$ $+0.5$ μW. A Power Meter Calibrator, the HP 8477A, will soon be available for the HP 432A.

The 434A Calorimetric Power Meter basic accuracy is $\pm 5\%$ of full scale, which includes both instrumentation error and efficiency. The built-in calibration source provides a 0.1 watt dc check point accurate to 1% for convenient verification of the 434A calibration. Instrumentation uncertainty can be substantially reduced by calibrating the 434A on the range to be used with an external dc test set. The HP K02-434A dc Test Set provides calibration power levels in convenient steps from 2 mW to 10 W, accurate to $\pm 0.5\%$ of output.

COAXIAL INSTRUMENTATION

For coaxial systems operating to 18 GHz

Instrument name	Uses	Frequency coverage by model (dc, 10 MHz, 100 MHz, 215 MHz, 450 MHz, 500 MHz, 940 MHz, 1 GHz, 2 GHz, 3 GHz, 4 GHz, 10 GHz, 12.4 GHz, 18 GHz)	Page
Adapters	Interconnect coaxial-waveguide and coaxial-coaxial systems	281A, 281B	312
		11524A, 11525A	472
Low-pass filters	Spectrum analyzer preselectors to eliminate signals outside the range of interest; output filters for signal sources to eliminate harmonics	360A, 360B, 360C, 360D	
Bandpass filters		8430A, 8431A, 8432A, 8433A, 8434A, 8435A, 8436A	306
Variable attenuators	Measurement of reflection coefficient, insertion loss, transfer characteristics by RF substitution; reduction of power levels; reduction of source mismatch	354A	303
		355C	302
		355D	302
		393A, 394A	
Fixed attenuators		8491A, 8491B, 8492A, 8493A, 8493B	304
Detectors	RF detection; reflection coefficient, attenuation measurements	420A, 420B, 423A, 440A, 8470A, 8471A, 8472A	307
Thermistor mounts	Power measurements with HP 430C (477B) and HP 432A (478A, 8478B)	477B, 478A, 8478B	288
Frequency meters	Frequency measurements	536A, 537A	308
Dual directional couplers	Reflectometer measurements; optimizing transmission characteristics of RF systems; power monitoring	774, 775D, 776D, 777D	297
		778D	296
Directional detectors	Closed-loop leveling of signal sources; power monitoring	X781A, 786D, 787D, 788C, 789C	297

Instrument name	Uses	Frequency coverage by model (dc, 10 MHz, 100 MHz, 215 MHz, 450 MHz, 500 MHz, 940 MHz, 1 GHz, 2 GHz, 3 GHz, 4 GHz, 10 GHz, 12.4 GHz, 18 GHz)	Page
Directional couplers	Power measurements; power leveling	779 796D 797D 798C	296 297
Slotted sections and sweep adapter	Measurement of SWR, wavelength, impedance, system flatness; adapter, detector for swept-frequency slotted line measurements	805C 816A 817A 448A	284 282 282 283
Terminations	Termination of 50-ohm systems; separation of load and other system reflections (905A, 907A)	905A 907A 908A 909A	309
PIN modulators	Sinusoidal and complex AM and RF pulsing of microwave sources without Incidental FM	8731A,B 8732A,B 8733A,B 8734A,B	301
Harmonic mixer	Mixing SHF and VHF signals	934A	312
Transistor fixtures	Make RF, dc connections to solid state devices	11600A 11602A	475
Bias tees	Apply dc bias to solid state devices in RF measuring systems	11589A 11590A	475
Coaxial switches	Electrically switch RF signals	8761	313
Power splitter	Divide RF power evenly for comparative phase and magnitude measurements	11549A	468
Air lines Flexible arm Straight sections	Adapt test equipment port spacing to devices under test. Add known line length to phase delay measuring equipment	11605A 11566A 11567A	476 472 472
Shorts	Establish measurement planes, reflection phase and magnitude references	11511A 11512A 11565A	309

MICROWAVE TEST EQUIPMENT

WAVEGUIDE INSTRUMENTATION

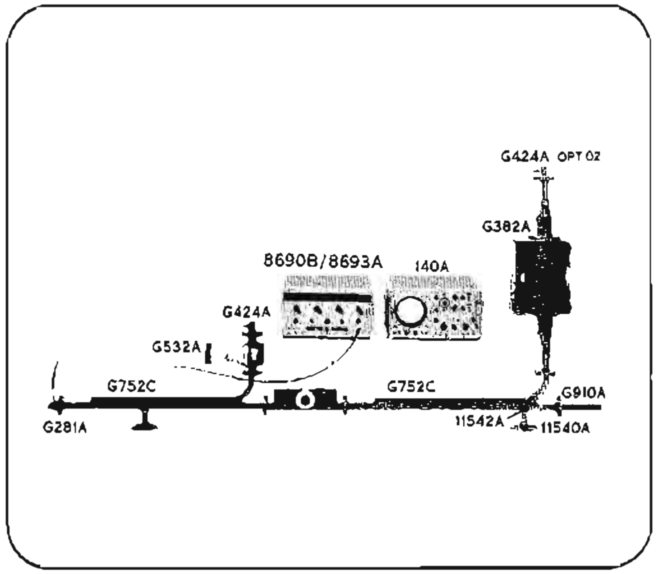
Quality equipment for microwave measurements

S-band, 2.60 to 3.95 GHz, and G-band, 3.95 to 5.85 GHz

The swept-frequency system illustrated on the right permits rapid measurement of attenuation (in this example a variable attenuator is being calibrated). The transmission characteristics of the system are accounted for in the initial calibration which is based on the G382A Attenuator.

Complementary Equipment

HP Instrument	Frequency Range (GHz)
8616A Signal Generator	1.8 to 4.5
8616B Signal Source	1.8 to 4.5
618C Signal Generator	3.8 to 7.6
8690B Sweep Oscillator	
8692A RF Unit	2 to 4
8692B RF Unit	2 to 4
8693A RF Unit	4 to 8
8693B RF Unit	4 to 8



S- and G-band Equipment

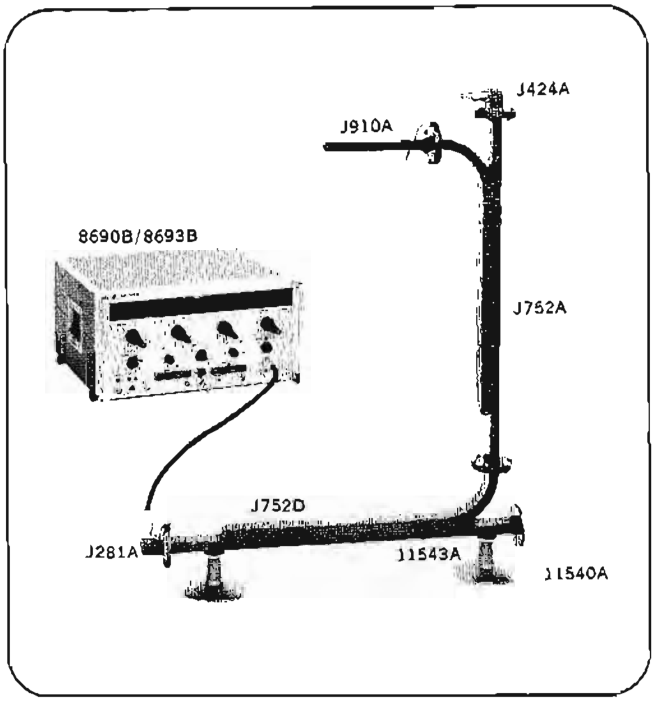
HP Model	Description	Accuracy	Range	SWR (max)	Power (watts)	Length (in)	Length (mm)	Page Reference	Price
S281A	Adapter, waveguide-to-coax			1.25		2½	64	312	$65
G281A						2⅛	54	312	$50
G347A	Noise source, waveguide	± 0.5 dB	15.2 dB	1.2		19	483	314	$310
S382C*	Attenuator, precision variable	± 1% or 0.1 dB to 50 dB ± 2% above 50 dB	0 to 60 dB	1.2 below 3 GHz; 1.15 above 3 GHz	10	25¼	641	305	$1120
G382A		± 2% of reading or 0.1 dB, whichever is greater	0 to 50 dB	1.15	15	31⅝	803	305	$550
G424A	Crystal detector	sensitivity: >0.4 mV/μW	sensitivity: 0.4 mV/μW	1.35	100 W pk 15 mW avg	2-1/16	52	307	$185
S486A	Thermistor mount, compensated		0.001 to 10 mW	1.35		3	76	288	$240
G486A				1.5		4	102	288	$210
G532A	Frequency meter, direct reading	dial: ± 0.033% overall: ± 0.065%				6¼	159	308	$400
G752A G752C G752D	Directional couplers, multi-hole	mean: ±0.4 dB variation: ±0.5 dB	3 dB 10 dB 20 dB	1.1 1.05 1.05	2 (in aux. guide)	34½ 33 33	876 838 838	299	$325
G810B (809C) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809C)			1.01		10¼	260	283 (284)	$140 ($200) ($55)
G910A	Termination, low power			1.04	2	6⅝	168	310	$70
G914A	Moving load	load reflection: <0.5%	> ½ wavelength	1.01	2	20½	521	310	$120
G920A	Adjustable short		> ½ wavelength			7-13/16	199	310	$125
11540A	Waveguide stand							312	$3
11541A	S-band waveguide clamp							312	$3
11542A	G-band waveguide clamp							312	$3

*Degree dial 0 to 90° in 0.01° increments.

WAVEGUIDE INSTRUMENTATION

Quality equipment for microwave measurements

J-band, 5.30 to 8.20 GHz



In the illustration leveled output power from the sweep oscillator is obtained through use of the J752 Directional Couplers in the configuration shown. The J424A Crystal Detector, with its extremely flat frequency response, provides the error voltage to the ALC input of the sweep oscillator. The power delivered at the output port of the J752D Coupler is flat to better than ½ dB, and the high directivity of the coupler makes the leveling loop virtually immune to load SWR.

Complementary equipment

HP Instrument	Frequency Range (GHz)
618C Signal Generator	3.8 to 7.6
620B Signal Generator	7 to 11
8690B Sweep Oscillator	—
8693A RF Unit	4 to 8
8693B RF Unit	4 to 8
H01-8693B RF Unit	3.7 to 8.3
493A Microwave Amplifier	4 to 8
8733A PIN Modulator	3.7 to 8.3
8733B PIN Modulator	3.7 to 8.3

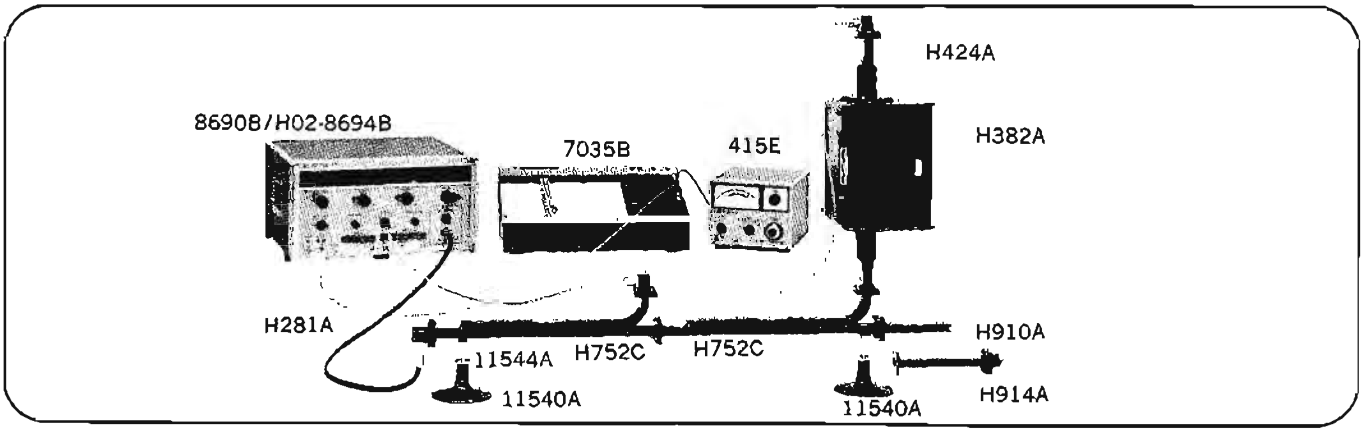
J-band equipment

HP Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
J281A	Adapter, waveguide-to-coax			1.25 (1.3 from 5.3 to 5.5 GHz)		2	51	312	$45
J347A	Noise source, waveguide	±0.5 dB	15.2 dB	1.2		19	483	415	$300
J382A	Attenuator, precision variable	±2% of reading or 0.1 dB which- ever is greater	0 to 50 dB	1.15	10	25	635	305	$415
J424A	Crystal detector	response: ±0.2 dB	sensitivity >0.4 mV/μW	1.35		1⅞	48	307	$185
J486A	Thermistor mount, compensated		0.001 to 10 mW	1.5	100 W pk 15 mW avg	3⅜	86	288	$200
J532A	Frequency meter, direct reading	dial: ±0.033% overall: ±0.065%				6¼	159	308	$375
J752A J752C J752D	Directional couplers, multi-hole	mean: ±0.4 dB variation: ±0.5 dB (5.85 to 8.2 GHz)	3 dB 10 dB 20 dB	1.1 1.05 1.05	1 (in aux. guide)	26½ 25-9/16 25-9/16	673 649 649	299	$220
J810B (809C) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809C)			1.01		10¼	260	283 (284) (284)	$125 ($200) ($55)
J885A	Waveguide phase shifter	lesser of 3° or 10%	−360° to +360°	1.35	10	25⅛	638	311	$650
J910A	Termination, low power			1.02	1	8⅛	206	310	$55
J914A	Moving load	load reflection: <0.5%	>½ wavelength	1.01	2	15½	394	310	$100
J920A	Adjustable short		>½ wavelength			6¼	159	310	$100
11540A	Waveguide stand							312	$3
11543A	Waveguide clamp							312	$3

WAVEGUIDE INSTRUMENTATION

Quality equipment for microwave measurements

H-band, 7.05 to 10 GHz



The setup shown here is a swept-frequency system for measuring the directivity of a directional coupler. The coupler nearest the 8690B is part of a leveling loop that minimizes test signal amplitude variations. The X-Y recorder plots directivity as a function of frequency. For calibration, the coupler under test is connected as shown with the main line terminated in a low-reflection fixed load, and the 382A is used to simulate values of directivity. For the measurement, the 382A is set to zero, the coupler is reversed, and the fixed load is replaced by a sliding load. With the oscillator sweeping slowly, the load is moved rapidly to phase the load reflection with the directivity signal and thus provide a way of separating the two signals for high-accuracy measurements.

Complementary equipment

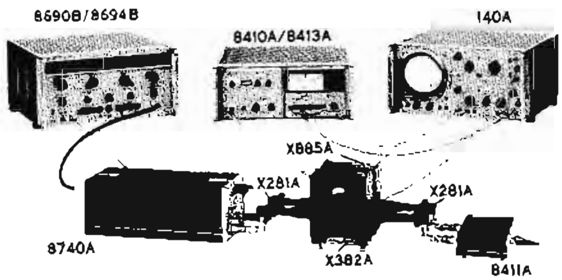
HP Instrument	Frequency Range (GHz)
620B Signal Generator	7 to 11
8690B Sweep Oscillator	—
H02-8694A RF Unit	7 to 11
H02-8694B RF Unit	7 to 11
495A Microwave Amplifier	7 to 12.4
8734A PIN Modulator	7 to 12.4
8734B PIN Modulator	7 to 12.4

H-band equipment

HP Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
H281A	Adapter, waveguide-to-coax			1.25		1⅝	41	312	$40
HX292B	Adapter, waveguide-to-waveguide		8.2 to 10 GHz	1.05		1½	38	312	$40
H347A	Noise source, waveguide	±0.5 dB	15.6 dB	1.2		16	406	314	$275
H382A	Attenuator, precision variable	±2% of reading, or 0.1 dB, whichever is greater	0 to 50 dB	1.15	10	20	508	305	$385
H424A	Crystal detector	response: ±0.2 dB	sensitivity >0.4 mV/μW	1.35		1-9/16	40	307	$175
H486A	Thermistor mount, compensated		0.001 to 10 mW	1.5		3⅜	86	288	$195
H532A	Frequency meter, direct reading	dial: ±0.040% overall: ±0.075%				6¼	159	308	$325
H752A H752C H752D	Directional couplers, multi-hole	mean: ±0.4 dB variation: ±0.5 dB	3 dB 10 dB 20 dB	1.1 1.05 1.05	1 (in aux. guide)	18⅝ 17½ 17½	473 445 445	299	$165
H810B (809C) (444A)	Slotted sections, waveguide (Carriage for 810B) (Detector probe for 809C)			1.01		10¼	260	283 (284) (284)	$110 ($200) ($55)
H910A	Termination, low power			1.02	1	5-9/16	141	310	$45
H914A	Moving load	load reflection: <0.5%	>½ wavelength	1.01	1	11½	267	310	$80
H920A	Adjustable short		>½ wavelength			4⅞	124	310	$85
11540A	Waveguide stand							312	$3
11544A	Waveguide clamp							312	$3

WAVEGUIDE INSTRUMENTATION
Quality equipment for microwave measurements
X-band, 8.2 to 12.4 GHz

MICROWAVE TEST EQUIPMENT



The variation of phase shift with attenuation of the X382A Precision Variable Attenuator is measured in this setup. The new HP 8410A Network Analyzer permits this measurement to be made quickly and easily on a swept-frequency basis.

Complementary equipment

HP Instrument	Frequency range (GHz)
620B Signal Generator	7 to 11
626A Signal Generator	10 to 15.5
8690B Sweep Oscillator	--
8694A RF Unit	8 to 12.4
8694B RF Unit	8 to 12.4
495A Microwave Amplifier	7 to 12.4
8734A PIN Modulator	7 to 12.4
8734B PIN Modulator	7 to 12.4

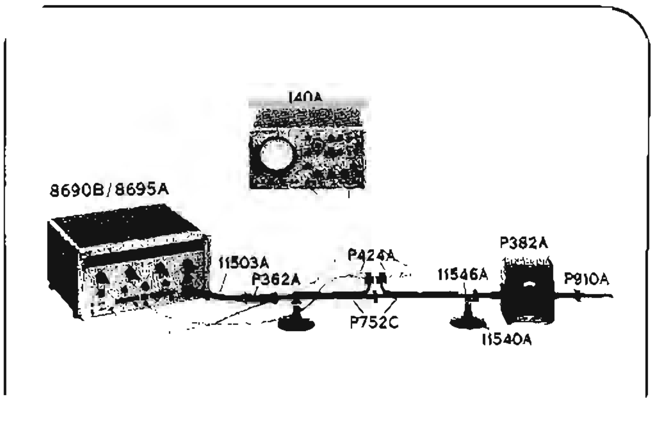
X-band equipment

HP Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page Reference	Price
X281A	Adapter, waveguide-to-coax			1.25		1⅜	35	312	$35
X281B	Adapter, waveguide-to-coax			1.25		1⅜	35	312	$70
HX292B	Adapter, waveguide-to-waveguide		8.2 to 10 GHz	1.05		1½	38	312	$40
MX292B	Adapter, waveguide-to-waveguide		10 to 12.4 GHz	1.05		2⅜	60	312	$50
X347A	Noise source, waveguide	±0.4 dB	15.7 dB	1.2		14¾	375	314	$225
X362A	Low-pass filter	insertion loss, passband: <1dB stopband: >40 dB	passband: 8.2 to 12.4 GHz stopband: 16 to 37.5 GHz	passband 1.5		5-11/32	136	306	$325
X375A	Attenuator, flap	±1 dB at <10 dB ±2 dB at >10 dB	0 to 20 dB	1.15	2	7-3/16	183	305	$110
X382A	Attenuator, precision variable	±2% of reading or 0.1 dB whichever is greater	0 to 50 dB	1.15	10	15⅝	397	305	$310
X424A	Crystal detector	response: ±0.3 dB	sensitivity >0.4 mV/μW	1.35		1⅜	35	307	$155
X485B	Detector mount (less detector)			with barretter 1.25		6-7/16	164	294	$100
X486A	Thermistor mount, compensated		0.001 to 10 mW	1.5		2⅛	54	288	$165
X487B	Thermistor mount, broadband		0.01 to 10 mW	1.5		1-3/16	30	289	$100
X532B	Frequency meter, direct reading	dial: ±0.05% overall: ±0.08%				4½	114	308	$225
X752A X752C X752D	Directional couplers, multi-hole	mean: ±0.4 dB variation: ±0.5 dB	3 dB 10 dB 20 dB	1.1 1.05 1.05	1 (in aux. guide)	16-11/16 15-11/16 15-11/16	424 399 399	299	$145
X810B (809C) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809C)			1.01		10¼	260	283 (284) (284)	$90 ($200) ($55)
X870A	Tuner, slide screw	insertion loss: <2 dB at 20:1 SWR	corrects swr of 20			5½	140	311	$150
X885A	Waveguide phase shifter	<2° at 8.2 to 10 GHz or 10% <3° at 10 to 12.4 GHz or 10%	−360° to +360°	1.35	10	15⅝	397	311	$475
X910B	Termination, low power			1.015	1	6⅝	168	310	$35
X913A	Termination, high power			1.05	500	9½	241	310	$125
X914B	Moving load	load reflection: <0.5%	>½ wavelength	1.005	1	10⅛	257	310	$60
X923A	Adjustable short		>½ wavelength			13	330	310	$75
X930A	Waveguide shorting switch	insertion loss "Open": <0.05 dB		"Open": 1.02 "Shorted": >125		3-11/16	94	310	$160
8735A	PIN modulator		35 dB	1.7 (min. atten.) 2 (max. atten.)	1	6¾	171	300	$350
8735B	PIN modulator		80 dB	2.0 (min. atten.) 2.2 (max. atten.)	1	10½	267	300	$575
11504A	Flexible waveguide					12	305		$35
11540A	Waveguide stand							312	$3
11545A	Waveguide clamp							312	$3
X8747A	Waveguide transmission-reflection unit for 8410A Network Analyzer	tracking: ±0.2 dB Directivity: >40 db		Residual: 1.01		47	1194	475	$1400

WAVEGUIDE INSTRUMENTATION

Quality equipment for microwave measurements

P-band, 12.4 to 18 GHz



The conventional swept-frequency reflectometer in the illustration is being used to examine the reflection characteristics of the P382A Attenuator. The flat frequency response and excellent square law characteristics of the P424A Crystal Detectors provide accurate measurement results, with the added advantage that reflection characteristics can be displayed directly on the oscilloscope CRT.

Complementary equipment

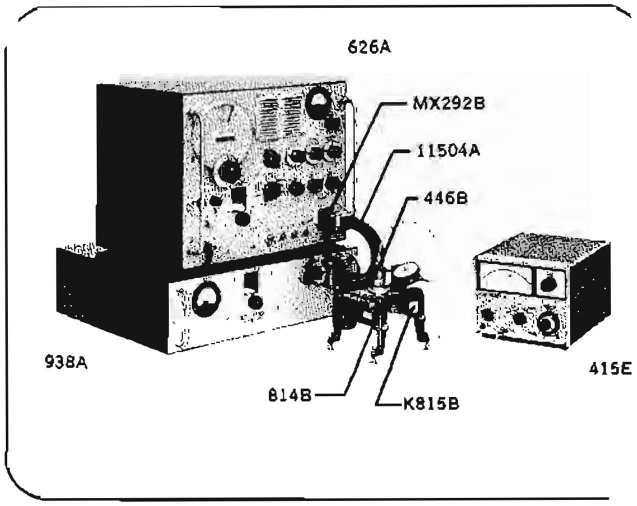
HP Instrument	Frequency Range (GHz)
626A Signal Generator	10 to 15.5
628A Signal Generator	15 to 21
8690B Sweep Oscillator	—
8695A RF Unit	12.4 to 18

P-band equipment

HP Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
P281B	Adapter, waveguide-to-coax		12.4 to 18 GHz	1.25		1⅜	35	312	$85
MP292B	Adapter, waveguide-to-waveguide		12.4 to 15 GHz	1.05		2⅜	60	312	$40
NP292A	Adapter, waveguide-to-waveguide		15 to 18 GHz	1.05		2⅜	60	312	$40
P347A	Noise source, waveguide	±0.5 dB	15.8 dB	1.2		14¾	375	314	$275
P362A	Low-pass filter	insertion loss, passband: <1 dB stopband: >40 dB	pass: 12.4 to 18 GHz stop: 23 to 54 GHz	passband 1.5		3-11/16	94	306	$350
P375A	Attenuator, flap	±1 dB at <10 dB ±2 dB at >10 dB	0 to 20 dB	1.15	1	7¼	184	305	$135
P382A	Attenuator, precision variable	±2% of reading or 0.1 dB, whichever is greater	0 to 50 dB	1.15	5	12½	318	305	$340
P424A	Crystal detector	response: ±0.5 dB	sensitivity >0.3 mV/μW	1.5		15/16	24	307	$195
P486A	Thermistor mount, compensated		0.001 to 10 mW	1.5	100 w pk 15 mW avg	2½	64	288	$220
P487B	Thermistor mount, broadband		0.01 to 10 mW	1.5		13/16	21	289	$135
P532A	Frequency meter, direct reading	dial: ±0.068% overall: ±0.1%				4½	114	308	$275
P752A P752C P252D	Directional couplers, multi-hole	mean: ±0.4 dB variation: ±0.5 dB	3 dB 10 dB 20 dB	1.1 1.05 1.05	1 (in aux. guide)	13¾ 12¼ 12¼	349 311 311	299	$170
P810B (809C) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809C)			1.01		10¼	260	283	$110 ($200) ($55)
P870A	Tuner, slide screw	insertion loss: <2 dB at 20:1 SWR	corrects swr of 20			5	127	311	$160
P885A	Waveguide phase shifter	lesser of ±4° or 10%	−360° to +360°	1.35	5	12-5/16	312	311	$675
P910A	Termination, low power			1.02	1	4⅜	111	310	$40
P914A	Moving load	load reflection: <0.5%	>½ wavelength	1.02	0.5	9¾	248	310	$75
P920B	Adjustable short		>½ wavelength			5¾	146	310	$125
P932A	Harmonic mixer				0.1			312	$250
11503A	Flexible waveguide, P-band					12	305	—	$48
11540A	Waveguide stand							312	$3
11546A	Waveguide clamp							312	$3
P8747A	Waveguide transmission-reflection unit for 8410A Network Analyzer	Tracking: ±0.75 dB Directivity: >40 dB		Residual: 1.1		35	889	475	on request

WAVEGUIDE INSTRUMENTATION
Quality equipment for microwave measurements
K-band, 18 to 26.5 GHz, and R-band, 26.4 to 40 GHz

Illustrated here is a typical system for fixed-frequency measurement of standing wave ratio in K-band.



Complementary Equipment

HP Instrument	Frequency Range (GHz)
626A Signal Generator and 938A Frequency Doubler Set	20 to 26.5
626A Signal Generator and 940A Frequency Doubler Set	26.5 to 31
628A Signal Generator and 940A Frequency Doubler Set	30 to 40
8696A RF Unit	18 to 26.5
8697A RF Unit	26.5 to 40

K- and R-band equipment

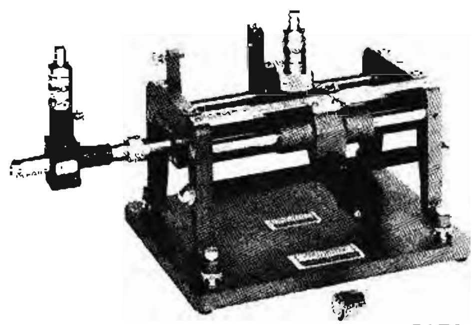
HP Model*	Description	Accuracy	Range	SWR (max)	Power (watts)	Length (in)	Length (mm)	Page Reference	Price
K362A	Low-pass filter	insertion loss, passband: <1 dB stopband: >40 dB	pass: 18 to 26.5 GHz stop: 31 to 80 GHz	passband 1.5		2½	64	306	$385
R362A		Insertion loss, passband: <2 dB stopband: >35 dB	pass: 26.5 to 40 GHz stop: 47 to 120 GHz	passband 1.8		1⅝	42		
K382A	Attenuator, precision variable	±2% of reading or 0.1 dB, which ever is greater	0 to 50 dB	1.15	2	7⅝	194	305	$525
R382A					1	6⅜	162	305	$550
K422A	Crystal detector	freq. resp: ±2 dB sens: 0.3 mV dc/µWCW		2.5		2	51	307	$230 $540 (matched pair)
R422A				3					
K486A	Thermistor mount, compensated		0.001 to 10 mW	2	100 W pk 15 mW avg	3	76	288	$330
R486A									$395
K532A	Frequency meter, direct reading	dial: ±0.077% overall: ±0.11%				4½	114	308	$350
R532A		dial: ±0.083% overall: ±0.12%							$400
K752A K752C K752D	Directional couplers, multi-hole	mean: ±0.7 dB variation: ±0.5 dB (±0.6 dB, R752D)	3 dB 10 dB 20 dB	1.1 1.05 1.05	0.5 (in aux. guide)	10⅝ 9-15/16 9-15/16	270 252 252	299	$200
R752A R752C R752D			3 dB 10 dB 20 dB	1.1 1.05 1.05		11⅝ 8⅝ 8¾	295 219 222		$250
K815B	Slotted section, waveguide			1.01		7-9/16	192	283	$525
R815B									$525
(814B) (446B)	(Carriage for 815B) (Detector probe for 814B)							284	$525 $225
K914B	Moving load	load reflection: <0.5%	>½ wavelength	1.01	0.5	6⅛	156	310	$275
R914B						5⅛	130		
K920B	Adjustable short		>½ wavelength			5½	140	310	$155
R920B						4½	114		$175
11540A	Waveguide stand							312	$3
11547A	K-band Waveguide clamp							312	$3
11548A	R-band Waveguide clamp							312	$3

* Circular flange adapters 11515A (UG-425/U) for K-band, $35 each; 11516A (UG-381/U) for R-band, $40 each.

SLOTTED LINES; DETECTORS

Precision tools for measurements to 40 GHz

Models 805C-817A; 440A-447B, 448A



817A

817A Coaxial Swept Slotted Line System

The 817A is a fully tested, complete swept slotted line system that enables you to make accurate swept-frequency SWR measurements in coax from 1.8 to 18 GHz. The 817A system consists of an 816A Coaxial Slotted Line, an 809C Carriage with an 11558A Baseplate, and a 448A Slotted Line Sweep Adapter. These items are discussed individually in the succeeding paragraphs. The 817A is provided with Type N female and APC-7 sexless connectors. On an optional basis, both Type N male and female connectors are available.

Specifications, 817A

(System consists of 816A Slotted Line, 809C Carriage with 11558A Baseplate, and 448A Slotted Line Sweep Adapter)

Frequency range: 1.8 to 18 GHz.

Impedance: 50Ω ±0.2Ω.

Output connector: APC-7 or Type N female, depending upon which end of the 816A is connected to the load (also see option below). Type N connector is stainless steel and mates compatibly with Type N connectors whose dimensions conform to MIL-C-39012 or MIL-C-71.

Residual SWR and (reflection coefficient)

APC-7 connector:

1.8 to 8 GHz: 1.02 (0.01).
8 to 12.4 GHz: 1.03 (0.015).
12.4 to 18 GHz: 1.04 (0.02).

Type N connector:

1.8 to 8 GHz: 1.04 (0.02).
8 to 12.4 GHz: 1.05 (0.024).
12.4 to 18 GHz: 1.06 (0.029).

Maximum power: 2 W average (limited by 6-dB pad in 448A).

Accessories furnished: 11512A N-male short, 11565A APC-7 short.

Dimensions (maximum envelope): 13½ in. long, 7 in. wide, 7 in. high (343 x 178 x 178 mm).

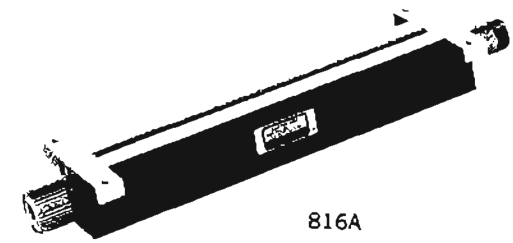
Weight: net 14¾ lb (6,6 kg); shipping 22 lb (9,9 kg).

Complementary equipment

HP 8690B Sweep Oscillator with 8692A/B through 8695A RF Unit (page 423).
HP 141A Oscilloscope with 1416A Swept-Frequency Indicator plug-in (page 513).
HP 905A Sliding Load (page 309).
HP 909A Termination (page 309).

Price: Model 817A, $925.

Option 22: Type N male connector in lieu of APC-7, less $15.



816A

816A Coaxial Slotted Section, 1.8-18 GHz

The 816A enables you to make swept-frequency slotted line measurements from 1.8 to 18 GHz in coaxial systems (HP 448A is required; see below). High accuracy is ensured with the low residual SWR of the 816A. Thus, you can take advantage of the complete coverage offered by the swept-frequency technique. Fixed-frequency measurements from 1.8 to 18 GHz can also be made using HP 447B Probe (see below). With its broad frequency range, the 816A covers the extremely important X-band (8.2 to 12.4 GHz). In addition, it extends the range of coaxial slotted line measurements through P-band (12.4 to 18 GHz), where there is an increasing use of coaxial devices.

Model 816A consists of two parallel planes and a rigid center conductor. This configuration virtually eliminates slot radiation and minimizes the effect of variation in probe penetration and centering. It also provides greater mechanical stability. The 816A is fitted with one APC-7 and one Type N female connector. On an optional basis, the APC-7 can be replaced with a Type N male connector, or both connectors can be APC-7's. Other combinations are available on special order.

Specifications, 816A

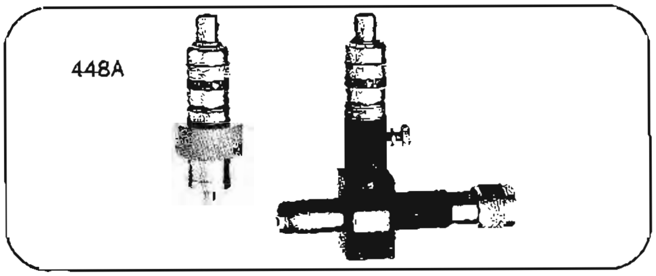
Carriage: fits HP 809C Carriage.

Frequency range: 1.8 to 18 GHz with 447B probe.

Impedance: 50Ω ±0.2Ω.

Connectors: one APC-7, one Type N female (stainless steel, compatible with connectors conforming to MIL-C-39012 and MIL-C-71); either end can be connected to the load.

Residual SWR and (reflection coefficient): 1.02 (0.01) to 8 GHz, 1.03 (0.015) to 12.4 GHz, 1.04 (0.02) to 18 GHz for APC-7 connector; 1.04 (0.02) to 8 GHz, 1.05 (0.024) to 12.4 GHz, 1.06 (0.029) to 18 GHz for N-female connector.
Slope and irregularities: 0.1 dB per half wavelength, 0.2 dB maximum cumulative when adjusted on 809C Carriage.
Length: 9¾ in. (248 mm).
Weight: net 1¼ lb (0,6 kg); shipping, 3 lb (1,4 kg).
Accessories furnished: 11512A Type N male short; 11565A APC-7 short.
Price: HP 816A, $250.
Option 22: Type N male connector in lieu of APC-7 (11512A N-male, 11511A N-female shorts supplied), less $15.



448A Slotted Line Sweep Adapter, 1.8-18 GHz

The HP 448A permits accurate swept-frequency SWR measurements in coax from 1.8 to 18 GHz with the 816A Slotted Section. The 448A includes a short slotted line section and two matched detectors with adjustable probes. One detector fits in the slotted section of the 448A, and its output levels the signal source. The other detector monitors the standing waves in the HP 816A Slotted Section.

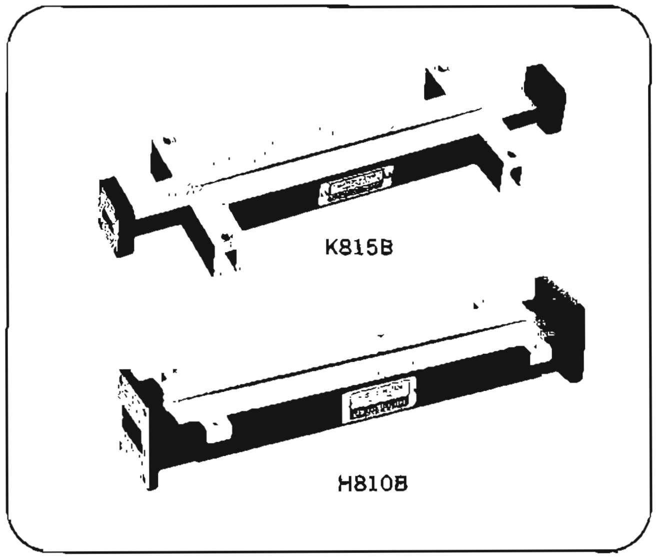
Specifications, 448A

Frequency range: 1.8 to 18 GHz.
Maximum power: 2 W average (limited by pad in leveling detector).
Equipment supplied: one fixed slotted section, one pair of matched detectors with adjustable probes.
Slotted line connectors: Type N, one male, one female, stainless steel (compatible with connectors conforming to MIL-C-39012 and MIL-C-71).
Detector output connector: BNC female.
Weight: net 14 oz (0,39 kg); shipping 2 lb (0,9 kg).
Price: HP 448A, $400.

810B, 815B Slotted Sections, 3.95-40 GHz

The 810B Waveguide Slotted Sections also are designed for use with the 809C Carriage. Each is a precision-manufactured section of waveguide in which a small longitudinal slot is cut. A traveling probe on the 809C Carriage samples the waveguide's electric field along the slot and permits precise plotting of variations along the entire length of probe travel. Ends of the slots are tapered to reduce SWR to less than 1.01. The waveguide sections are broached and checked with precision gauges for careful control of guide wavelength. Broaching is essentially a linear cutting stroke which eliminates even the minor surface irregularities inherent with milling cutters. Six waveguide sizes are available.

The 815B Waveguide Slotted Sections are designed to fit the 814B Carriage. Like the lower-frequency slotted sections, each 815B is precision-manufactured, broached and checked with precision gauges for careful control of guide wavelength. The slot is tapered to insure a low SWR.



Specifications, 810B

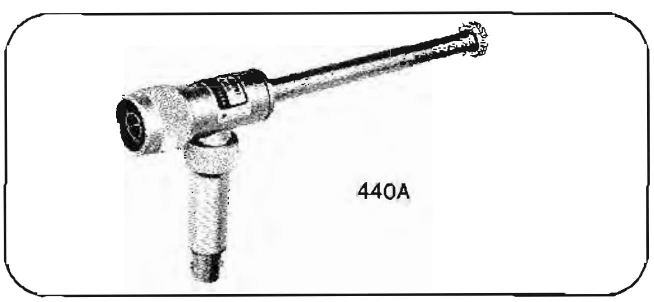
HP Model	Frequency range (GHz)	Fits waveguide size nom. OD (in.)	EIA	Equivalent flange	Price
G810B	3.95–5.85	2 x 1	WR187	UG407/U	$140
J810B	5.30–8.20	1½ x ¾	WR137	UG441/U	$125
H810B	7.05–10.0	1¼ x ⅝	WR112	UG138/U	$110
X810B	8.20–12.4	1 x ½	WR90	UG135/U	$ 90
P810B	12.4–18.0	0.702 x 0.391	WR62	UG419/U	$110

Carriage: fits 809C Carriage.
Length of all sections: 10¼" (260 mm).
Slope and irregularities: slot discontinuity results in SWR <1.01.

Specifications, 815B

	HP K815B	HP R815B
Frequency range (GHz):	18 to 26.5	26.5 to 40
Residual SWR:	1.01	1.01
Equivalent flange:*	UG595/U	UG599/U
Fits waveguide size:	(in.) 1/2 x 1/4 (EIA) WR42	0.360 x 0.220 WR28
Overall length:	7-9/16" (192 mm)	7-9/16" (192 mm)
Price:	$525	$525

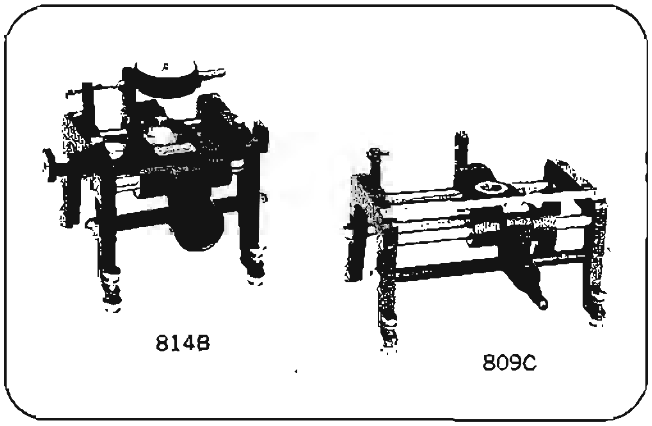
*Circular flange adapters: K-band (UG425/U) 11515A, $35 each; R-band (UG381/U) 11516A, $40 each.



440A Detector Mount

The HP 440A is a tunable, easy-to-use instrument for detecting RF energy in coaxial systems (2.4 to 12.4 GHz) or, in conjunction with the HP 442B, in waveguide or coaxial slotted sections. Just one adjustment is required for tuning. Crystals or bolometers may be used interchangeably in the same holder. A built-in RF bypass is provided. The detector (not supplied) can be a 1N21 or 1N23 Crystal or 821 Series Barretter. Input connector is Type N male; detector output BNC female. Price: HP 440A, $100.

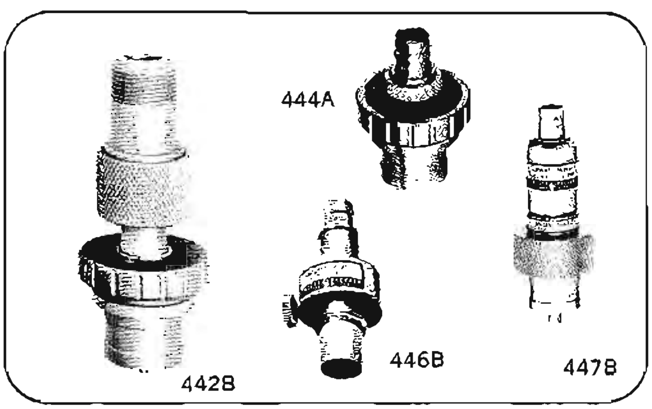
Precision tools for measurements to 40 GHz
Models 805C - 817A; 440A - 447B; 448A



809C, 814B Carriages

The Model 809C Carriage is a precision mechanical assembly which operates with five HP 810B Waveguide Slotted Sections (3.95 to 18 GHz) and with HP 816A Coaxial Slotted Section (1.8 to 18 GHz). The carriage eliminates the cost of a probe carriage for each frequency band. Sections can be interchanged in seconds. The 809C is designed for use with the HP 444A or 447B Untuned Probe, the HP 442B Broadband Probe, or 448A Slotted Line Sweep Adapter. The carriage has a centimeter scale with a vernier reading to 0.1 mm, and provision is made also for mounting a dial gauge if more accurate probe position readings are required. Price: HP 809C, $200.

The HP 814B Carriage, also a precision assembly, is designed for use with the HP K and R815B Waveguide Slotted Sections (18 to 40 GHz) and HP 446B Untuned Probe. The carriage is equipped with a dial indicator for accurate reading. Slotted sections are easily interchanged. Price: HP 814B, $525.



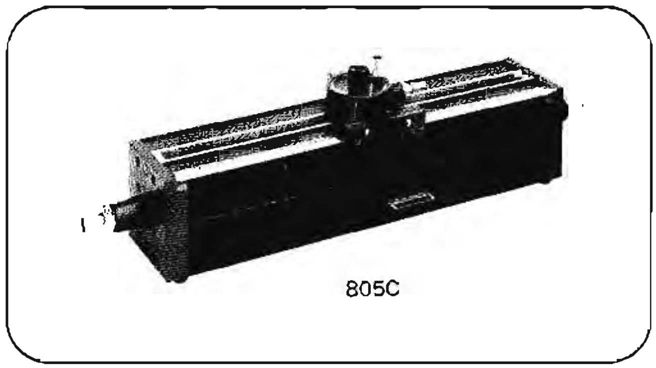
442B, 444A, 446B, 447B Probes

Model 442B is a probe whose depth of penetration into a slotted section is variable. Held in position by friction, it may be fixed in place by a locking ring. Sampled RF appears at a Type N jack. It can be connected to a 440A Detector Mount to form a sensitive and convenient tuned RF detector for HP 810B waveguide slotted sections. The 442B fits the 809C Carriage. Frequency range is 2.6 to 12.4 GHz. Price: HP 442B, $50.

The 444A Untuned Probe, for use with HP 810B Waveguide Slotted Sections, consists of a crystal, plus a small antenna in a convenient housing. The probe is held in position by friction or may be fixed by a locking ring. No tuning is required, and sensitivity equals or exceeds many elaborate single- and double-tuned probes. The 444A fits the 809C Carriage or other carriages with a ¾ in. (19 mm) mounting hole. Frequency range is 2.6 to 18 GHz. Accessory furnished: 11506A Probe Extension Kit. Price: HP 444A, $55.

The HP 446B is a broadband detector and probe which consists of a modified 1N53 silicon diode in a carefully designed shielded housing. No tuning is required, and probe penetration may be varied quickly and easily. Designed for use with the 814B Carriage, the 446B has a frequency range of 18 to 40 GHz. Price: HP 446B, $225.

Model 447B consists of a crystal diode detector plus a small antenna probe for sampling energy in HP 816A Coaxial Slotted Lines. The untuned probe is extremely sensitive over its frequency range of 1.8 to 18 GHz. Such performance is achieved through the use of a unique, easily replaced diode package developed by Hewlett-Packard. The 447B fits HP 809C. Carriage or other carriages with a ¾ in. (19 mm) mounting hole. Price: HP 447B, $125.



805C Slotted Line, 500-4,000 MHz

Model 805C is a coaxial slotted line with an integral probe circuit tunable from 500 to 4,000 MHz. The slotted line consists of two parallel planes and a rigid center connector. This configuration results in negligible slot radiation, minimum sensitivity to variation in probe depth or centering, and greater structural stability.

Specifications, 805C

Frequency range: 500 to 4,000 MHz; minimum frequency determined by usable length of 14½ in. (368 mm).
Impedance: 50Ω.
Residual SWR: less than 1.04:1.
Slope: 0.2 dB or less.
Connectors: Type N, one male, one female; either end may be connected to the load.
Calibration: metric, cm and mm; vernier reads to 0.1 mm.
Detector probe: tunable; detector may be 1N21B Crystal (supplied) or 821 series barretter or selected 1/100-amp instrument fuse.
Accessories furnished: 11511A Shorting Jack; 11521A Shorting Plug.
Accessory available: 11510A Carrying Case, $65.
Price: HP 805C, $550.

RATIO METER
Simplified reflection coefficient measurements
Model 416B

Advantages:

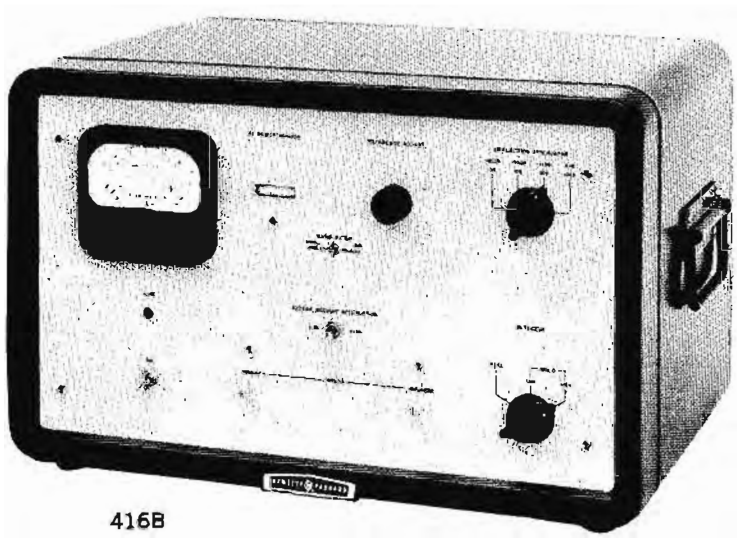
Eliminates amplitude-variation error
Operates accurately over 20:1 incident power range

Use:

Reflection coefficient measurements over broad frequency range, independent of RF power level

The HP 416B is designed for use with unleveled sweep oscillators and signal sources in the measurement of reflection coefficient. The ratio meter provides valid results independent of incident power variations as high as 20:1. Either swept- or fixed-frequency measurements can be made using the Model 416B, and a high-impedance output on the rear of the instrument permits swept-frequency measurements to be presented on an oscilloscope or preserved on a graphic recorder. The panel meter is calibrated in percent reflection and equivalent SWR.

The 416B operates with either crystals or bolometers, and a panel switch permits selection of 4.3 or 8.7 mA bias for bolometers. Positive bolometer protection is provided.



416B

Specifications

Meter presentation

Reflection coefficient (%): four ranges, 100%, 30%, 10% and 3% reflection, equivalent to reflection coefficients of 1, 0.3, 0.1 and 0.03.

Equivalent SWR: two ranges, 1.06 to 1.22 and 1.2 to 1.9.

DB: for use with both reflection coefficient and equivalent SWR scales; scale calibrated 0 to −10 dB; with ranging, spans 0 to −40 dB in four 10-dB steps.

Accuracy: crystal, ±3% of full scale; bolometer, same as crystal except ±5% for incident input voltage below 1 mV.

Calibration: square law for use with crystal detectors or barretters.

Frequency: 1000 Hz ±40 Hz (±20 Hz for bolometer detectors when incident input voltage is <1 mV rms).

Input voltage (for full-scale deflection):

	Crystal	Bolometer
Incident channel	3 to 100 mV rms	0.3 to 10 mV rms
Reflected channel	3 μv to 100 mV rms	0.3 μv to 10 mV rms

Input impedance (both channels): crystal, approximately 75 kΩ; bolometer, approximately 500Ω (High Bolo) or 1000Ω (Low Bolo).

Excess incident attenuation: provision for 10 dB increase of incident channel sensitivity for reflectometers using couplers with different coefficients; under certain circumstances, accuracies can be improved by this procedure.

Output

Open circuit voltage: approx. 10 V dc at full scale.

Source impedance: 100 kΩ; BNC type connector.

Bolo bias: high range, 8.7 mA; low range, 4.3 mA; bias variable approximately 10% by means of rear-panel control; positive bolometer protection.

RF power monitor: level indicator monitors input amplitude (and frequency, indirectly) to ensure proper operating range for the instrument and for crystal detectors.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 115 watts.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14⅞" deep (527 x 324 x 378 mm); rack mount: 19" wide, 10½" high, 14" deep behind panel (483 x 267 x 356 mm).

Weight: net 34 lb (15,3 kg), shipping 45 lb (20,3 kg) (cabinet); net 27 lb (12,2 kg), shipping 41 lb (18,5 kg) (rack mount).

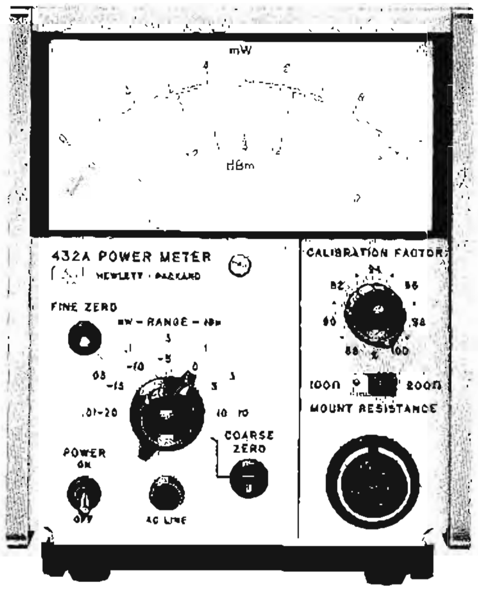
Accessories available: 10503A Cable Assembly, $7; 11001A Cable Assembly, $6.

Price: HP 416B, $675 (cabinet); HP 416BR, $660 (rack mount).

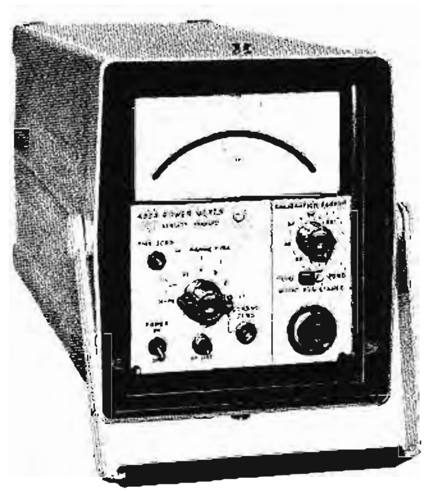
POWER METER; THERMISTOR MOUNTS

Increased accuracy; automatic zero

Models 432A, 478A, 486A, 8478A



432A



432A in 11076A Carrying Case

The new 432A Power Meter, together with the 478A, 8478B and 486A Thermistor Mounts, enables you to conveniently make even routine microwave power measurements with standards lab accuracy from 10 MHz to 40 GHz. The 432A replaces the successful 431C Power Meter. It has 1% accuracy on all ranges, a dc bridge circuit, and an automatic zero feature that brings new time-saving convenience to otherwise tedious power meter measurements.

The 432A was designed to operate with thermistor mounts already in use in many installations—the same mounts designed for use with the 431C Power Meter. Therefore, you can incorporate the new meter with all its advantages directly into these applications without costly mount replacement.

With this power meter you can measure power levels from —30 dBm to +10 dBm (1 μW to 10 mW). This 40-dB measurement range is covered in seven 5-dB steps. The meter face is calibrated in both milliwatts and dBm with a 10-dB full scale dynamic range.

Automatic zeroing: a unique circuit allows you to zero the 432A by merely depressing a toggle switch. The time required is so short that the meter can be zeroed easily before each reading if desired, eliminating possible inaccuracy caused by thermistor drift. This feature offers advantages not found in any previous instruments.

DC bridge circuit: four notable advantages stem from the use of dc rather than the conventional 10 kHz bias current in the bridge circuits:

First, because there is no signal emission from the cable or mount, you can make measurements in extremely sensitive circuits without affecting their operation;

Second, meter zeroing is independent of the impedance connected to the RF terminal of the thermistor mount. The mount need not be connected to the signal source during the meter zeroing process;

Third, measurements are not affected by capacitive changes caused by movement of the thermistor mount cable; and,

Fourth, the specified accuracy of 1% is maintained even on the most sensitive range (10 mW or —70 dBm full scale) because the error due to thermoelectric effect is reduced to a negligible level.

Higher accuracy: the 432A offers you 1% accuracy on all power ranges over a wide temperature range, 0° to 55°C. Even higher accuracy, 0.2% ±0.5 μW, can be attained by measuring the output voltage of the thermistor bridges (test points are available on the rear panel of the 432A) with a digital voltmeter and computing the corresponding RF power.

The instrument accuracy is maintained through the utilization of the Effective Efficiency and Calibration Factor* data on each thermistor mount. A front panel control on the 432A is set to the required Calibration Factor or Effective Efficiency to automatically account for the losses introduced in the mount.

More flexibility: the 432A is truly portable because it is small (1/3 module), light, and can be battery-operated. With the optional battery installed, you can operate the 432A for 24 hours without recharging. A built-in power supply makes recharging easy. A carrying case is available as an accessory.

You can use optional thermistor mount cables up to

20 feet long and still maintain 1% accuracy *without* special matching of the bridge circuit. Cables up to 200 feet long can be used if the cable is matched to the bridge circuit.

Due to the exceptional temperature stability of the power meter/thermistor mount, operation over extended time periods is practical without resetting the meter to zero. Thus, long term power level recording is possible. This temperature stability results from the use of dual self-balancing bridges (of which the thermistor mount is a part) in a dc feedback amplifier. One bridge senses the RF power and the other corrects the meter for changes in ambient temperature. A high percentage of feedback ensures extremely stable amplifier operation.

Specifications

Instrument type: automatic, self-balancing power meter for use with temperature-compensated thermistor mount.

Power range: 7 ranges with full-scale readings of 10, 30, 100, and 300 μW, 1, 3, and 10 mW; also calibrated in dBm from −20 dBm to +10 dBm full scale in 5-dB steps.

Accuracy: ±1% of full scale on all ranges (+0° to +55°C).

Calibration factor control: 13-position switch normalizes meter reading to account for thermistor mount Calibration Factor*. Range 100% to 88% in 1% steps.

Thermistor mount: external temperature-compensated thermistor mounts required for operation (HP 486A, 8478B, and 478A series; mount resistance 100 or 200 ohms).

Meter: taut-band suspension, individually computer-calibrated, mirror-backed scales. Milliwatt scale more than 4¼" (108 mm) long.

Zero carryover: less than 0.25% of full scale when zeroed on most sensitive range.

Fine zero: automatic, operated by toggle switch.

Recorder output: 1.000 volt into open circuit corresponds to full-scale meter deflection (1.0 on 0-1 scale) ±0.5%; 1000-ohm output impedance, BNC connector.

RFI: meets all conditions specified in MIL-I-6181D.

Power: 115 or 230 V ac ±10%, 50 to 400 Hz, 2½ watts. Optional rechargeable battery provides up to 24 hours continuous operation. Automatic battery recharge.

Weight: net, 6½ lb (3 kg). Shipping, 9¼ lb (4,2 kg).

Weight with optional battery pack: net, 9¼ lb (4,2 kg). Shipping, 12 lb (5,5 kg).

Dimensions: 5⅛" wide, 6-3/32" high, 11" deep (130 x 155 x 279 mm).

Accessories furnished: 5-ft (1,42-m) cable for Hewlett-Packard temperature-compensated thermistor mounts; 7½ ft (2,29 m) power cable, NEMA plug.

Accessories available:
- 00415-606 Rechargeable Battery Pack for field installation, $80.
- 5060-0797 Rack Adapter Frame, $25 (holds three instruments the size of the 432A).
- 8477A Power Meter Calibrator.
- 11076A, Carrying Case, $45.

Combining cases:
- 1051A, 11¼" (286 mm) deep, $110.
- 1052A, 16⅜" (416 mm) deep, $120.

Options
- 01: Rechargeable battery installed, provides up to 24 hours continuous operation, add $100.

Note: Thermistor mount cable impedance is part of the 432A input bridge circuit. For cables over 20 feet long the bridge is matched to specific cable options, so the various cables should not be interchanged.
- 09: 10-foot (3,05 m) cable for 100-ohm or 200-ohm mount, add $25.
- 10: 20-foot (6,10 m) cable for 100-ohm or 200-ohm mount, add $50.
- 11: 50-foot (15,24 m) cable for 100-ohm or 200-ohm mount, add $100.
- 12: 100-foot (30,48 m) cable for 100-ohm or 200-ohm mount, add $150.
- 13: 200-foot (60,96 m) cable for 100-ohm or 200-ohm mount, add $250.

Price: Model 432A, $495.

8477A Power Meter Calibrator

The 8477A Power Meter Calibrator produces highly accurate dc voltages for verifying full-scale calibrations (for all ranges) plus meter tracking of the 432A Power Meters simply by connecting three cables between the power meter and the calibrator; no additional instruments or charts are needed.

8477A

*"Calibration Factor" and "Effective Efficiency" are figures of merit expressing the ratio of the substituted signal measured by the power meter to the microwave power incident on and absorbed by the mount, respectively. The data supplied with each thermistor mount are traceable to the National Bureau of Standards.

THERMISTOR MOUNTS

Compensated mounts reduce drift

Models 478A, 8478B and 486A

478A, 8478B, and 486A Thermistor Mounts

The HP 432A Power Meter was designed to operate with these thermistor mounts. Each is supplied with Calibration Factor and Effective Efficiency Data, permitting power measurements to be made with absolute accuracy. The data, provided at several points across each band, are traceable to the National Bureau of Standards to the extent allowed by the Bureau's facilities. Thus, mount losses and reflections (that part of the incident power which does not reach the power-sensing thermistor) can be accounted for under all measurement conditions.

The calibration data at points not yet on the NBS schedule are based on interim standards established at Hewlett-Packard after years of designing, manufacturing, and testing thermistor mounts. Literally thousands of tests and measurements have gone into the development of these standards, including cross-checks against NBS-calibrated mounts wherever possible. Thus efficiency data are provided at many points in addition to those on the NBS schedule to facilitate interpolation and help you to make more accurate power measurements more easily. For easy access, these data are affixed directly to each mount.

Both Calibration Factor and Effective Efficiency Data are furnished to provide complete measurement flexibility. Calibration Factor is used as the correction factor for general applications when a tuner is not used; Effective Efficiency is used whenever a tuner is part of the measurement system.

These mounts are temperature-compensated for low drift, permitting measurement of microwave power as low as one microwatt. Thus, the 432A can be zeroed with the mount disconnected from the RF system if the RF power cannot be turned off.

Models 478A and 8478B are designed for 50-ohm coaxial systems. They operate over frequencies from 10 MHz to 10 and 18 GHz respectively. Each presents a good 50-ohm match over its frequency range, and no tuning is required.

The subject of power measurements is covered in detail in Hewlett-Packard Application Note 64, "Microwave Power Measurement." This comprehensive note discusses principles of operation, techniques of measurement, interpretation of results, and accuracy considerations. Application Note 64 is available upon request from any Hewlett-Packard Field Office.

Specifications

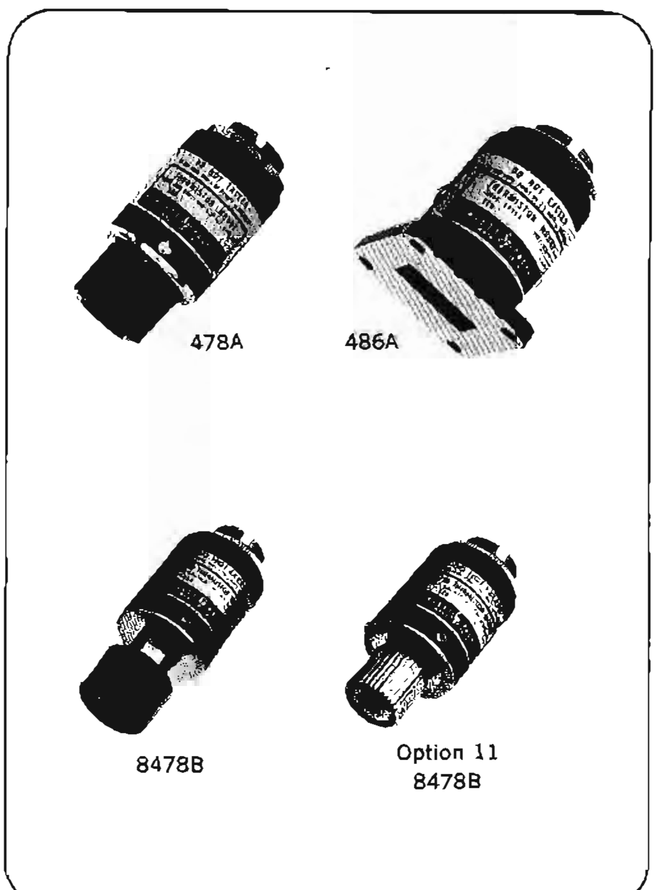
HP Model[1]	Frequency range, GHz	Maximum SWR	Operating resistance (ohms)	Price
478A	10 MHz to 10 GHz	1.75, 10 to 25 MHz 1.3, 25 MHz to 7 GHZ 1.5, to 10 GHz	200	$165
8478B[2]	10 MHz to 18 GHz	1.75, 10 to 30 MHz 1.35, 30 to 100 MHz 1.1, 0.1 to 1 GHz 1.35, 1 to 12.4 GHz 1.6, 12.4 to 18 GHz	200	$300[4]
S486A	2.60 to 3.95	1.35	100	$240
G486A	3.95 to 5.85	1.5	100	$210
J486A	5.30 to 8.20	1.5	100	$200
H486A	7.05 to 10.0	1.5	100	$195
X486A	8.20 to 12.4	1.5	100	$165
M486A	10.0 to 15.0	1.5	100	$250
P486A	12.4 to 18.0	1.5	100	$220
K486A[3]	18.0 to 26.5	2.0	200	$330
R486A[3]	26.5 to 40.0	2.0	200	$395

[1] 11528A Adapter adapts mount to 430 Series Power Meter (thermistor circuit unbalanced, no temperature compensation), $10.

[2] 11527A Adapter adapts 8478B to 431A/B Power Meters (thermistor circuit unbalanced), $25.

[3] Circular flange adapters: K-band (UG-425/U) HP 11515A, $35 each; R-band UG-381/U) HP 11516A, $40 each.

[4] Option 11, furnished with APC-7 RF connector, add $25.



478A

486A

8478B

Option 11 8478B

MICROWAVE POWER METER
Reads directly in mW and dBm, 0.01 to 10mW
Models 430C; 477B, 487 Thermistor Mounts

The HP 430C reads RF power directly in dBM or mW—and completely eliminates tedious computation and troublesome adjustments during operation. The instrument may be used at any frequency for which there are bolometer mounts—and measurements are entirely automatic.

In measuring power, HP 430C uses a bolometer at either 100- or 200-ohm levels. Power is read directly in milliwatts, 0.01 to 10 mW, or in dBm from −20 to +10. Higher powers may be measured by adding attenuators to the system. Directional couplers also may be used to sample energy.

When used in an appropriate bolometer mount, instrument fuses are generally satisfactory for measuring power at frequencies up to 4 GHz. Barretters and thermistors can be used for measurements at much higher frequencies, up to 12.4 GHz for barretters (in HP mounts) and up to 40 GHz for certain thermistors.

Hewlett-Packard waveguide bolometer mounts for the 430C are available covering, collectively, the frequency spectrum from 2.6 to 40 GHz. In addition, the Model 477B Thermistor Mount covers the frequency spectrum from 10 MHz to 10 GHz.

Specifications, 430C

Power range: 5 ranges, front-panel selector; full-scale readings of 0.1, 0.3, 1, 3, and 10 mW; also continuous readings from −20 to +10 dBm.

External bolometer: frequency range depends on bolometer mount; bolometers can operate at resistance levels of 100 or 200 ohms and can have positive or negative temperature coefficients; any dc bias current up to 16 mA is available for biasing bolometers; dc bias current is continuously adjustable and independent of bolometer resistance and power level range.

Accuracy: ±5% of full scale.

Power: 115 or 235 V ±10%, 50 to 400 Hz, 90 W.

Dimensions: cabinet: 7½" wide, 11½" high, 14¼" deep (191 x 292 x 362 mm); rack mount: 19" wide, 7" high, 13⅛" deep behind panel (483 x 178 x 333 mm).

Weight: net 14 lb (6,3 kg), shipping 16 lb (7,2 kg) cabinet); net 18 lb (8,1 kg); shipping 27 lb (12,2 kg) (rack mount).

Accessory available: 11528A Adapter, adapts HP 478A, 486A, 8478B Thermistor Mounts for use with 430C, $10.

Price: HP 430C, $345 (cabinet); HP 430CR, $355 (rack mount).

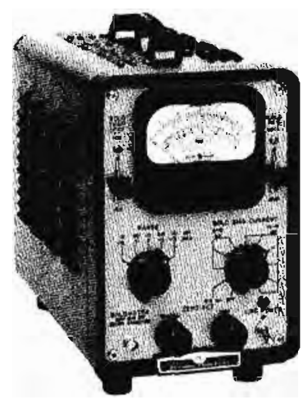
477B Thermistor Mount

This coaxial thermistor mount, designed for use in 50-ohm systems with the HP 430C, covers 10 MHz to 10 GHz with a SWR of less than 1.5. It requires no tuning and employs long-time-constant elements that ensure measurement accuracy—even for low duty cycle pulses. In addition, it is not susceptible to burnout even at 1 watt peak.

Specifications, 477B

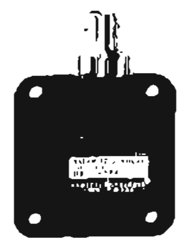
Frequency range: 10 MHz to 10 GHz.

Reflection coefficient: full range, <0.2 (1.5 SWR, 14 dB return loss); 50 MHz to 7 GHz, <0.13 (1.3 SWR, 17.7 dB return loss).



430C

477B



H487B

Power range: 0.01 to 10 mW (with HP 430C).

Element: 200-ohm, negative temperature coefficient thermistor included; approx. 13 mA bias required.

RF connector: Type N male.

Price: HP 477B, $95.

487 Waveguide Thermistor Mounts

Hewlett-Packard Series 487 instruments, for use with HP 430C Power Meters, collectively cover frequencies from 5.3 to 18 GHz. Each 487 series mount covers the full frequency range of its waveguide band and requires no tuning. The long time constant of the mount makes it ideal for measuring average power of low duty cycle pulses. Burnouts are virtually impossible. All models may be used to measure a maximum average power of 10 mW.

Specifications, 487

HP Model	Maximum SWR	Frequency range* GHz	Price
J487B	1.5	5.3 - 8.2	$ 90
H487B	1.5	7.05 - 10.0	$ 80
X487B	1.5	8.2 - 12.4	$100
P487B	1.5	12.4 - 18.0	$135

*HP 486A Waveguide Thermistor Mounts are available in S- through R-band (2.6 to 40 GHz); 11528A Adapter required.

PEAK POWER CALIBRATOR

Power measurements, 50 to 2000 MHz, to ±0.6dB

Model 8900B

Features

- Measures true peak power ±0.6 dB absolute
- Measurement completely independent of repetition rate and pulse width (>0.25 μsec)
- Readily standardized against external bolometer or calorimeter
- Incorporates wide-band (7 MHz) detector output for pulse monitoring

The HP 8900B Peak Power Calibrator provides a convenient means for measuring the peak RF power of pulses in the range from 50 to 2000 MHz. The power level is read out directly on the panel meter and is completely independent of repetition rate and pulse width (>0.25 μsec). The instrument consists basically of a precision terminated input circuit, diode detector, dc reference supply, meter and a chopped video output system.

In operation, the RF signal is applied to the input circuit, which, through a power splitter, feeds the diode detector. The demodulated diode output and the output of the dc reference supply are simultaneously fed to the video output through a mechanical chopper. In making a measurement, a suitable external oscilloscope is connected to the video output, and the dc reference voltage is adjusted so that it is exactly equal to the peak value of the demodulated pulse.

Panel meter readout

The level of the required dc reference voltage is then indicated on the panel meter, calibrated to read peak RF power. The diode is operated in a biased condition for maximum stability of calibration. Provision is made, however, for readily standardizing the instrument against an external bolometer or calorimeter by simply connecting to a rear-panel output in place of a standard termination.

Specifications

Radio frequency measurement characteristics

RF range: 50 to 2000 MHz.

RF power range: 200 mW peak full scale (may be readily increased through use of external attenuators or directional couplers).

RF power accuracy: ±1.5 dB (±0.6 dB with custom calibration curve furnished with instrument).

RF power precision: 0.1 dB.

RF pulse width: >0.25 μs.

RF repetition rate: 1.5 MHz maximum.

RF impedance: 50 ohms.

RF vswr: <1.25.

Monitor output

Level: >0.2 volt for 20 mW input (nominal).

Impedance: 150 ohms nominal.

Bandwidth: >7 MHz.

Physical characteristics

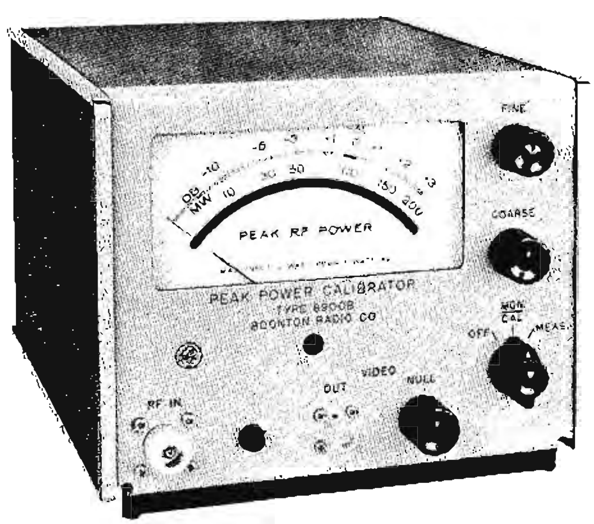
Dimensions: 7¾" wide, 6⅛" high, 11" deep (197 x 156 x 279 mm).

Weight: net 10 lbs (4,5 kg); shipping 13 lbs (5,9 kg).

Power: 105 to 125 or 210 to 250 volts, 50 to 60 Hz.

Price: HP 8900B, $625 (includes calibration curve).

Option 01: calibrated and offset for use with 8925A DME/ATC Test Set; no additional charge.



8900B

RUGGEDIZED POWER METER

Accurate power measurements, 10 MHz to 40 GHz

Model C34-431C

The Power Meter C34-431C—a militarized version of the highly successful 431C Power Meter—was specially developed by Hewlett-Packard as the Wattmeter Absorption CT495 for the Navy and Army Departments of the Ministry of Defence, U.K. While it fully retains the electronic accuracy of the 431C, the Model C34-431C has been ruggedized to meet the climatic, shock and vibration tests of DEF-133, Table N.1 (where applicable). In addition, the C34-431C has the important advantage that it can function in 75-ohm coaxial systems.

The Power Meter C34-431C, together with its companion 478A, 486A and 8478B Thermistor Mounts, enables you to make microwave power measurements with standards-laboratory accuracy. You have complete confidence in the accuracy of your measurements because all sources of error are taken into consideration. Thermistor Mount efficiency, stated as both Effective Efficiency and Calibration Factor, is given with each 478A, 486A and 8478B Thermistor Mount, and the C34-431C itself affords high instrumentation accuracy (better than 1% of full scale on most ranges)—thus the characteristics of the measurement system are known from thermistor mount input to power meter readout.

Thermistor mount efficiency plays a very significant role in determining overall measurement accuracy, and the C34-431C provides a convenient method of using the efficiency data imprinted on each mount. The C34-431C includes a front-panel Calibration Factor control, calibrated from 88% to 100% in 1% steps, which nomalizes the meter reading to allow for the efficiency correction factor of the mount. Simply set the control and read the meter; no calculations are required.

Specifications

Instrument type: automatic self-balancing power meter.

Power range: 8-position switch provides null and 7 ranges with full-scale readings of 10, 30, 100, and 300 μW, 1, 3, and 10 mW; also calibrated in dBm from −20 dBm to +10 dBm full scale in 5-dB steps.

Accuracy:

(+20°C to +35°C)
±1% of full scale (100 μW range and above),
±1.5% of full scale (30 μW range),
±2% of full scale (10 μW range).
(0°C to +55°C)
±3% of full scale (all ranges).

Calibration factor control: 13-position switch normalizes meter reading to allow for thermistor mount Effective Efficiency or Calibration Factor. Range: 88% to 100% in 1% steps.

Thermistor mount input: external tempertaure-compensated thermistor mounts required for operation (HP 478A, 486A or 8478B). Connection through 6-contact socket (Pleassey Mk.4).

Mount resistance control: 4-position switch permits operation with mounts of different operating resistances. Range: 100 ohm (WG), 200 ohm (50Ω coax), 300 ohm (75Ω coax) and 200 ohm balanced (coax).

Meter: taut-band suspension; individually calibrated mirror-backed scales with calibration in mW (0-1 and 0-3) and dBm (−10 to 0).

Zero carryover: less than 1% of full scale when zeroed on most sensitive range (.01 mW).

Zero balance: continuous control above zero point. Range below zero is equivalent to at least 2% of full scale.

DC calibration input: permits dc substitution method of power measurement and precise dc calibration of instrument with HP 8420B Power Meter Calibrator. Connection through female coaxial connector (BNC).

Power supply: 115 or 230 volts ±10%, 50 to 400 Hz, 2.5 watts. Connection through 3-contact plug (Plessey Mk.4). As option, rechargeable 24-volt battery provides up to 24 hours continuous portable operation.

Dimensions:

Height: 12.6″ (31.9 cm)—with feet 13.1″ (33.3 cm).
Width: 8.6″ (21.7 cm).
Depth: 9.7″ (24.5 cm)—with feet 10.2″ (25.9 cm).

Weight: net, 15 lb (6,8 kg); with battery 17.5 lb (7,9 kg). Shipping, 20 lb (9,1 kg); with battery 22.5 lb (10,2 kg).

Price: HP Model C34-431C (NSN: 6625-99-519-8443), excluding Thermistor Mount Cable and Power Cable, $810 at factory in Scotland. (Available only in Western Europe.)

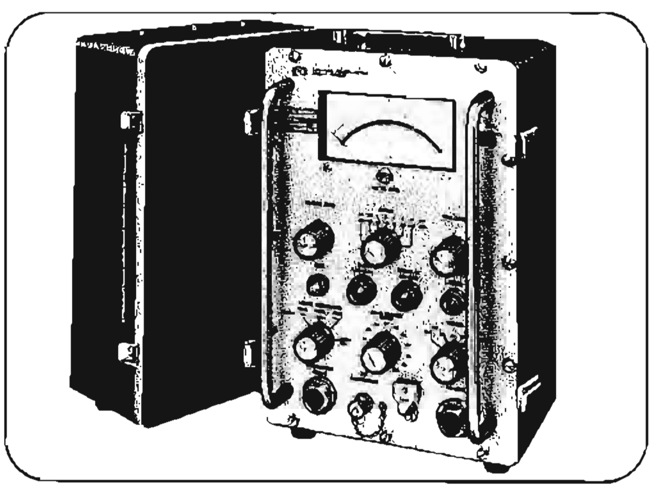
Option 01: HP 00415-606 Rechargeable Battery Pack installed, $110. ($100. at factory in Scotland).

Available: HP 15527A Thermistor Mount Cable (NSN: 6625-99-520-0905), 5 ft (152 cm) long, with 6-contact female connector (Amphenol) and 6-contact plug (Plessey Mk.4), $30.00.

HP 8120-0601 Power Cable (NSN: 5995-99-940-0491), 9 ft (274 cm) long, with 5-amp 3-contact (round) plug and 3-contact socket (Plessey Mk.4), $3.00.

HP 15529A Power Cable, 7.5 ft (229 cm) long, with 3-prong plug (NEMA) and 3-contact socket (Plessey Mk.4), $3.00.

HP 8402B Power Meter Calibrator, $475.00.



CALORIMETRIC POWER METER
Just connect, read power 10 mW to 10 watts
Model 434A

With the 434A, measurement is literally as simple as connecting to a 50-ohm Type N front-panel terminal and reading power directly. The instrument has only two simple front-panel controls and is ideal for use by nontechnical personnel.

Model 434A fills the important range between bolometer-type microwave power meters such as HP 432A and conventional calorimeters whose lower range is approximately 10 watts. But, unlike previous cumbersome and costly equipment suggested for this range, the HP 434A is completely self-contained and requires no external detectors. In addition, the wider frequency response permits the unit to be conveniently calibrated by the application of a known dc power.

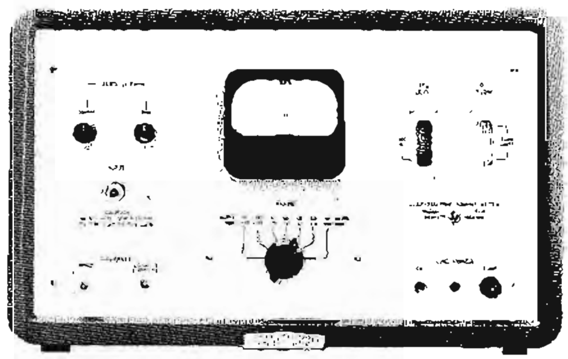
Rapid response time

Model 434A employs a self-balancing bridge and a high-efficiency heat transfer system to and from an oil stream to provide a full-scale response time of 5 seconds or less. This fast reaction, a fraction of the response time needed by ordinary calorimeters, means the 434A quickly follows small power changes, such as may be encountered in tuning.

Basically, the Model 434A consists of a self-balancing bridge which has identical temperature-sensitive resistors (gauges) in two legs, an indicating meter and two load resistors, one for the unknown input power and one for the comparison power. The input load resistor and one gauge are in close thermal proximity so that heat generated in the input load resistor heats the gauge and unbalances the bridge. The unbalance signal is amplified and applied to the comparison load resistor which is in close thermal proximity to the other gauge so that the heat generated in the comparison load resistor is transferred to its gauge and nearly rebalances the bridge.

The meter measures the power supplied to the comparison load to rebalance the bridge. The characteristics of the gauges are the same, and the heat transfer characteristics from each load are the same, so the power dissipated in each load is the same, and the meter may be calibrated directly in input power.

The power measurement is accurate because the flow rates through the two heads are the same and the oil enters the heads at nearly the same temperature. To ensure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger just before entering the heads. Identical flow rates are obtained by placing all elements of the oil system in series.



434A

Specifications

Input power range: seven meter ranges; full-scale readings of 0.01, 0.03, 0.1, 0.3, 1, 3 and 10 watts; meter scale also calibrated from −10 to 0 dBW, providing continuous readings from −30 to +10 dBW; power range can be extended upward with attenuators or directional couplers.

Maximum input power: 1 kW peak; 10 watts average.

Frequency range: dc to 12.4 GHz.

Accuracy: within ±5% of full scale; includes dc calibration and RF termination efficiency but not mismatch loss; greater accuracy can be achieved through appropriate techniques.

Estimated attainable accuracy

	Upper ranges	Two lowest ranges
DC	0.5%	2%
0 to 1 GHz	1%	3%
1 to 4 GHz	2%	4%
4 to 10 GHz	3%	5%
10 to 12.4 GHz	4%	5%

DC input resistance: 50 ± 5 ohms at Type N input jack.

Reflection coefficient: dc to 5 GHz, <0.13 (1.3 SWR, 17.7 dB return loss); 5 to 11 GHz, <0.2 (1.5 SWR, 14 dB return loss); 11 to 12.4 GHz, <0.26 (1.7 SWR, 11.7 dB return loss).

Meter response time: less than 5 seconds for full-scale deflection.

Internal calibrator: 100 mW dc ±1% into 45 to 55 ohms.

Power: 115 or 230 volts (specify) ±10%, 50 to 60 Hz approximately 180 watts with no input, 200 watts with 10 watts input.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14" deep (527 x 324 x 356 mm); rack mount: 19" wide, 10-15/32" high, 13½" deep behind panel (483 x 266 x 343 mm).

Weight: net 49 lb (22,1 kg), shipping 59 lb (26,6 kg) (cabinet); net 43 lb (19,4 kg), shipping 56 lb (25,2 kg) (rack mount).

Accessories available: 281A,B Waveguide-to-Coax Adapters (see page 312); K02-434A DC Test Set (for more accurate power measurements), $1025.

Price: HP 434A, $1750 (cabinet); HP 434AR, $1735 (rack mount).

SWR METER

Reduced noise for greater usable range

Model 415E

The Hewlett-Packard Model 415E SWR Meter is a low-noise tuned amplifier-voltmeter calibrated in dB and SWR for use with square-law detectors. It is an extremely useful and versatile instrument, measuring SWR, attenuation, gain, or any other parameter determined by the ratio of two signal levels. The standard tuned frequency is 1000 Hz and is adjustable over a range of about 7% for exact matching to the source modulation frequency. Amplifier bandwidth is also adjustable, from 15 to 130 Hz. The narrow bandwidth facilitates single-frequency measurements by reducing noise, while the widest setting accommodates a sweep rate fast enough for oscilloscope presentation.

The 415E has a very low noise figure, less than 4 dB. This represents a 6 to 10 dB improvement over other SWR meters. Equally significant is the fact that the noise figure has been optimized for source impedances presented by detectors most often used with SWR meters. As a result the 415E has greater measurement range because the reduction in noise permits the measurement of lower-level signals for a given signal-to-noise ratio.

A precision 60-dB attenuator with an accuracy of 0.05 dB/10 dB assures high accuracy in attenuation measurements. In addition, an expand-offset feature allows any 2-dB range to be expanded to full scale for maximum resolution. Linearity on the expanded ranges is ±0.02 dB, permitting full utilization of the increased resolution; high accuracy is possible on the normal scales as well, for linearity is limited only by meter resolution. The meter itself has individually calibrated, mirror-backed scales plus a rugged taut-band movement for full realization of the inherently high accuracy, resolution, and linearity of the instrument.

The Model 415E operates with either crystal or bolometer detectors. Both high- and low- impedance inputs are available for crystal detectors (see page 307), optimum crystal source impedances being 50 to 200 and 2500 to 10,000 ohms respectively. For operation with bolometers, the 415E provides precise bias currents of 4.5 and 8.7 mA into 200 ohms, as selected at the front panel. This bias is peak-limited for positive bolometer protection.

Both ac and dc outputs are provided for use of the 415E as a high-gain tuned amplifier and with recorders. The solid-state 415E can be operated with an internally mounted battery pack (optional extra) for completely portable use or to eliminate ground loops.

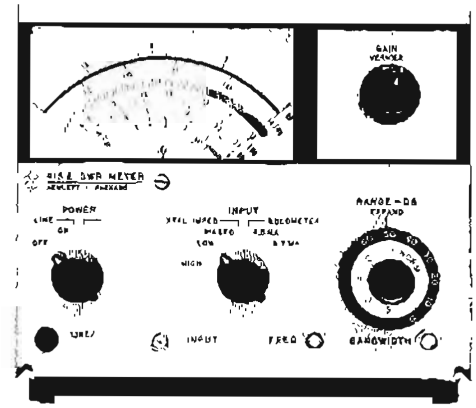
Specifications

Sensitivity: 0.15 μV rms for full-scale deflection at maximum bandwidth (1 μV rms on high impedance crystal input).

Noise: at least 7.5 dB below full scale at rated sensitivity and 130 Hz bandwidth with input terminated in 100 or 5000 Ω; noise figure less than 4 dB.

Range: 70 dB in 10- and 2-dB steps.

Accuracy: ±0.05 dB/10-dB steps; maximum cumulative error between any two 10-dB steps, ±0.10 dB; maximum cumulative error between any two 2-dB steps, ±0.05 dB; linearity, ±0.02 dB on expand scales, determined by inherent meter resolution on normal scales.



415E

Input: unbiased low and high impedance crystal (50-200 and 2500-10,000 Ω optimum source impedance respectively for low noise); biased crystal (1 V into 1 kΩ); low and high current bolometer (4.5 and 8.7 mA ±3% into 200 Ω), positive bolometer protection; input connector, BNC female.

Input frequency: 1000 Hz adjustable 7%; other frequencies between 400 and 2500 Hz available on special order.

Bandwidth: variable, 15-130 Hz; typically less than 0.5 dB change in gain from minimum to maximum bandwidth.

Recorder output: 0-1 V dc into an open circuit from 1000 Ω source impedance for ungrounded recorders; output connector, BNC female.

Amplifier output: 0-0.3 V rms (Norm), 0-0.8 V rms (Expand) into at least 10,000 Ω for ungrounded equipment; output connector, dual banana jacks.

Meter scales: calibrated for square-law detectors; SWR: 1-4, 3.2-10 (Norm); 1-1.25 (Expand). dB: 0-10 (Norm); 0-2.0 (Expand); battery: charge state.

Meter movement: taut-band suspension, individually calibrated mirror-backed scales; expanded dB and SWR scales greater than 4¼ in. (108 mm) long.

RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D.

Power: 115-230 V ±10%, 50-400 Hz, 1 W; optional rechargeable battery provides up to 36 hr continuous operation.

Dimensions: 7²⁵⁄₃₂ in. wide, 6³⁄₃₂ in. high, 11 in. deep from panel (190 x 155 x 279 mm).

Weight: net, 9 lb (4 kg), 11 lb (5 kg) with battery; shipping, 10 lb (4,5 kg), 13 lb (6,3 kg) with battery.

Accessory available: 11057A Handle, fits across top of instrument for carrying convenience, $5.

Combining cases: 1051A, 11¼ in. (286 mm) deep, $110; 1052A, 16¾ in. (416 mm) deep, $120.

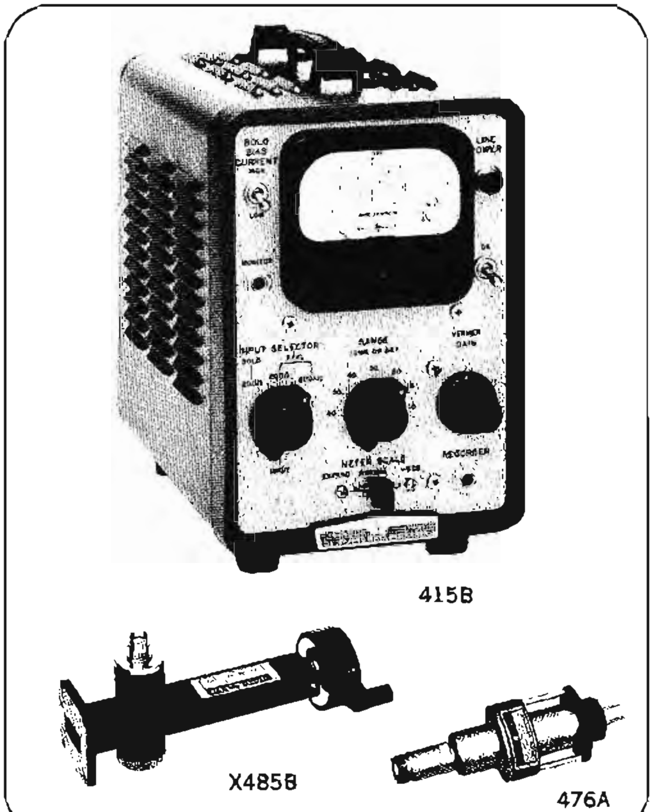
Price: HP Model 415E, $375.

Options: 01. rechargeable battery installed, add $100; 02. rear-panel input connector in parallel with front-panel connector, add $15.

SWR INDICATOR; MOUNTS

For convenient SWR measurements

Models 415B; 476A, 485B



415B

X485B

476A

415B Standing Wave Indicator

Similar to the HP 415E, this meter is a tuned voltmeter for SWR measurements with HP slotted lines and detector mounts. It also is useful as a null indicator for bridge measurements, with a 200 kΩ input circuit for this use.

A 60-dB attenuator adjustable in 10-dB range steps provides a calibrated range of 70 dB. An output is provided for use with a recording milliammeter, and a special 5-dB attenuator is incorporated to increase resolution through use of the upper portion of the logarithmic meter scale.

Inputs include a 200-ohm termination with bias of 4.3 or 8.7 mA for bolometers, unbiased for crystals, or a 200 kΩ load for null measurements. A jack and monitor cable are provided for connecting an external milliammeter to measure bolometer current.

Specifications, 415B

Input: "Bolo" (200 ohms), bias provided for 8.7 or 4.3 mA bolometer or 1/100 amp fuse; "Crystal" (200 ohms) for crystal rectifier; "Crystal" (200 kΩ) high impedance for crystal rectifier as null detector; BNC connector.

Sensitivity: 0.1 μV at 200 ohms for full-scale deflection.

Noise: at least 5 dB below full scale when operated from 200-ohm resistor at room temperature.

Frequency: 1000 Hz ±2%; other frequencies, 315 to 2020 Hz, available on special order; should not be harmonically related to power line frequency.

Bandwidth: 30 Hz (nominal).

Range: 70 dB; input attenuator provides 60 dB in 10-dB steps, accuracy ±0.1 dB per 10-dB step; maximum accumulative error, ± 0.2 dB.

Scale selector: "Normal", "Expand" and "—5 dB".

Output: jack provided for recording milliammeter having 1 mA full-scale deflection and internal resistance of 1500 ohms or less.

Meter scales: SWR 1 to 4, SWR 3 to 10, expanded SWR 1 to 1.3; dB 0 to 10, expanded dB 0 to 2.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 55 watts.

Dimensions: cabinet: 7½" wide, 11¾" high, 12½" deep (191 x 299 x 318 mm); rack mount: 19" wide, 6-31/32" high, 10⅞" deep behind front panel (483 x 177 x 276 mm).

Weight: net 14 lb (6,3 kg), shipping 15 lb (6,8 kg) (cabinet); net 17 lb (7,7 kg), shipping 27 lb (12,2 kg) (rack mount).

Accessories available: plug-in filters (specify frequency): 415B-42B (315 to 699 Hz), $60, and 415B-42C (700 to 2000 Hz), $50; 10501A Cable Assembly, $4; 10503A Cable Assembly, $7.

Price: HP 415B, $310 (cabinet); HP 415BR, $320 (rack mount).

476A Bolometer Mount

Model 476A Bolometer Mount covers the 10 MHz to 1 GHz frequency range with very low standing-wave ratios. The inherently good square-law characteristics of the bolometers used make the 476A especially useful for calibrating attenuators when used with an HP 415 Series Meter.

Specifications, 476A

Nominal impedance: 50 ohms.

Reflection coefficient: 50 to 500 MHz, ≤0.07 (1.15 SWR, 23.1 dB return loss); 25 to 1000 MHz, ≤0.11 (1.25 SWR, 19.1 dB return loss); 10 to 25 MHz, ≤0.2 (1.5 SWR, 14 dB return loss).

Maximum power level: 10 mW.

Bolometer element: four 8.25 mA instrument fuses (supplied with mount); operating level is approximately 200 ohms, positive temperature coefficient.

Replacement elements: Part #2110-0024, $1.50 each.

Weight: net ½ lb (0,3 kg); shipping 2 lb (0.9 kg).

Price: HP 476A, $85.

485B Detector Mounts

The HP 485B Detector Mounts (5.3 to 12.4 GHz) permit the accurate matching of waveguide sections to a bolometer element. The mounts are tuned by a variable short, and they can be used with a barretter or, where SWR is not critical, with a silicon crystal.

Specifications, 485B[1]

HP Model	Frequency range (GHz)	Maximum SWR[2]	Fits waveguide size (in.)	(EIA)	Length (in.)	(mm)	Price
J485B[3]	5.85 - 8.2 5.50 - 5.85 5.30 - 5.50	1.25 1.35 1.50	1½ x ¾	WR137	8⅜	213	$120
H485B[3]	7.05 - 10	1.25	1¼ x ⅝	WR112	6⅜	162	$100
X485B[3]	8.2 - 12.4	1.25	1 x ½	WR90	6-7/16	163	$100

[1] Detector elements are not supplied
[2] With Narda N821 barretter
[3] May use 1N21 or 1N23 for maximum detection sensitivity where SWR is not critical

KLYSTRON POWER SUPPLIES

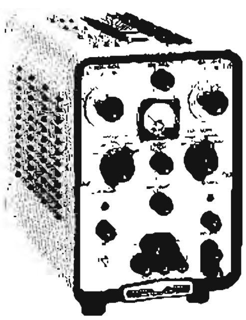
Versatile power sources for many klystrons

Models 715A, 716B

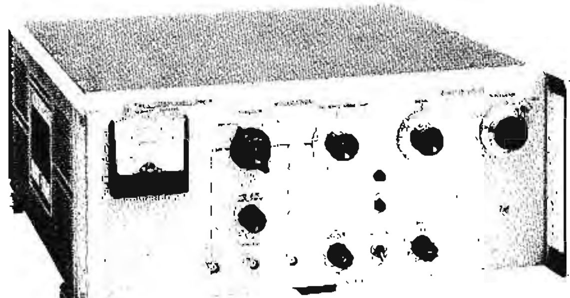
The HP 716B Supply offers superior regulation, noise, ripple and hum characteristics, plus the broad capability of powering at least 250 types of klystrons. Beam and reflector voltages are closely regulated and continuously adjustable, using calibrated controls accurate to within ±2% on beam voltage and to within 0.5% ±1 volt on repeller voltage. In addition, a regulated dc filament supply minimizes residual FM and AM from the klystrons.

The reflector supply can be internally modulated with a sawtooth for FM or with a square wave for on-off operation. The positive excursion of the square wave is clamped to the reflector voltage, simplifying setup and minimizing double moding. Sawtooth and external modulation are ac-coupled to the reflector. A protective diode prevents the klystron reflector voltage from becoming positive with respect to the cathode. Special circuitry eliminates turn-on transients that could be harmful to the klystron. Relays disconnect the beam supply to prevent klystron failure should the filament voltage drop below 1 volt or rise above 9 volts. The filament circuit in the 716B is protected against voltage surges up to 800 volts. These relays also disconnect the supplies whenever a klystron filament short circuits.

The HP 715A, designed to operate many types of low-power klystrons, offers a regulated 250-to-400 volt beam voltage, a 0-to-900 volt regulated reflector supply and a 6.3 volt ac filament supply. The reflector supply can also be square-wave modulated internally at the nominal frequency of 1000 Hz, externally modulated or sine-wave modulated at the power line frequency. Klystron protection is built in.



715A



716B

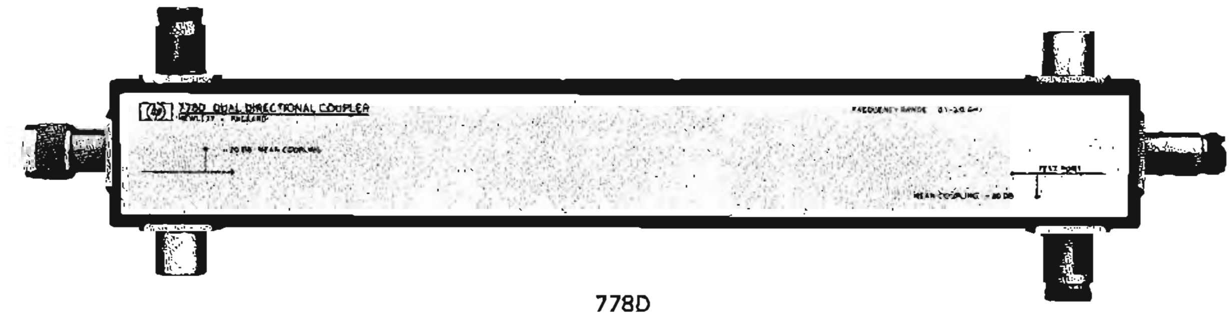
	Specifications, 715A	Specifications, 716B
Reflector supply	0 to 900 V neg. with respect to beam supply, calibrated voltage controls; regulation within 1% ±10% line voltage variation; ripple <10 mV; 10 μA max.	0 to 800 V neg. with respect to beam supply, accuracy ±0.5% of dial reading ±1 V, line regulation better than 0.05%; ripple <500 μV
Beam supply	250 to 400 V negative with respect to chassis ground, calibrated voltage controls; current 30 mA max. at 250 V, 50 mA max. at 400 V; regulation better than 1%, no load to full load or for ±10% normal line voltage variation; ripple less than 7 mV	250 to 800 V negative with respect to chassis ground, accuracy ±2% of dial reading; current 100 mA max.; line regulation better than 0.1%; load regulation better than 0.05%; ripple less than 1 mV
Filament supply	6.3 V ac, 1.5 amp maximum	6.3 V dc, adjustable nominally between 5 and 9 volts, isolated from ground; current 0 to 2 amps; 2 amps max. available to 6.5 V, decreasing to approx. 150 mA at 9 V, ripple <2 mV; line regulation better than 1% with ±10% line change
Internal modulation	square wave: 1000 ±100 Hz, adjustable; 0 to 110 V p-p, negative from reflector voltage; less than 10 μsec rise and decay times; sinusoidal power line frequency, 0 to 350 V p-p	square wave: 400 Hz to 2.5 kHz; 0.1% short-term stability; 10 to at least 150 V p-p, negative from reflector voltage; 5 μsec rise time; external sync of internal square wave 10 V peak, 500 kΩ nominal input impedance; sawtooth: 75 Hz nominal, 0 to at least 150 V nominal p-p, ac-coupled to reflector
External modulation	terminals provided; input impedance 100 kΩ	max. input 200 V p-p; input impedance 500 kΩ, 100 pF nominal
Oscilloscope output		with internal square-wave modulation: 1 V p-p min. for scope sync. 600 ohms output impedance; with internal sawtooth modulation: 10 V p-p min. for scope sweep, 50 kΩ output impedance
Meter	monitors beam current 0 to 50 mA	monitors beam current 0 to 100 mA
Power	115 V ±10%, 50 to 60 Hz, 200 W	115/230 V switch ±10%, 50 to 60 Hz, 200 to 350 W
Dimensions	7⅜" wide, 11½" high, 13¾" deep (187 x 292 x 349 mm)	16¾" wide, 6-25/32" high, 16⅜" deep (425 x 172 x 416 mm); hardware furnished for rack mounting
Weight	net 19 lbs (8,6 kg); shipping 24 lbs (10,8 kg)	net 46 lbs (20,7 kg); shipping 62 lbs (28,3 kg)
Accessories furnished	715A-16C shielded output cable, for connection to klystron	6′ cable, terminated end mates with 716B (one furnished with instrument) HP Stock No. 00716-61601, $25
Price	HP 715A, $400; 50 to 60 Hz input	HP 716B, $925

Manufactured by Yokogawa Hewlett-Packard Ltd., Tokyo.

BROADBAND COAX COUPLERS

Multi-Octave coverage with high directivity

778D, 779D



778D

778D dual directional coupler

The HP 778D is a 20-dB dual directional coupler with a frequency range of 100 MHz to 2 GHz. High directivity (36 dB below 1 GHz, 32 dB above) and close tracking (typically 0.7 dB and 4°) of the auxiliary arms make it ideal for reflectometer measurements of complex reflection coefficient. Maximum errors in such measurements are:

Freq. Range (GHz)	Maximum Magnitude Error $\Delta\Gamma_L$	
	Swept Frequency	Fixed Frequency
0.1-1	$\pm(0.015+0.02\,|\Gamma_L|+0.05\,|\Gamma_L|^2)$	$\pm(0.015+0.05\,|\Gamma_L|^2)$
1-2	$\pm(0.025+0.02\,|\Gamma_L|+0.05\,|\Gamma_L|^2)$	$\pm(0.025+0.05\,|\Gamma_L|^2)$

Maximum phase error $= \pm \sin^{-1}(\Delta\Gamma_L/\Gamma_L)$.
$|\Gamma_L|$ = reflection coefficient of unknown.

Errors include directivity, source match, and tracking, but do not include any detection errors. They are also based on the following conditions: auxiliary arms terminated in matched loads, the mean of open- and short-circuit readings set to 1.0, and the short-circuit phase measured over a band of frequencies and the mean set to 180°.

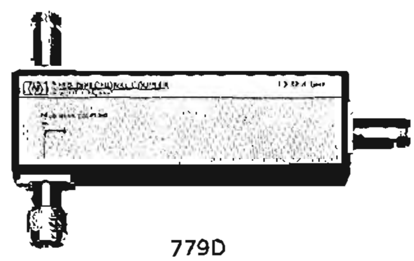
Although the coupling factor increases 6 dB/octave below 100 MHz, directivity remains 36 dB. Thus, the coupler can be used below 100 MHz as well as above.

To accommodate test devices with Type N or APC-7 connectors, a choice of TEST PORT (RF output) connectors is available as indicated in the specifications. With an APC-7 TEST PORT connector the coupler can be adapted to other types of connector. Adapters to OSM®, TNC, NC, GR900, and others are available.

®Omni-Spectra, Inc.

779D directional coupler

Representing the latest achievement in broadband coaxial couplers, the HP 779D spans more than two octaves from 1.7 to 12.4 GHz with 30-dB directivity below 8 GHz and 26-dB to 12.4 GHz. With increased coupling factor (typically 24 dB) but directivity still 30 dB, the 779D is useful down to 500 MHz. Upper frequency usefulness extends to 18 GHz with a like increase in coupling factor and directivity reduced to about 15 dB.



779D

The 779D is normally supplied with Type N connectors on all ports, as detailed in the table of specifications below. These connectors are stainless steel for long wear and are compatible with all connectors whose dimensions conform to MIL-C-39012 or MIL-C-71. On special order, a precision 7 mm APC-7 connector can be supplied on any, or all, port(s).

778D, 779D Specifications

HP Model	Frequency Range (GHz)	Coupling Attenuation	Coupling Variation	Directivity	SWR	Max Input	Connectors[2]	Length in (mm)	Price
778D	0.1-2	20 dB nominal	±1 dB[1]	Inc. port: 36 dB, 0.1-1GHz, 32 dB, 1-2GHz Refl. port: 30 dB	1.1 all ports	50 W avg, 10 kW pk	Pri line[3]: N-male input, N-female output Aux arms: N-female	16¾ (425)	$450 Opt 11: $475 Opt 12: $450
779D	1.7-12.4	20 dB ±0.5 dB	<±0.75 dB	30 dB min, 1.7-8 GHz; 26 dB min, 8-12.4 GHz	1.1 all ports	50 W	Pri line[4]: N-male input N-female output Aux arms: N-female	7¾ max (197)	$550 Opt 010: $550

[1] Auxiliary outputs typically track within 0.7 dB and 4°.
[2] All Type N connectors stainless steel, compatible with MIL-C-39012 and MIL-C-71.
[3] Option 11: APC-7 output, N-female input.
Option 12: N-male output, N-female input.
[4] Option 010: N-female input, N-male output. Also, APC-7 on any or all port(s) on special order.

DIRECTIONAL COUPLERS
High directivity—low SWR
770, 780, 790 Series

770 Dual Directional Couplers

The economical HP 774D-777D Couplers cover frequency spreads of more than two-to-one, each centered on one of the important VHF/UHF bands. With their high directivity, these couplers are ideal for reflectometer applications. Reflectometers can save appreciable time in the design and manufacture of broadband antennas, ECM equipment, television receivers and transmitters, etc. The close tracking of the auxiliary arms makes these couplers particularly useful for reflectometers driven by externally-leveled sweep oscillators such as the HP 8690 series. The forward signal is detected and used to level the output of the sweep oscillator while the reflected signal, after detection, is applied to a display device such as an oscilloscope or graphic recorder. Changes in the leveled power due to the coupling variation in the forward arm are virtually cancelled by a similar coupling variation in the reverse arm.

The couplers are also capable of materially improving the speed and accuracy of power measurements because of their accurate coupling and low SWR. The units are capable of handling fairly high amounts of power and have low insertion loss so they can be permanently installed in coaxial lines for continuous monitoring. Also, a power meter can be alternately connected to the "incident" and "reflected" ports to aid in adjusting for maximum forward power.

780 Directional Detectors

The HP 780-series Directional Detectors are directional couplers with built-in crystal detectors. The couplers have flat frequency response and good directivity, while the detectors also have good frequency response plus high sensitivity. The configuration of the directional detector reduces the number of ambiguities over the standard system of separate coupler and detector and makes possible tighter correlation between main-arm power and detected signal.

The directional detector is well-suited to closed-loop leveling applications, for it permits establishment of a leveled-power point anywhere in a system irrespective of the characteristics of intervening cables, connectors, etc.

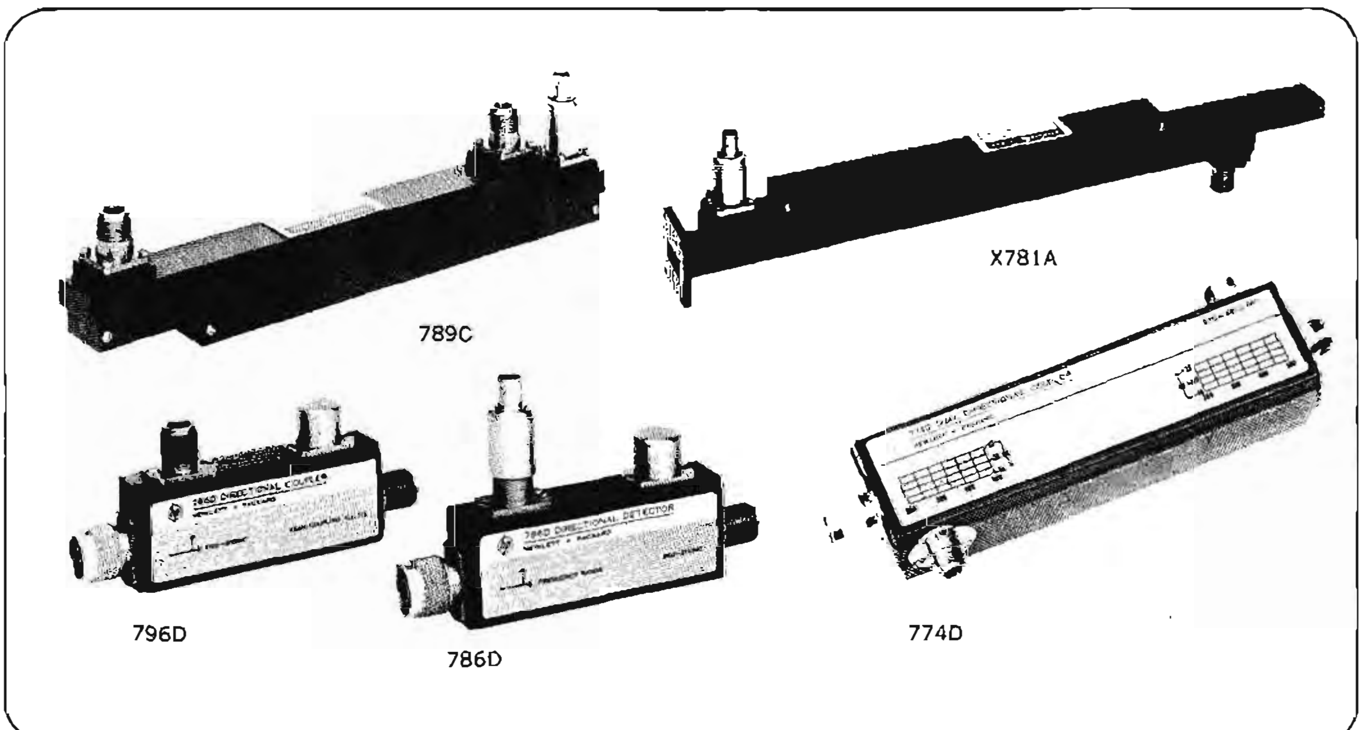
These directional detectors can also be used to monitor power, with a voltmeter or oscilloscope indicating detected output. For applications where conformance to square law is important, factory-selected load resistors can be supplied.

The 786D, 787D, 788C, and 789C are strictly coaxial devices, both RF connectors being Type N. The X781A is a hybrid, having a Type N RF input connector and a waveguide cover flange RF output. The X781A is intended for monitoring or leveling the output of a signal source with a coaxial output when it is being used to drive a waveguide system.

Detector elements can be replaced without special tools or procedures. Type N connectors are stainless steel for long wear.

790 Directional Couplers

The 790 Directional Couplers are ultra-flat, high directivity couplers which are ideal for power-monitoring applications in coaxial systems. Output coupling (ratio of output power from main and auxiliary arms) is specified rather than coupling factor. Thus, no corection factor is required to account for insertion and coupling losses in the main arm.



Specifications, 774D — 777D

HP Model	774D	776D	778D	777D
Frequency range	215 to 450 MHz	450 to 940 MHz	940 to 1900 MHz	1900 to 4000 MHz
Minimum directivity[1]	40 dB	40 dB	40 dB	30 dB
Coupling attenuation (each auxiliary arm)	20 dB	20 dB	20 dB	20 dB
Accuracy of coupling (each auxiliary arm)	mean coupling level within 0.5 dB of specified values			
Max. coupling variation (50-ohm terminations)	±1 dB	±1 dB	±1 dB	±0.4 dB
Auxiliary arm tracking[2]	——	——	≤0.3 dB	≤0.5 dB
Max. primary line SWR[1] (50-ohm terminations)	1.15	1.15	1.15	1.2
Max. auxiliary arm SWR (50-ohm terminations)	1.2	1.2	1.2	1.25
Power-handling capacity	50 watts avg. 10 kW peak	50 watts avg. 10 kW peak	50 watts avg. 10 kW peak	50 watts avg. 10 kW peak
Primary line insertion loss	0.3 dB max.	0.4 dB max.	0.35 dB max.	0.75 dB max.
Primary line connectors	Type N, one male, one female[3]			
Auxiliary arm connectors	Type N, female[3]			
Accessories available	11511A Type N Female Shorting Jack, $4; 11512A Type N Male Shorting Plug, $5			
Length	9-1/16" (230 mm)	9-1/16" (230 mm)	6-5/16" (161 mm)	8-7/8" (225 mm)
Shipping weight	4 lb (1,8 kg)	4 lb (1,8 kg)	3 lb (1,4 kg)	3 lb (1,4 kg)
Price	$225	$225	$225	$275

[1] Measured with HP 907A Sliding Termination or H01-909A Termination.
[2] Maximum change in the coupling curve of one auxiliary arm relative to the other.
[3] Compatible with connectors whose dimensions conform to MIL-C-39012 or MIL-C-71.

Specifications, 780 Series

HP Model	Frequency range (GHz)	Freq. resp. (dB)[1]	Low-level sens. (μV/μWCW)	Directivity (dB)[1]	Equiv. source SWR[2]	Max. SWR	Max. input (W, peak or avg.)	Max. insertion loss (dB)	Length (in)	Length (mm)	Shipping weight (lb)	Shipping weight (kg)	Price
786D	0.96 to 2.11	±0.2	>4	30	1.13	1.15	10	0.4	6	152	2	0,9	$300
787D	1.9 to 4.1	±0.2	>4	26	1.16	1.15	10	0.5	4⅞	124	2	0,9	$300
788C	3.7 to 8.3	±0.3	>40	20	1.25	1.20	1	0.8	4⅞	124	2	0,9	$325
789C	8.0 to 12.4	±0.5	>20	17	1.25	1.40	1	1.2	11⅝	295	2	0,9	$350
X781A	8.0 to 12.4	±0.5	>20	17	1.07	1.25	1	1.2	15¾	400	2	0,9	$350

[1] Includes coupler and detector variation with frequency as read on a meter calibrated for square-law detectors (e.g., HP 415E SWR Meter).
[2] The apparent reflection coefficient at the output of an RF generating system, using a directional detector in a closed-loop leveling system.
[3] Type N connectors mate compatibly with connectors whose dimensions conform to MIL-C-39012 or MIL-C-71.

For all models

Detector output impedance: 15 kΩ max. shunted by approx. 10 pF.

Detector element: supplied.

Noise: <200 μV peak-to-peak with CW power applied to produce 100 mV output.

Detector output polarity: negative.

Detector output connector: BNC female.

RF connectors:[3] Type N, one male (input), one female (789C: both female); X781A: input, Type N female; output, precision cover flange, fits 1" x ½" waveguide (EIA WR90).

Options

02. Furnished with load resistor for optimum square law characteristics at 24°C (75°F), <±0.5 dB variation from square law over a range of at least 30 dB from low level up to 50 mV peak output (working into external load >75 kΩ); sensitivity typically one-fourth of unloaded sensitivity; add $20.
03. Positive polarity detector output; no additional charge.

Specifications, 790 Series

HP Model	Frequency range (GHz)	Mean output coupling (dB)[1]	Output coupling variation (dB)[2]	Directivity (dB)[2]	Equiv. source match[2,3]	Max. primary line SWR	Max. aux. arm SWR	Max. input (W)	Max. insertion loss (dB)[4]	Length (in)	Length (mm)	Shipping weight (lb)	Shipping weight (kg)	Price
796D	0.96 to 2.11	20 ±0.5	±0.2	30	1.13	1.15[2]	1.20[2]	50	0.4	6	152	2	0,9	$200
797D	1.9 to 4.1	20 ±0.5	±0.2	26	1.16	1.15[2]	1.25[2]	50	0.5	4⅞	124	2	0,9	$200
798C	3.7 to 8.3	10 ±0.3	±0.3	20	1.25	1.20	1.20	10	0.8	4⅞	124	2	0,9	$225
For all models: RF connectors: primary line: type N, one male (input), one female; auxiliary arm: type N female.[5]														

[1] Difference in dB between power out of primary line and auxiliary arm.
[2] Swept-frequency tested.
[3] The apparent SWR at the output port of a directional coupler when it is used in a closed-loop leveling system.
[4] Includes loss due to coupling.
[5] Type N connectors mate compatibly with connectors whose dimensions conform to MIL-C-39012 or MIL-C-71.

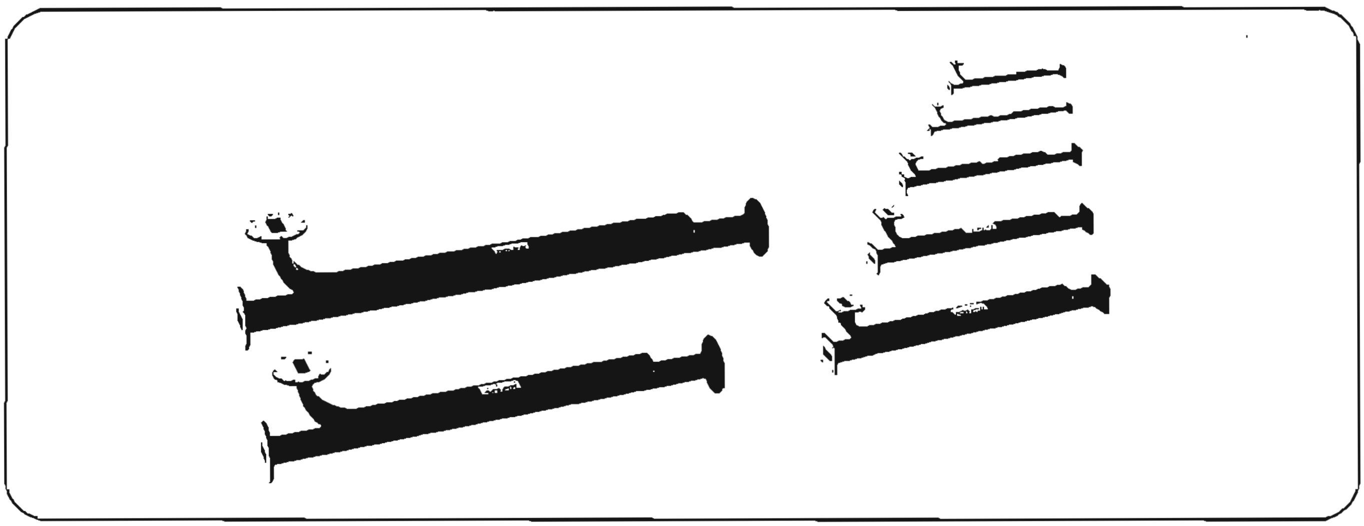
DIRECTIONAL COUPLERS
Easy-to-use, precision instruments
Model 752A,C,D

The HP 752 Directional Couplers are important tools in waveguide measurements. They can be used to monitor power, measure reflections, mix signals, or isolate signal sources or wavemeters.

Each coupler has an overall directivity of better than 40 dB (including reflection from built-in termination and flange) over its entire range. Performance characteristics are unaffected by humidity, temperature or time, thus making these units especially useful in microwave "standards" measurements. Coupling factors are 3, 10 and 20 dB; mean coupling accuracy is ±0.4 dB (±0.7 dB for K- and R-bands); and coupling variation vs frequency is ±0.5 dB (±0.6 dB for R752D).

Used together and connected back to back, two couplers are most useful with the HP 8690B Sweep Oscillator (see Signal Sources) in broadband reflection and SWR measurements. One directional coupler samples power traveling toward the load, and the detected sample can be used to maintain a constant forward power. The output of the auxiliary arm of the second coupler, which samples power reflected from the load, is then a direct indication of reflection coefficient and swr. After detection, this signal can be viewed on an oscilloscope or permanently recorded on an x-y recorder. The HP 424A Series Crystal Detectors are ideal for use with the 752 couplers.

In the system described above, the variation in coupling with frequency of the two couplers tends to cancel. This cancellation effectively improves the leveling of the signal source and increases the accuracy of the measurement. For applications in which the actual variations in source output must be minimized, matched pairs of couplers for the leveling loop are available on special order. The pair comprises a 3- and 10- or 20-dB coupler. The 3-dB coupler is connected to the auxiliary arm of the 10- or 20-dB coupler, reducing coupling variation to less than ±0.2 dB. Swept-frequency techniques are described in detail in Application Note 65, available from any HP field office.



Specifications, 752 Series

Band[1,2] (prefix)	Frequency (GHz)	Fits waveguide size (in)	Mean coupling accuracy (dB)[3,4]	SWR[5,6] main guide 752A	752C,D	Average power aux. guide load (W)	Length (in) A	C	D	Shipping weight (lbs)	(kg)	Price
G	3.95–5 85	2 x 1	±0 4	1.1	1 05	2	34½	33	33	16	7,4	$325
J*	5.85–8 2	1½ x ¾	±0.4	1.1	1.05	1	26½	25-9/16	25-9/16	13	5,8	$220
H	7.05–10	1¼ x ⅝	±0.4	1.1	1 05	1	18⅜	17½	17½	4	1,8	$165
X	8 2–12 4	1 x ½	±0 4	1 1	1.05	1	16-11/16	15-11/16	15-11/16	3	1,4	$145
P	12 4–18	702 x .391	±0.4	1.1	1.05	1	13¾	12¼	12¼	2	0,9	$170
K†	18–26.5	½ x ¼	±0.7	1.1	1.05	½	10⅝	9-15/16	9-15/16	1	0,45	$200
R†	26.5–40	.360 x .220	±0.7	1.1	1.05	½	11⅝	8⅝	8-23/32	1	0,45	$250

[1]When ordering, specify suffix letter to indicate nominal coupling: A for 3 dB, C for 10 dB, D for 20 dB (example: G-band, 3 dB coupling, Model G752A).
[2]Directivity is at least 40 dB; swept-frequency tested.
[3]Mean coupling is the average of the maximum and minimum coupling values in the rated frequency range.
[4]Coupling variation over rated frequency range is not more than ±0.5 dB about mean coupling (±0.6 dB for R752D).
[5]Auxiliary arm swr is 1.15 (1.2 for P-, K- and R-band units).
[6]Swept-frequency tested.
*J752 Couplers operate to 5.3 GHz with reduced performance.
†Circular flange adapters: K-band (UG425/U), HP 11515A, $35 each; R-band (UG-381/U), HP 11516A, $40 each.

PIN MODULATORS, MODULATORS

Versatile modulation

8730 Series, 8403A

8730 PIN Modulators

The Hewlett-Packard 8730 Series PIN Modulators increase the flexibility and performance of signal sources by providing increased modulation capability. With PIN modulators, signal sources, including klystrons, can be pulse-modulated, leveled or amplitude-modulated with sinusoidal and complex waveforms. Incidental FM is virtually eliminated, because modulation is accomplished by absorption of RF power, independent of the signal source, with a nearly constant match presented to both the source and load. Thus, the source can operate continuously at its optimum output level. Extremely fast rise times, typically 30 ns, also result from the absorption type of modulation, which sidesteps the bandwidth limitations imposed by the high-Q RF output circuits.

The 8730 PIN Modulators cover the coaxial range from 0.8 to 12.4 GHz in four overlapping bands, in addition to X-band in waveguide. Two models are available within each band: an "A" model, which provides at least 35 dB of attenuation range, and a "B" model, which provides at least 80 dB.

Physically, the PIN modulator comprises a number of PIN diodes mounted as shunt elements across a transmission line. Since PIN diodes have appreciable storage time, they do not rectify at signal frequencies above 100 MHz. However, when a dc forward bias is applied, the diodes conduct, and their resistance goes down. Thus, the diodes act as low-reactance, variable resistors shunting the transmission line. Their resistance and the degree of attenuation of an RF signal are functions of the modulating current. However, due to the storage time of the diodes, specially shaped modulation signals must be applied to realize the fast RF rise and decay times of which the PIN modulators are capable. The HP Model 8403A Modulator is specifically designed to supply these modulation signals.

8403A Modulator

The Model 8403A provides complete control of the PIN modulators, supplying the appropriate modulation wave shapes and bias levels for fast rise times, rated on/off ratios and amplitude modulation. An internal square-wave and pulse modulator, which can be synchronized with external signals, has a free-running PRF from 50 Hz to 50 kHz. In the pulse-modulation mode both pulse width and pulse delay are adjustable from 0.1 to 100 μs, and jitter with respect to the sync pulse and pulse width is less than 1 ns. An external AM input permits remote control of attenuation or sinusoidal modulation from dc to 10 MHz.

The Model 8403A also provides square wave and pulses for general pulse applications. Repetition rate, delay and jitter are the same as above. The output signal has an amplitude of 25 to 30 volts.

For situations requiring an absorption-type modulator complete with controls in a single unit, a PIN modulator can be installed in the Model 8403A. This combination is fully portable and convenient for bench use.

Specifications, 8403A

Output characteristics

AM and pulse output for driving 8730 PIN Modulators: pulse output specially shaped for optimum RF rise and decay times.

Pulse output for general pulse applications: positive dc-coupled pulse 25 to 30 volts in amplitude, approximately symmetrical about 0 volt; no AM signal.

Output signals available concurrently from separate front-panel connectors.

Internal modulation

Square wave

Frequency: continuously variable from 50 Hz to 50 kHz, 3 decade ranges.

Symmetry: better than 45/55%.

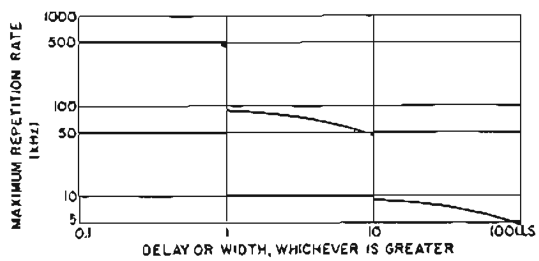
Pulse

Repetition rate: continuously variable from 50 Hz to 50 kHz, 3 decade ranges.

Delay: continuously variable from 0.1 μs to 100 μs, in 3 decade ranges, between sync out pulse and RF output pulse.

Width: continuously variable from 0.1 μs to 100 μs in 3 decade ranges.

Maximum duty cycle: see graph.



External sync

Amplitude: 5 volts to 20 volts peak.

Waveform: pulse or sine wave.

Polarity: either positive or negative.

Input impedance: approx. 2000 ohms, dc-coupled.

Rate: subject to internal recovery time considerations; see graph.

Trigger out

Sync out: 0.1 to 100 μs in advance of RF pulse, as set by Delay control (internal pulse mode); simultaneous with RF pulse (internal square wave and external pulse mode).

Delayed sync out: simultaneous with output pulse (internal pulse mode only).

Amplitude: approximately −2 volts.

Source impedance: approximately 330 ohms.

External modulation

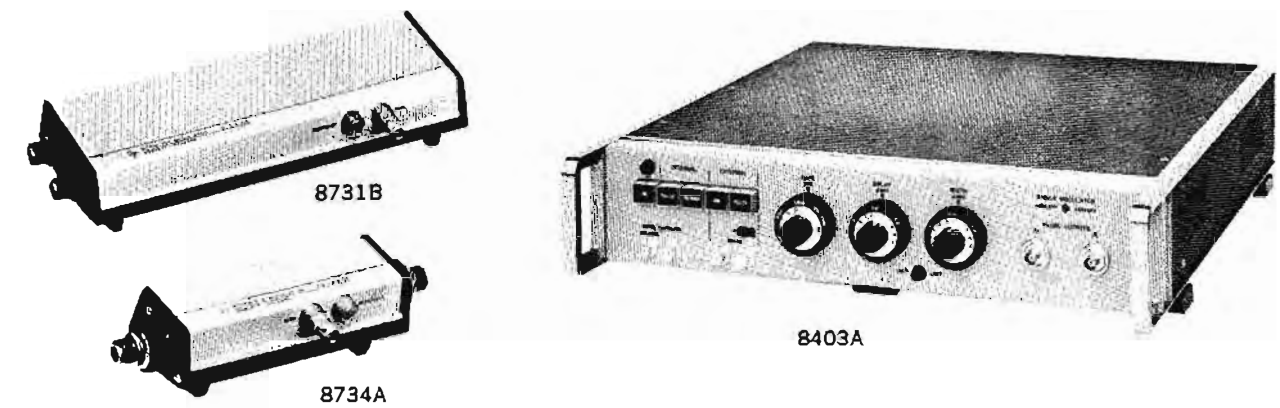
Pulse input

Amplitude and polarity: 5 volts to 20 volts peak, either positive or negative.

Repetition rate: maximum average PRF, 500 kHz.

Input impedance: approx. 2000 ohms, dc-coupled.

Minimum width: 0.1 μs.



Maximum width: $\frac{1}{PRF}$ —0.4 μs.

Continuous amplitude modulation (with 8730 Series)

Frequency response: dc to approximately 10 MHz (3 dB).

Sensitivity: approximately 10 dB/volt with HP 8730A Series, approximately 20 dB/volt with HP 8730B Series.

Input impedance: approximately 1000 ohms.

Level control: AM input is dc-coupled, permitting control by bias of AM input; rear-panel control for use with ac-coupled modulation.

General

Power: 115 or 230 volts ±10%, 50 to 400 Hz, approximately 10 watts.

Dimensions: 16¾" wide, 3¾" high, 18⅜" deep (425 x 96 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 3-15/32" high, 16⅜" deep behind panel (483 x 88 x 416 mm).

Weight: net 16½ lb (7,4 kg); shipping 21 lb (9,5 kg).

Price: HP 8403A, $800.

Options

01. HP 8731A PIN Modulator installed, add $350.
02. HP 8731B PIN Modulator installed, add $575.
03. HP 8732A PIN Modulator installed, add $350.
04. HP 8732B PIN Modulator installed, add $575.
05. HP 8733A PIN Modulator installed, add $375.
06. HP 8733B PIN Modulator installed, add $600.
07. HP 8734A PIN Modulator installed, add $400.
08. HP 8734B PIN Modulator installed, add $625.
09. Sync output and external modulation input connectors on rear panel in parallel with front-panel connectors; pulse output (or RF input and output) connectors on rear panel only, add $25.

Specifications, 8730 Series

HP Model	8731A	8731B	8732A	8732B	8733A	8733B	8734A	8734B	8735A	8735B	H10-8731B[6]
Frequency range (GHz)	0.8–2.4	0.8–2.4	1.8–4.5	1.8–4.5	3.7–8.3	3.7–8.3	7.0–12.4	7.0–12.4	8.2–12.4	8.2–12.4	0.4–0.9
Dynamic range (dB)	35	80	35	80	35	80	35	80	35	80	35
Max. residual atten. (dB)[1]	<1.5	<2.0	<2.0	<3.5[2]	<2.0	<3.0	<4.0	<5.0	<4.0	<5.0	<2.0
Typical rise time (ns)[3]	40	30	40	30	30	30	30	30	30	30	40
Typical decay time (ns)[3]	30	20	30	20	20	20	20	20	20	20	30
SWR, min. attenuation	1.5	1.6	1.5	1.6[4]	1.8	2.0	1.8	2.0	1.7	2.0	1.25[7]
SWR, max. attenuation	1.8	2.0	1.8	2.0	2.0	2.2	2.0	2.2	2.0	2.2	1.5[7]
Froward bias input resistance (ohms)	300	100	300	100	300	100	300	100	300	100	300
RF connector type	N	N	N	N	N	N	N	N	W/G[5]	W/G[5]	N
Weight, net (lb)	3	5½	3	5½	2½	3½	2½	3½	2½	3½	5½
(kg)	1,4	2,5	1,4	2,5	1,1	1,6	1,1	1,6	1,1	1,6	2,5
shipping (lb)	5	8	5	8	4	5	4	5	4	5	8
(kg)	2,2	3,6	2,2	3,6	1,8	2,3	1,8	2,3	1,8	2,3	3,6
Dimensions Length (in)	11⅛	11⅜	11⅛	11⅜	8⅜	12¼	8⅜	12¼	¾	10½	11⅜
(mm)	283	289	283	289	213	311	213	311	171	267	289
Width (in)	3¼	4⅞	3¼	4⅞	3¼	3¼	3¼	3¼	3½	3¼	4⅞
(mm)	83	124	83	124	83	83	83	83	83	83	124
Height (in)	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼
(mm)	57	57	57	57	57	57	57	57	57	57	57
Price	$300	$525	$300	$525	$325	$550	$350	$575	$350	$575	$525

Maximum ratings: maximum input power, peak or CW: 1W, bias limits: +20 V, -10 V.
Bias polarity: negative voltage increases attenuation.
RFI: radiated leakage limits are below those specified in MIL-I-61810 at input levels less than 1 mW; at all input levels radiated interference is sufficiently low to obtain rated attenuation.
[1] With -5 V bias.
[2] 4 dB, 4 to 4.5 GHz.
[3] Driven by HP 8403A Modulator.
[4] 2.0 SWR, 4 to 4.5 GHz.
[5] Fits 1 x ½ in. (WR90) waveguide.
[6] External high-pass filters required.
[7] Excluding high-pass filters.

VARIABLE COAXIAL ATTENUATOR

Versatile application to 2 GHz

Models 355C,D, 393A, 394A

355C,D VHF Attenuators

Unique design provides accurate attenuation from dc to 1 GHz with the HP 355C (0 to 12 dB in 1-dB steps) and HP 355D (0 to 120 dB in 10-dB steps). Attenuator sections are inserted and removed by cam-driven microswitches. These sections are adjusted by a time-domain reflectometry system to minimize reflections and ensure high accuracy. Insertion loss is low, and using both instruments provides attenuation in 1-dB steps to 132 dB. The units can be connected with either terminal as input or output, and their small size and mounting versatility permit several installation schemes—even within other equipment.

393A, 394A Coaxial Attenuators

Each of these coaxial variable attenuators uses the principle of a directional coupler (see Figure 1) to achieve a wide range of attenuation over a full octave. The HP 393A covers 5 to 120 dB from 500 to 1000 MHz; HP 394A covers 6 to 120 dB from 1 to 2 GHz. With special high-power terminations, they will handle up to 200 watts average.

Since these instruments are variable directional couplers, they are particularly useful for mixing signals while maintaining isolation.

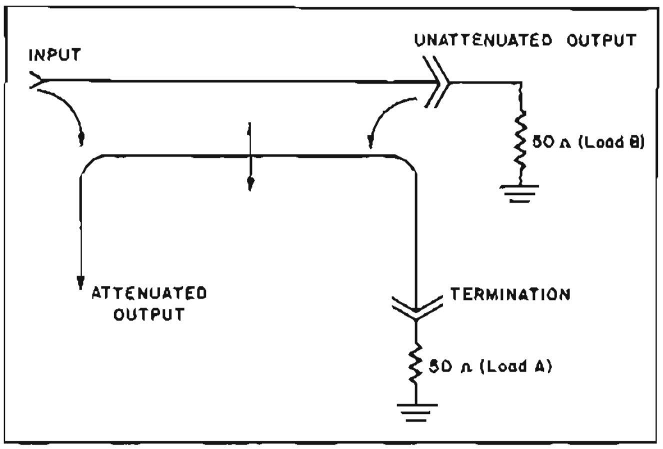
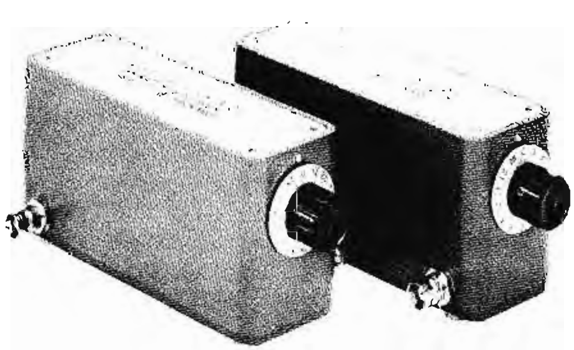
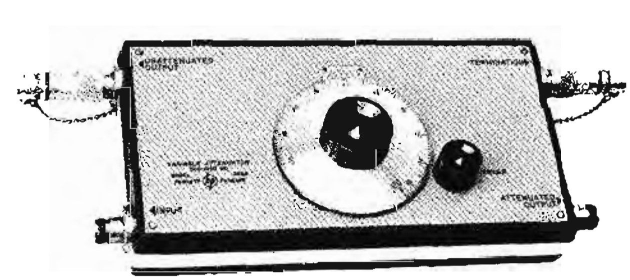


Figure 1. With loads A and B in place the instrument is an attenuator. With load A only, the instrument is a variable directional coupler.

Specifications	355C	355D
Attenuation:	12 dB in 1-dB steps	120 dB in 10-dB steps
Frequency range:	dc to 1 GHz	
Overall accuracy:	±0.1 dB at 1000 Hz; ±0.25 dB dc to 500 MHz; ±0.35 dB dc to 1 GHz	±0.3 dB to 120 dB at 1000 Hz; ±1.5 dB to 90 dB below 1 GHz; ±3 dB to 120 dB below 1 GHz
Impedance:	50 ohms nominal	
Power dissipation:	0.5 watt average, 350 volts peak	
Maximum SWR (input and output):	1.2 below 250 MHz; 1.3 below 500 MHz; 1.5 below 1 GHz	
Maximum insertion loss:	0.25 dB at 100 MHz; 0.75 dB to 500 MHz; 1.5 dB to 1 GHz	
Dimensions (in.):	6 long, 2¾ wide, 2⅝ high (152 x 70 x 67 mm)	
Weight:	net 1½ lb (0,7 kg); shipping 3 lb (1,4 kg)	
Price:	HP 355C, $160	HP 355D, $160
Option 01, HP 355C, 355D (Type N connectors). Add $33		
Specifications	**393A**	**394A**
Frequency range:	500 MHz to 1 GHz	1 to 2 GHz
Attenuation or coupling:	5 to 120 dB, variable	6 to 120 dB, variable
Directivity (with loads less than 1.05 SWR):	typically >10 dB, 10 to 40 dB attenuation	
Absolute accuracy (between matched generator and load):	±1.25 dB or ±1.75% of dial reading, whichever is greater	±1.25 dB or ±2.5% of dial reading, whichever is greater
SWR input:	<2.5, 5 to 15 dB attenuation <1.5, 15 to 30 dB attenuation <1.2, 30 to 120 dB attenuation	<2.5, 6 to 10 dB attenuation <1.8, 10 to 15 dB attenuation <1.6, 15 to 120 dB attenuation
SWR output:	<2.5, 5 to 15 dB attenuation <1.5, 15 to 30 dB attenuation <1.4, 30 to 120 dB attenuation	<2.5, 6 to 10 dB attenuation <1.8, 10 to 15 dB attenuation <1.6, 15 to 120 dB attenuation
Impedance:	50 ohms nominal	
Maximum voltage:	500 volts peak	
Average power:	approx. 200 watts maximum; power rating of terminations must be observed (908A, 0.5 watt terminations furnished)	
Dimensions (in.):	5½ wide, 12 long, 2¾ deep (140 x 305 x 70 mm)	
Weight:	net 6 lb (2,7 kg); shipping 13 lb (5,8 kg)	
Price:	HP393A, $525	HP 394A, $550
Option 01.	supplied without 908A coaxial terminations, less $70	



355C,D



393A

COAXIAL ATTENUATOR SETS

Models 11581A, 11582A, 11583A

11582A

Attenuator Set

A set of four HP attenuators, 3, 6, 10, and 20 dB, are furnished in a handsome walnut accessory case. In addition to protecting the units when not being used, the case is also a convenient storage place for the attenuator calibration reports provided with the set of four attenuators. These calibration reports include the accuracy of the measurement and are certified traceable to the National Bureau of Standards.

Attenuation calibrations are stamped on the attenuators at dc, 4, 8, and 12 GHz for the 8491A and at dc, 4, 8, 12, and 18 GHz for the 8491B and 8492A. In addition, the calibration report includes both the attenuation and the reflection coefficient at each port of the attenuator at these frequencies. Calibrations at other frequencies are available on request.

Specifications

Accuracy of insertion loss measurements: (S_{21}, S_{12})

DC	±0.01 dB
0-20 dB	
4 - 12 GHz	±0.062 dB
12 - 18 GHz	±0.097 dB
Above 20 dB	±1% of Attenuation

Accuracy of reflection coefficient measurements: (S_{11}, S_{22})

4 = 12 GHz $\Delta\Gamma_L \le \pm(0.036 + 0.03\Gamma_L + 0.045\Gamma_L^2)$

12 = 18 GHz $\Delta\Gamma_L \le \pm(0.046 + 0.03\Gamma_L + 0.055\Gamma_L^2)$

Prices

Attenuator set:

11581A (for 8491A) includes 3, 6, 10, 20 dB values, $225.

11582A (for 8491B) includes 3, 6, 10, 20 dB values, $285.

11583A (for 8492A) includes 3, 6, 10, 20 dB values, $525.

COAXIAL STEP ATTENUATOR

DC to 12.4 GHz

Model 354A

Specifications

Frequency range: dc to 12.4 GHz.

Incremental attenuation: 0 to 60 dB in 10-dB steps.

Accuracy (including frequency response): ±2 dB.

Residual attenuation: less than 1.5 dB.

Impedance: 50Ω.

Reflection coefficient

0 to 8 GHz: less than 0.2 (1.5 SWR, 14 dB return loss).
8 to 12.4 GHz: less than 0.273 (1.75 SWR, 11.3 dB return loss).

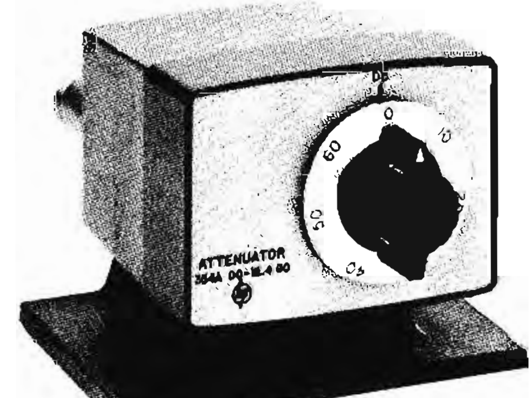
Maximum power: 2 W average, 300 W peak.

Connectors: Type N female, stainless steel.

Dimensions (maximum envelope): 4" wide, 3⅛" high, 4½" deep (102 x 79 x 114 mm); panel mount, 3-1/16" wide, 2-5/16" high, 3¾" deep behind panel (78 x 59 x 95 mm).

Weight (with base): net 2¾ lb (1,2 kg); shipping 4 lb (1,8 kg).

Price: Model 354A, $350.



354A

Attenuation 0 to 60 dB in 10-dB steps

Flat response dc to 12.4 GHz

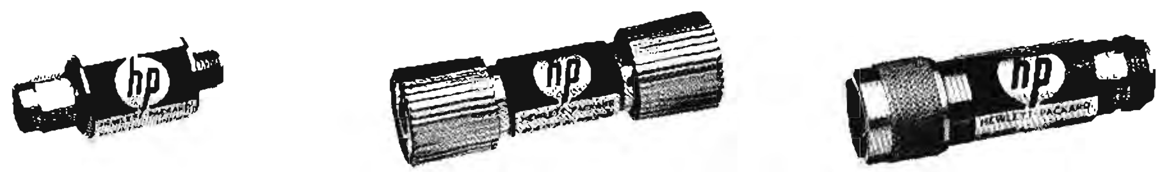
Low residual attenuation

Simple knob rotation

COAXIAL ATTENUATORS

Performance at low cost

Models 8491A, B, 8492A, 8493A, B



8493A, B 8492A 8491A, B

Hewlett-Packard fixed coaxial attenuators provide precision attenuation, flat frequency response, and low VSWR over broad frequency ranges at low prices. Attenuators are available in nominal attenuations of 3-dB, 6-dB and 10-dB increments from 10 dB to 60 dB.

Each attenuator is swept-frequency tested. Swept-frequency testing to 18-GHz ensures that the attenuator meets specifications at all frequencies in the specified range. Spot frequency testing can easily miss narrow "resonances".

Specifications

	8491A and 8493A		8491B and 8493B			8492A		
Freqency Range	DC to 12.4 GHz		DC to 18 GHz			DC to 18 GHz		
Attenuation Accuracy			DC-12.4 GHz	12.4–18 GHz		DC-12.4 GHz	12.4–18 GHz	
3 dB	±0.3 dB		±0.3 dB			±0.3 dB		
6 dB	±0.3 dB		±0.3 dB	±0.4 dB		±0.3 dB	±0.4 dB	
10 dB	±0.5 dB		±0.5 dB			±0.5 dB		
20 dB	±0.5 dB		±0.5 dB	±1 dB		±0.5 dB	±1 dB	
30 dB	±1 dB		±1 dB			±1 dB		
40 dB[4]	±1.5 dB		±1.5 dB			±1.5 dB		
50 dB[4]	±1.5 dB		±1.5 dB			±1.5 dB		
60 dB[4]	±2 dB		±2 dB			±2 dB		
SWR	DC–8 GHz	8–12.4 GHz	DC–8 GHz	8–12.4 GHz	12.4–18 GHz	DC–8 GHz	8–12.4 GHz	12.4–18 GHz
3 dB	1.25	1.35	1.25	1.35	1.6	1.2	1.3	1.5
6 dB	1.2	1.3	1.2	1.3	1.5	1.2	1.3	1.35
10 dB	1.2	1.3	1.2	1.3	1.5	1.15	1.25	1.3
20 dB	1.2	1.3	1.2	1.3	1.5	1.15	1.25	1.3
30 dB	1.2	1.3	1.2	1.3	1.5	1.15	1.25	1.3
40 dB[4]	1.2	1.3	1.2	1.3	1.6	1.15	1.25	1.35
50 dB[4]	1.2	1.3	1.2	1.3	1.5	1.15	1.25	1.35
60 dB[4]	1.2	1.3	1.2	1.3	1.5	1.15	1.25	1.35
Calibration Frequencies	DC, 4, 8, 12 GHz		DC, 4, 8, 12, 18 GHz			DC, 4, 8, 12, 18 GHz		
Maximum Input Power	2 W avg, 100 W pk		2 W avg, 100 W pk			2 W avg, 100 W pk		
Connectors (50Ω)	8491A: Type N[1] 8493A: SMA[2]		8491B: Type N[1] 8493B: SMA[2]			APC-7[3]		
Dimensions: in. mm	8491A: 2-7/16×13/16 dia. 62×21 8493A: 1¼×½ dia. 38×13		8491B: 2-7/16×13/16 dia 62×21 8493B: 1¼×½ dia. 38×13			2¾×13/16 dia. 70×21		
Weight: net shipping	8491A: 4 oz (110 g) 8 oz (220 g) 8493A: 0.6 oz (20 g) 3 oz (60 g)		8491B: 4 oz (110 g) 8 oz (220 g) 8493B: 0.6 oz (20 g) 3 oz (60 g)			4 oz (110 g) 8 oz (220 g)		
Price (Give Option Number for desired attentuation)[5]	8491A	8493A[4]	8491B	8493B[4]		8492A		
	3–30 dB, $50 each 40–60 dB, $75 each	3–30 dB, $60 each	3–30 dB, $65 each 40–60 dB, $100 each	3–30 dB, $75 each		3–30 dB, $125 each 40–60 dB, $160 each		

VARIABLE ATTENUATORS

Frequency coverage to 40 GHz

Models 382A, C and 375A

Precision Variable Attenuators

Operation of these direct-reading, precision attenuators depends on a mathematical law, rather than on the resistivity of the attenuating material. Accurate attenuation from 0 to 50 dB (0 to 60 dB for S382C) is assured regardless of temperature and humidity. The instruments can handle considerable power and feature large, easily read dials. In addition, the S382C achieves both long electrical length and short physical dimensions through dielectric loading. The result is an S-band attenuator which is only 25¼ inches long and yet is more accurate than previously available units.

HP Model	S382C	G382A[1]	J382A[1]	H382A	X382A	P382A	K382A[2]	R382A[2]
Frequency range (GHz):	2.6-3.95	3.95 - 5.85	5.3 - 8.2	7.05 - 10.0	8.2 - 12.4	12.4 - 18.0	18.0 - 26.5	26.5 - 40.0
Waveguide size (in):	3 x 1½	2 x 1	1½ x ¾	1¼ x ⅝	1 x ½	.702 x .391	½ x ¼	.360 x .220
(EIA):	WR284	WR187	WR137	WR112	WR90	WR62	WR42	WR28
Power handling capacity, watts, average continuous duty:	10	15	10	10	10	5	2	1
Size length, in. (mm):	25¼ (641)	31⅝ (803)	25 (635)	20 (508)	15⅝ (397)	12½ (318)	7⅝ (194)	6⅜ (162)
height, in. (mm):	6 (152)	9⅝ (245)	7⅞ (220)	7-15/16 (202)	7⅝ (194)	7¾ (197)	6⅛ (156)	6⅛ (156)
depth, in. (mm):	8 (203)	7¾ (197)	6-3/16 (157)	6½ (165)	4-11/16 (119)	4¾ (121)	4¾ (121)	4¾ (121)
Weight net, lb (kg):	18 (8,1)	21.5 (9,7)	13 (5,9)	10 (4,5)	6 (2,7)	6 3.5	4 (1,8)	4 (1,8)
shipping, lb (kg):	28 (12,6)	32 (14,4)	24 (10,8)	22 (9,9)	8 (3,6)	8 (3,6)	9 (4,1)	9 (4,1)
Price:	$1120	$550	$415	$385	$310	$340	$525	$550

For all 382A Models

Incremental attenuation range: 0 to 50 dB.

Residual attenuation: less than 1 dB.

Reflection coefficient: less than 0.07 (1.15 SWR, 23.1 dB return loss).

Accuracy: ±2% of reading in dB, or 0.1 dB, whichever is greater. Includes calibration and frequency error.

For Model S382C

Calibrated attenuation range: 0 to 60 dB (above residual attenuation).

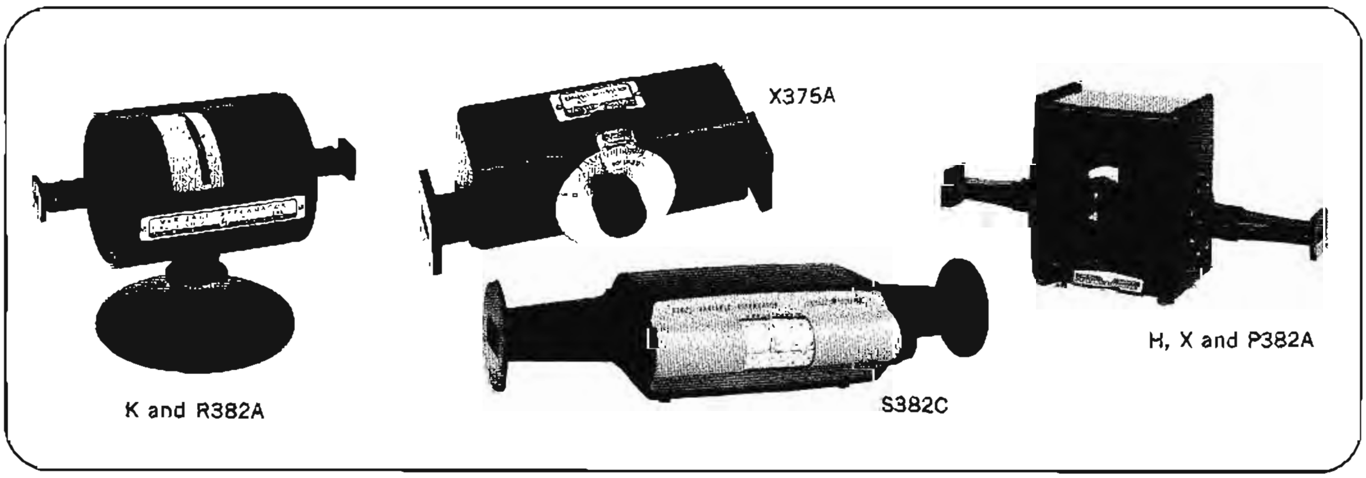
Residual attenuation: less than 1 dB.

Accuracy: ±1% of reading in dB, or 0.1 dB, whichever is greater, from 0 to 50 dB; ±2% of reading above 50 dB; includes calibration and frequency error.

Reflection coefficient: less than 0.091 (1.2 SWR, 20.8 dB return loss), 2.6to 3 GHz; less than 0.07 (1.15 SWR, 23.1 dB return loss), 3 to 3.95 GHz.

Degree dial: 0 to 90°; calibrated in 0.01° increments.

[1]Circular flange.
[2]Circular flange adapters: K-band (UG-425/U) 11515A, $35 each; R-band (UG-381/U) 11516A, $40 each.



General-Purpose Attenuators

Variable flap attenuators provide a simple, convenient means of adjusting waveguide power level or isolating source and load. They consist of a slotted section in which a matched resistive strip is inserted. The degree of strip penetration determines attenuation. A dial shows average reading over the frequency band, and a shielded dust cover reduces external radiation and eliminates hand capacity effects. Attenuation is variable from 0 to 20 dB. Dial calibration is accurate within ±1 dB from 0 to 10 dB, ±2 dB from 10 to 20 dB. Maximum reflection coefficient is 0.07 (1.15 SWR, 23.1 dB return loss).

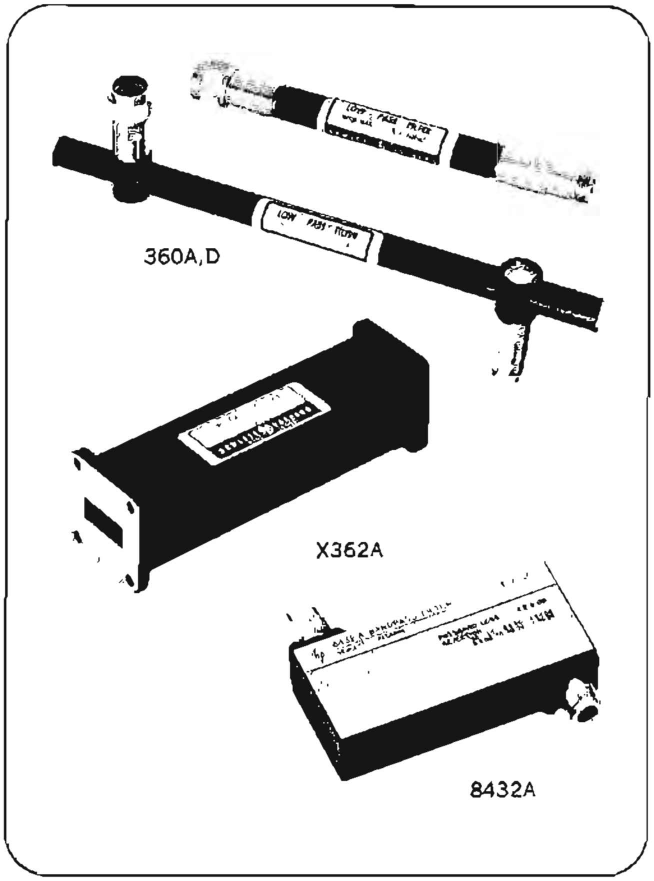
Specifications, 375A

HP Model	Frequency (GHz)	Power dissipation (watts)	Length (in.)	Length (mm)	Fits waveguide size (in.)	Price
X375A	8.2 - 12.4	2.0	7-3/16	183	1 x ½	$110
P375A	12.4 - 18.0	1.0	7¼	184	.702 x .391	$135

LOW-PASS; BANDPASS FILTERS

Effective elimination of undesirable signals

Models 360A-D; 362A; 8430



These Hewlett-Packard low-pass and bandpass filters facilitate microwave measurements by eliminating undesirable signals (such as harmonics) from the measurement system. Suppression of such signals is particularly important in applications such as slotted-line measurements, where harmonics generated by the signal source could otherwise impair measurement accuracy. These filters also can be used as preselectors for the HP 8551B Spectrum Analyzer. As such, they permit the maximum utilization of the analyzer's broad spectrum-width capability while ensuring virtually spurious-free displays.

Specifications, 360 Series

HP Model	360A	360B	360C	360D
Cut-off frequency	700 MHz	1200 MHz	2200 MHz	4100 MHz
Insertion loss	≤1 dB below 0.9 times cut-off frequency			
Rejection	≥50 dB at 1.25 times cut-off frequency			
Impedance	50 ohms through pass band; should be matched for optimum performance			
SWR	<1.6 to within 100 MHz of cut-off		<1.6 to within 200 MHz of cut-off	<1.6 to within 300 MHz of cut-off
Connectors	Type N, one male, one female			
Overall length (in.) / (mm)	10⅛ 276	7-7/32 183	10-25/32 274	7⅜ 187
Center line to male end (in.) / (mm)	2⅛ 54	2⅛ 54	——	——
Center line to female end (in.) / (mm)	2¼ 57	2¼ 57	——	——
Shipping weight (lb) / (kg)	2 0,9	2 0,9	2 0,9	1 0,45
Price	$75	$70	$65	$60

Specifications, 362A Series

HP Model	X362A	M362A	P362A	K362A*	R362A*
Passband (GHz)	8.2–12.4	10.0–15.5	12.4–18.0	18.0–26.5	26.5–40.0
Stop band (GHz)	16–37.5	19–47	23–54	31–80	47–120
Insertion loss	less than 1 dB	less than 1 dB	less than 1 dB	less than 1 dB	less than 2 dB
Stopband rejection	at least 40 dB	at least 40 dB	at least 40 dB	at least 40 dB	at least 35 dB
SWR	1.5	1.5	1.5	1.5	1.8
Waveguide size, in. (EIA)	1 x ½ (WR 90)	0.850 x 0.475 (WR 75)	0.702 x 0.391 (WR 62)	½ x ¼ (WR 42)	0.360 x 0.220 (WR 28)
Length, in. (mm)	5-11/32(136)	4-15/32(114)	3-11/16(94)	2½(64)	1-21/32(42)
Shipping weight, lb (kg)	2(0,9)	1(0,45)	1(0,45)	½(0,23)	½(0,23)
Price	$325	$350	$350	$385	$385

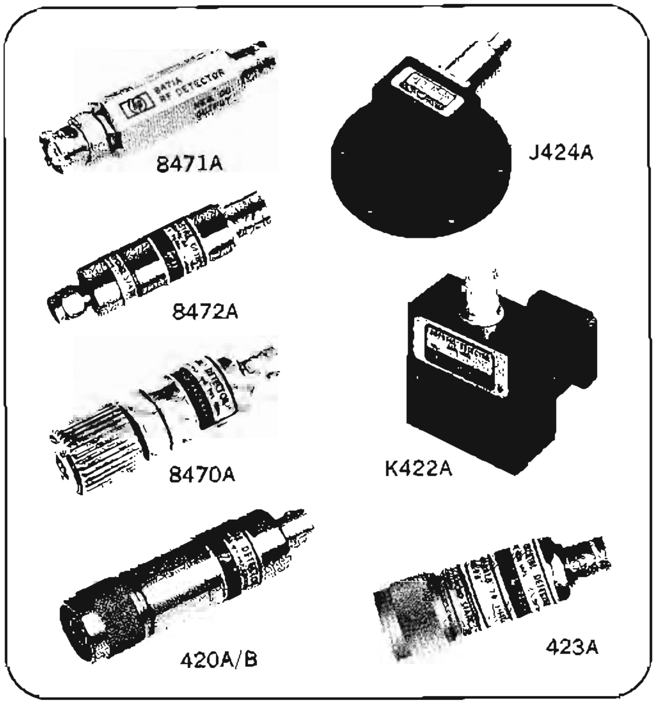
* Circular flange adapters: K-band (UG-425/U), HP 11515A, $35 each; R-band (UG-381/U), HP 11516A, $40 each.

Specifications, 8430 Series

HP Model	Passband frequency (GHz)	Max. passband insertion loss	Rejection band attenuation: Below passband Frequency (GHz)	Below passband Attenuation	Above passband Frequency (GHz)	Above passband Attenuation	Dimensions (in.)	Dimensions (mm)	Shipping weight (lb)	Shipping weight (kg)	Price
8430A	1 to 2	2 dB	≤0.8	≥50 dB	2.2 to 20	≥45 dB	5½ x 4¾ x 1	140 x 121 x 25	3	1,4	$210
8431A	2 to 4	2 dB	≤1.6	≥50 dB	4.4 to 20	≥45 dB	5½ x 3 x 1	140 x 76 x 25	3	1,4	$210
8432A	4 to 6	2 dB	≤3.5	≥50 dB	6.5 to 20	≥45 dB	4½ x 2 x 1	114 x 51 x 25	2	0,9	$275
8433A	6 to 8	2 dB	≤5.5	≥50 dB	8.5 to 20	≥45 dB	4 x 1½ x 1	102 x 38 x 25	2	0,9	$275
8434A	8 to 10	2 dB	≤7.5	≥50 dB	10.5 to 17	≥45 dB	4⅝ x 1 x 1	118 x 25 x 25	2	0,9	$275
8435A	4 to 8	2 dB	≤3.2	≥50 dB	8.8 to 20	≥45 dB	3⅝ x 1¾ x 1	92 x 45 x 25	2	0,9	$210
8436A	8 to 12.4	2 dB	≤6.9	≥50 dB	13.5 to 17	≥45 dB	2⅞ x 1 x 1	73 x 25 x 25	2	0,9	$210

Connectors: Type N, one male, one female.

CRYSTAL DETECTORS
Flat response, high sensitivity, low SWR
Models 8470A, 8471A, 8472A, 423A, 424A, 420A,B, 422A



The HP 8470A and 8472A extend the frequency range of coaxial crystal detectors to 18 GHz. Like the 423A and 424A Crystal Detectors, the 8470A and 8472A combine extremely flat frequency response with high sensitivity and low SWR, making them extremely useful as the detecting element in closed-loop leveling systems. Matched pairs are available for applications requiring the utmost in detector tracking, and all but the 8472A can be supplied with video loads for optimum conformance to square law over a range of at least 30 dB.

The 422A Crystal Detectors are convenient waveguide detectors which cover K- and R-bands. They have a dynamic range of 40 dB or more, making them suitable for reflectometer as well as general-purpose applications.

The 420A is a low-cost crystal detector which covers the coaxial range from 10 MHz to 12.4 GHz, making it ideal for general-purpose video detection. The 420B is essentially the same unit as the 420A with the addition of a selected video load for optimum square-law characteristics in the 1 to 4 GHz range. Price: HP 420A, $65; HP 420B, $95.

RF Detector

The 8471A is a low-cost RF detector which covers the frequency range from 100 kHz to 1.2 GHz. This unit is a broadband, flat detector with a built-in filter. It is extremely well-suited for use with the HP 8690B/8698B Sweep Oscillator/RF Unit (pages 423-429).

HP Model	Frequency range (GHz)	Frequency resp.[1] (dB)	Low-level sensitivity (mV/µW)	Maximum SWR	RF Input	Matched pair available	Square-law load available	Length (in.)	Length (mm)	Shipping weight (lb)	Shipping weight (kg)	Price
8471A	100 kHz 1.2 GHz	±0.6; typ ±0.1 over 100 MHz	>0.5	typically 1.3	BNC male	no	no	2¾	70	1	0,5	HP 8471A, $ 50
423A	0.01-12.4	± 0.2/octave to 8 GHz; ±0.5 overall	>0.4	1.2 to 4.5 GHz; 1.35 to 7 GHz; 1.5 to 12.4 GHz	Type N male	yes[2]	yes[3]	2-15/32	63	1	0,5	HP 423A, $135
8470A	0.01-18	±0.2/octave to 8 GHz; ±0.5 to 12.4 GHz; ±1 overall	>0.4	1.2 to 4.5 GHz; 1.35 to 7 GHz; 1.5 to 12.4 GHz; 1.7 to 18 GHz	APC-7	yes[2]	yes[3]	2½	64	1	0,5	HP 8470A, $190
8472A	0.01-18	±0.2/octave to 8 GHz; ±0.5 to 12.4 GHz; ±1 overall	>0.4	1.2 to 4.5GHz; 1.35 to 7GHz; 1.5 to 12.4 GHz; 1.7 to 18 GHz	OSM® type male	Yes	no	2½	64	1	0,5	HP 8472A, $175
S424A	2.60-3.95	±0.2	>0.4	1.35	Wave-guide cover flange	yes[4]	yes[3]	2-7/16	62	2	0,9	HP S424A, $195
G424A	3.95-5.85	±0.2	>0.4	1.35		yes[4]	yes[3]	2-1/16	52	1	0,45	HP G424A, $185
J424A	5.30-8.20	±0.2	>0.4	1.35		yes[4]	yes[3]	1-7/8	48	0.5	0,23	HP J424A, $185
H424A	7.05-10.0	±0.2	>0.4	1.35		yes[4]	yes[3]	1-9/16	40	0.5	0,23	HP H424A, $175
X424A	8.20-12.4	±0.3	>0.4	1.35		yes[4]	yes[3]	1-3/8	35	0.5	0,23	HP X424A, $155
M424A	10.0-15.0	±0.5	>0.3	1.5		yes[4]	yes[3]	1	25	0.5	0,23	HP M424A, $275
P424A	12.4-18.0	±0.5	>0.3	1.5		yes[4]	yes[3]	15/16	24	0.5	0,23	HP P424A, $195
K422A[6]	18.0-26.5	±2	≈0.3	2.5		yes[5]	yes[3]	2	51	1	0,5	HP K422A, $230
R422A[6]	26.5-40.0	±2	≈0.3	3		yes[5]	yes[3]	2	51	1	0,5	HP R422A, $230

For all models

Maximum input: 100 mW peak or average, (8471A: 3 V rms, 4.2 V pk).

Detector element: supplied.

Output polarity: negative (positive output available with 423A, 8470A, 424A—specify Option 03; 8471A—Specify Option 04; no additional charge; 8472A, available on special order, add $20.)

Output connector: BNC female.

[1] As read on a 416 Ratio Meter or 415 SWR Meter calibrated for square-law detectors.

[2] Frequency response characteristics (excluding basic sensitivity) track within ±0.2 dB per octave from 10 MHz to 8 GHz, ±0.3 dB from 8 to 12.4 GHz, and (8470A and 8472A) ±0.6 dB from 12.4 to 18 GHz; specify Option 01., add $40 per pair. (8472A, available on special order, add $50 per pair).

[3] <±0.5 dB variation from square law up to 50 mV peak output into >75 kΩ; sensitivity typically >0.1 mV/µW; specify Option 02.; add $20.

[4] Frequency response characteristics (excluding basic sensitivity) track within ±0.2 dB for S-, G-, J- and H-band units, ±0.3 dB for X-band units, and ±0.5 dB for M- and P-band units; specify Option 01.; add $40 per pair.

[5] Matched pair of units fitted with square-law loads. Frequency response characteristics (excluding basic sensitivity) track within ±1 dB for power levels less than approx. 0.05 mW; specify Option 01.; add $80 per pair.

[6] Circular flange adapters: 11515A (UG-425/U) for K-band, $35 each; 11516A (UG-381/U) for R-band, $40 each.

®Omni Spectra Inc.

FREQUENCY METERS

For general-purpose or lab use

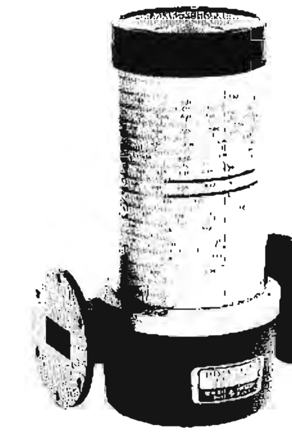
Models 532A/B, 536A, 537A

Advantages

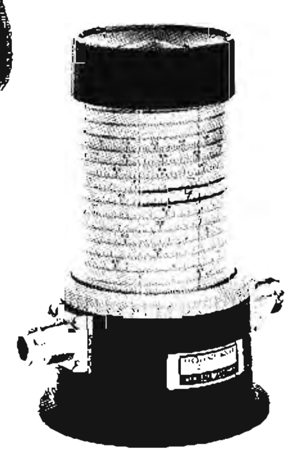
- High resolution, easy-to-read dial
- Direct reading
- Broadband
- Accuracy specified over 20°C and 0 to 100% relative humidity

These direct-reading frequency meters allow you to measure frequencies from 3.95 to 40 GHz in waveguide and from 960 MHz to 12.4 GHz in coax quickly and accurately. Their long scale length and numerous calibration marks provide a high resolution which is particularly useful when measuring frequency differences or small frequency changes. Frequency is read directly in GHz so no interpolation or charts are required.

The instruments comprise a special transmission section with a high-Q resonant cavity which is tuned by a choke plunger. A 1-dB or greater dip in output indicates resonance; virtually full power is transmitted off resonance. Tuning is by a precision lead screw, spring-loaded to eliminate backlash. Resolution is enhanced by a long, spiral scale calibrated in small frequency increments. For example, Model X532B has an effective scale length of 77 inches (1956 mm) and is calibrated in 5-MHz increments. Resettability is extremely good, and all frequency calibrations are visible so you can tell at a glance the specific portion of the band you are measuring. Except for the J532A, there are no spurious modes or resonances. (See note 4 below.)



G532A



537A

Specifications, 532A, 536A and 537A

Model	Frequency Range (GHz)	Dial Accuracy (%)	Overall Accuracy[1] (%)	Dip at Resonance	Calibration Increment (MHz)	Fits Waveguide: Nom. OD(in)	Fits Waveguide: EIA	Equivalent Flange	Size in. (mm): Length	Size in. (mm): Height	Size in. (mm): Depth	Weight lb (kg): Net	Weight lb (kg): Shipping	Price
536A	0.96–4.20	0.10[2]	0.17[3]	Note 6	2				6 (152)	9⅛ (232)	6 (152)	10 (4,5)	13 (5,9)	$550
537A	3.7–12.4	0.10	0.17	1 dB min	10				4⅝ (118)	5¾ (146)	3½ (89)	3½ (1,6)	5 (2,3)	$550
G532A	3.95–5.85	0.033	0.065	1 dB min	1	2 x 1	WR187	UG–407/U	6¼ (159)	9½ (241)	5 (127)	9¼ (4,1)	12 (5,4)	$400
J532A	5.30–8.20[4]	0.033	0.065	1 dB min	2	1½ x ¾	WR137	UG–441/U	6¼ (159)	9⅛ (232)	4½ (114)	7½ (3,4)	11 (5,0)	$375
H532A	7.05–10.0	0.040	0.075	1 dB min	2	1¼ x ⅝	WR112	UG–138/U	6¼ (159)	8 (203)	4⅜ (111)	6 (2,7)	9 (4,1)	$325
X532B	8.20–12.4	0.050	0.08	1 dB min	5	1 x ½	WR90	UG–39/U	4½ (114)	6⅛ (156)	2⅞ (73)	3½ (1,6)	4 (1,8)	$225
M532A	10.0–15.0	0.053	0.085	1 dB min	5	0.850 x 0.475	WR75	Cover	4½ (114)	6¼ (159)	2¾ (70)	3½ (1,6)	4 (1,8)	$350
P532A	12.4–18.0	0.068	0.10	1 dB min	5	0.702 x 0.391	WR62	UG–419/U	4½ (114)	6¼ (159)	2¾ (70)	3 (1,4)	4 (1,8)	$275
K532A	18.0–26.5	0.077	0.11	1 dB min	10	½ x ¼	WR42	UG–595/U	4½ (114)	5⅜ (137)	2⅞ (73)	2 (0,9)	3 (1,8)	$350
R532A	26.5–40.0	0.083	0.12	1 dB min	10	0.360 x 0.220	WR28	UG–599/U	4½ (114)	5½ (140)	2¾ (70)	2 (0,9)	3 (1,8)	$400

[1] Includes allowance for 0 to 100% relative humidity, temperature variation from 13 to 33°C, and backlash.

[2] 0.15, 0.96 to 1 GHz.

[3] 0.22, 0.96 to 1 GHz.

[4] Because of the wide frequency range of the J532A, frequencies from 7.6 to 8.2 GHz can excite the TE_{112} mode when the dial is set between 5.3 and 5.6 GHz.

[5] Circular flange adapters: K-band (UG-425/U) 11515A, $35 each; R-band (UG-381/U) 11516A, $40 each.

[6] 1 dB min., 1-4 GHz; 0.6 dB min., 0.96-1 GHz and 4-4.2 GHz.

COAXIAL TERMINATIONS, SHORTS
Basic tools for measurements to 18 GHz
Models 905A, 907A, 908A, 909A, 11511A, 11512A, 11565A

905, 907A Sliding Loads

The 905A and 907A are movable, low-reflection loads for precision microwave measurements. They are ideal for use with the 8410A Network Analyzer and the 817A Swept Slotted Line for reducing the ambiguity of reflection measurements. Both loads have removable connector bodies and inner conductor pins. APC-7 and type N (male and female) bodies and pins are supplied. The type N bodies are stainless steel for long wear. Center conductors have no supporting beads and can be moved to seat accurately with the mating connector to keep SWR low. Load travel is greater than a half wavelength at the lowest frequency. The 905A features compact size, light weight, and index marks for accurate, repeatable load positioning. Prices include carrying cases and wrenches for changing connectors.

905A, 907A Specifications

HP model	Frequency Range	Load SWR	Power Rating Watts	Length In. (mm)	Weight	Price
907A	1–18 GHz	0.024, 1.5–18 GHz; 0.048, 1–1.5 GHz	1W avg, 5kW pk	30-5/8 (778)	2 lb (0.9 kg)	$275
905A	1.8–18 GHz	1.05	1W avg, 5kW pk	17-1/4 (440)	7 oz (196 gm)	$225

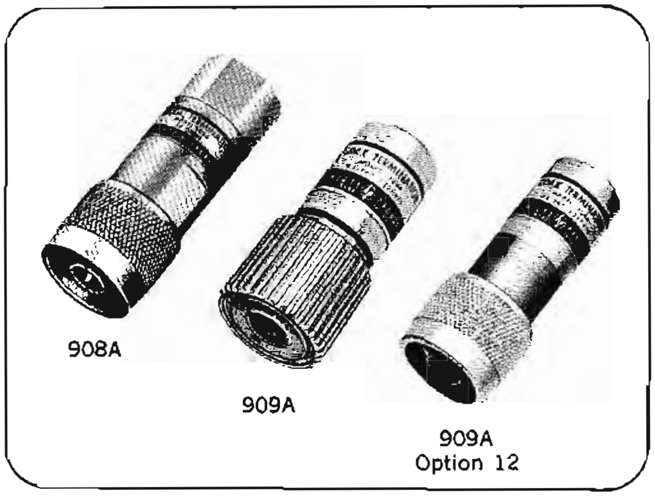
908A, 909A Terminations

The 908A and 909A Terminations are low-reflection loads for terminating 50-ohm coaxial systems in their characteristic impedance. Model 909A is extremely broadband, covering the range from dc to 18 GHz. Combining economy with utility, the 908A covers the range from dc to 4 GHz.

Model 909A is normally supplied with a precision 7-mm connector (APC-7), but may be ordered with a stainless steel male or female type N connector. The type N connectors are compatible with connectors conforming to MIL-C-39012. Model 908A has a phosphor-bronze type N male connector that is compatible with MIL-C-71.

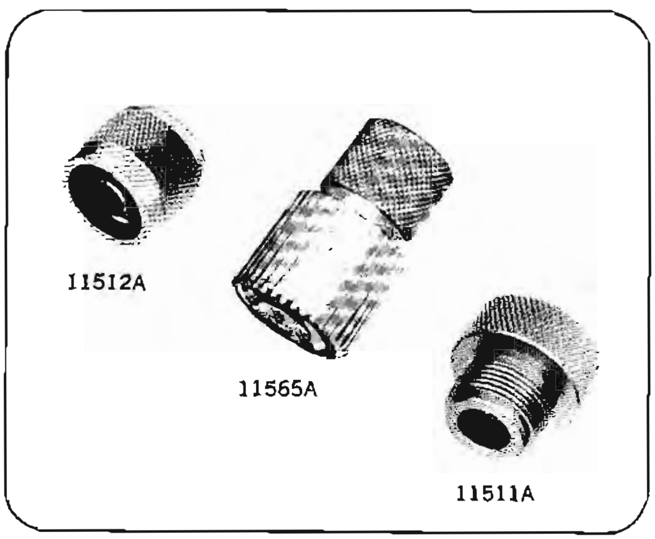
908A, 909A Specifications

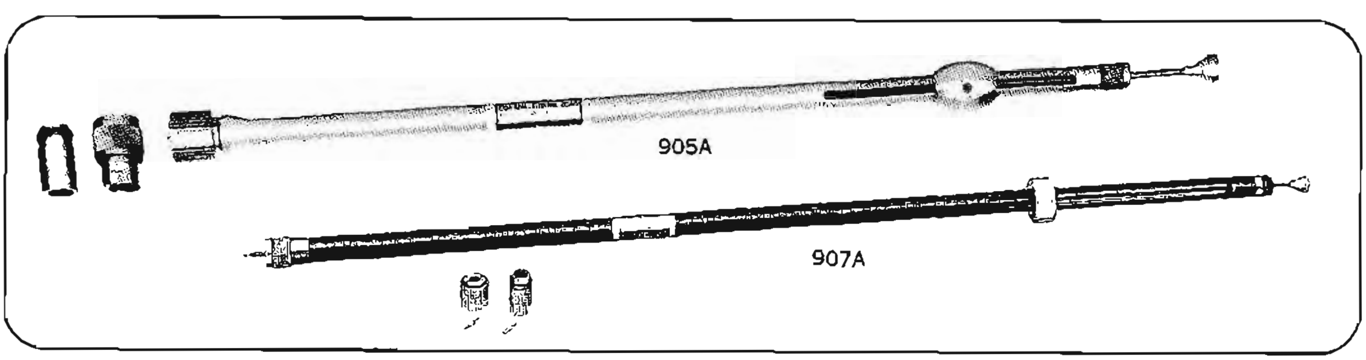
HP Model	Frequency Range	Impedance	SWR	Power Rating	Connector	Length in. (mm)	Price
908A	dc–4GHz	50 ohms	1.05	1/2 W avg, 1kW pk	N male	2 (51)	$35
909A	dc–18GHz	50 ohms	1.05, 0–4GHz. 1.1, 4–12.4GHz. 1.25, 12.4–18GHz.	2W avg, 100W pk	APC-7	2 (51)	$75
909A Option 12 and Option 13	dc–18GHz	50 ohms	1.06, 0–4GHz. 1.11, 4–12.4GHz. 1.3, 12.4–18GHz.	2W avg, 100W pk	Option 12: N male. Option 13: N female	2 (51)	$60



11511A, 11512A, 11565A Shorts

These accessory coaxial shorts are useful for establishing measurement planes and known reflection phase and magnitude in 50-ohm coaxial systems. The 11511A and 11512A are type N female and male shorts and are compatible with connectors conforming to MIL-C-39012. The 11565A has a precision 7-mm (APC-7) connector. Prices: 11511A Type N Female Shorting Jack, $4; 11512A Type N Male Shorting Plug, $5; 11565A APC-7 Short, $25.





WAVEGUIDE TERMINATIONS, SHORTS

General-application types

Models 910, X913A, 914, 920, X923A, X930A

910 Terminations

Model 910 is designed for terminating waveguides systems operating at low average powers. The terminations are carefully designed to absorb virtually all of the applied power and assure a low SWR.

910 Specifications

Model	Frequency Range (GHz)	SWR	Power Ratings	Fits waveguide size OD (in.)	(EIA)	Price
G910A	3.95–5.85	1.04	2 watts	2 x 1	WR 187	$70
J910A	5.3–8.2	1.02	1 watt	1½ x ¾	WR 137	$55
H910A	7.05–10	1.02	1 watt	1¼ x ⅝	WR 112	$45
X910B	8.2–12.4	1.015	1 watt	1 x ½	WR 90	$35
P910A	12.4–18	1.02	1 watt	0.701 x 0.391	WR 62	$40

914 Loads

Model 914 Moving Load consists of a section of waveguide in which is mounted a sliding tapered low-reflection load. A lockable plunger controls the position of the load, moving it at least ½ wavelength at the lowest waveguide frequency. Eight models cover the frequency range from 2.6 to 40 GHz.

914 Specifications

Model	Frequency Range (GHz)	SWR load	Avg Pwr Rating (watts)	Waveguide Size (EIA)	Price
G914A	3.95–5.85	1.01	2	WR 187	$120
J914A	5.3–8.2	1.01	2	WR 137	$100
H914A	7.05–10	1.01	1	WR 112	$ 80
X914B	8.2–12.4	1.01	1	WR 90	$ 60
P914A	12.4–18	1.01	½	WR 62	$ 75
K914B	18–26.5	1.01	½	WR 42	$275
R914B	26.5–40	1.01	½	WR 28	$275

X913A Termination

The X913A is a high-power termination which requires no cumbersome water connections. The unit will dissipate 500 watts average, 100 kW peak, and its SWR over the full 8.2 to 12.4 GHz range is less than 1.05. Price: X913A, $125.

X923A, 920A,B Waveguide Shorts

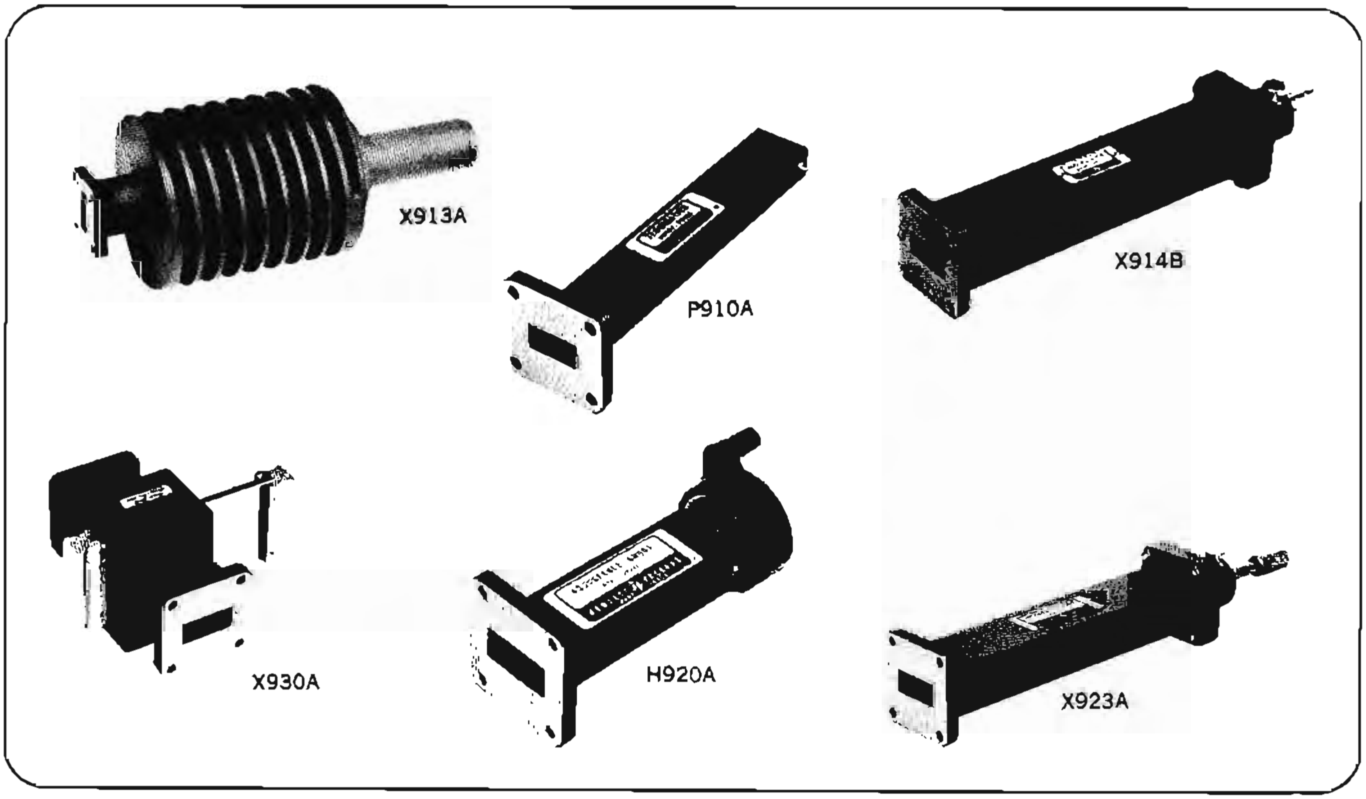
Models X923A and 920A,B are low loss movable shorts. Each of the 920 series is adjustable through at least half a wavelength at the lowest frequency in its band. The X923A is adjustable through about two wavelengths at 8.2 GHz. The 920A features a crank-driven leadscrew that positions a contacting, conducting plane. The 920B uses a choke-type short positioned by a micrometer drive. The X923A employs a non-contacting, conducting plane positioned by a sliding shaft.

X923A, 920A, B Specifications

Model	Frequency Range (GHz)	Fits waveguide Size OD (In.)	(EIA)	Price
G920A	3.95–5.85	2 x 1	WR 187	$125
J920A	5.3–8.2	1½ x ¾	WR 137	$100
H920A	7.05–10.0	1¼ x ⅝	WR 112	$ 85
X923A	8.2–12.4	1 x ½	WR 90	$ 75
P920B	12.4–18	0.702 x 0.391	WR 62	$125
K920B	18.0–26.5	0.600 x 0.250	WR 42	$155
R920B	26.5–40.0	0.360 x 0.220	WR 28	$175

X930A Shorting Switch

Model X930A, 8.2 to 12.4 GHz, provides a removable short in a waveguide circuit. SWR is less than 1.02 in the "open" position, greater than 125 in the "short" position. Price: HP X930A, $160.



TUNERS, PHASE SHIFTERS

Precision instruments for lab or general use
Models 870A, 885A

885A Waveguide Phase Shifters

HP 885A Phase Shifters provide accurate, controllable phase variation in the J-, X-, and P-band frequency ranges. They are particularly useful in microwave bridge circuits where phase and amplitude must be adjusted independently. They also are used in the study of phased arrays.

The instruments are differential phase devices; that is, they add or subtract a known phase shift from the total phase shift which a wave undergoes in traveling through the device.

The instruments have high accuracy over their entire phase range, −360 to +360 electrical degrees, have low power absorption, are simple to operate, and require no charts or interpolation. They are sturdily built, comprising two rectangular-to-circular waveguide transitions with a dial-driven circular waveguide mid-section. These waveguide phase shifters are housed in cast aluminum containers for extreme rigidity and durability.

Specifications, 885A

Model	Frequency Range (GHz)	Differential Phase Angle Range[1]	Accuracy[2] (The smaller of)	Insertion Loss[3]	SWR (max.)	Power Rating (Watts)	Waveguide Size (EIA)	Waveguide Flange	Weight Net lb	Weight Net kg	Weight Shipping lb	Weight Shipping kg	Price
J885A	5.3–8.2	−360° to +360°	±3° or 0.1 $\Delta\phi$	<2 dB	1.35	10	WR137	UG-344/U	14	6,3	25	11,3	$650
X885A	8.2–12.4	−360° to +360°	±2° (±3°, 10–12.4 GHz) or 0.1$\Delta\phi$	<1 dB, 8.2–10 GHz; <2 dB, 10–12.4 GHz	1.35	10	WR90	UG-39/U	8	3,6	10	4,5	$475
P885A	12.4–18	−360° to +360°	±4° or 0.1 $\Delta\phi$	<3 dB	1.35	5	WR62	UG-419/U	7	2,5	10	4,5	$675

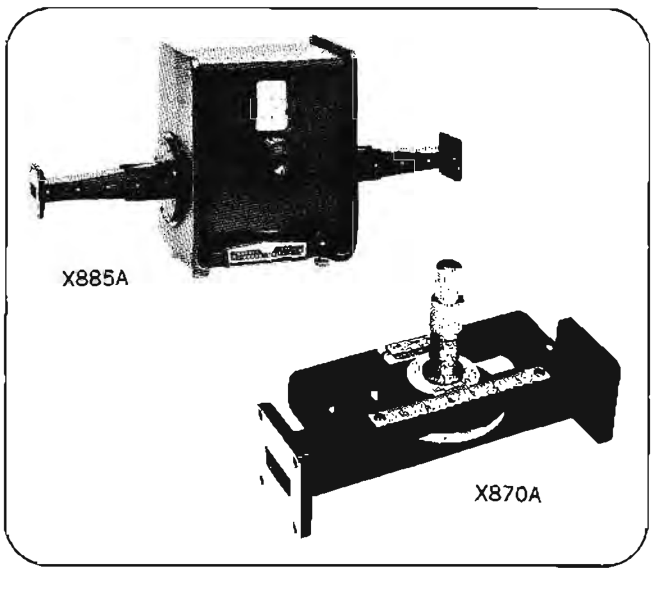
[1] Can be shifted continuously through any number of cycles.
[2] $\Delta\varnothing$ = phase difference in degrees.
[3] Variation with frequency (fixed phase setting): approx. 1 dB.
Variation with phase setting (fixed frequency): <0.4 dB, J885A; 0.3 dB max. 8.2 to 10 GHz and 0.4 dB max. 10 to 12.4 GHz, X885A; <0.5 dB, P885A.

870A Slide-Screw Tuners

Waveguide slide-screw tuners are used primarily for correcting discontinuities or for "flattening" waveguide systems. They are also used to match loads, terminations, bolometer mounts, or antennas to the characteristic admittance of the waveguide. They are particularly valuable in determining experimentally the position and magnitude of matching structures required in waveguide systems.

HP 870A tuners consist of a waveguide slotted section with a precision-built carriage on which is mounted an adjustable probe. The position and penetration of the probe is adjusted to set up a reflection which is used to cancel out an existing reflection in a system.

Probe penetration into the guide is varied by a micrometer drive. Position of the probe along the guide is adjusted by a thumb-operated wheel, and position can be read to 0.1 mm on a vernier scale. An SWR of 20 can be corrected to 1.02, and small SWR's can be corrected exactly.



Specifications, 870A

Model	Freq. Range (GHz)	Fits Waveguide Size Nom. OD (In.)	(EIA)	Equivalent Flange Type	Length (in.)	(mm)	Net Weight (lbs.)	(kg)	Shipping Weight (lbs.)	(kg)	Price
P870A	12.40-18.00	0.702 x 0.391	WR62	UG-419/U	5	127	¾	0,34	2	0,9	$160
X870A	8.20-12.40	1 x ½	WR90	UG-39/U	5½	140	1¼	0,56	2	0,9	$150

Correctable SWR on all models: 20.
Insertion loss dB at corrected SWR of 20: 2 dB max.; 3 dB max. for K and R bands.

MISCELLANEOUS EQUIPMENT

Increase flexibility of microwave measurements

Models 281A/B, 292A/B, P932A, 934A, 11540A-11548A

281A,B; 292A,B Adapters

HP 281A,B Adapters transform waveguide impedance into 50-ohm coaxial impedance. Power can be transmitted in either direction, and each adapter covers the full frequency range of its waveguide band with SWR less than 1.25. The 281A Adapter is fitted with a cover flange and brass type N female connector; the 281B, with a cover flange and an APC-7 or optional stainless steel type N female connector.

Models 292A,B Waveguide-to-Waveguide Adapters connect two different waveguide sizes with overlapping frequency ranges. The 292A consists of a short tapered section of waveguide. The 292B is broached waveguide with a step transition between waveguide sizes.

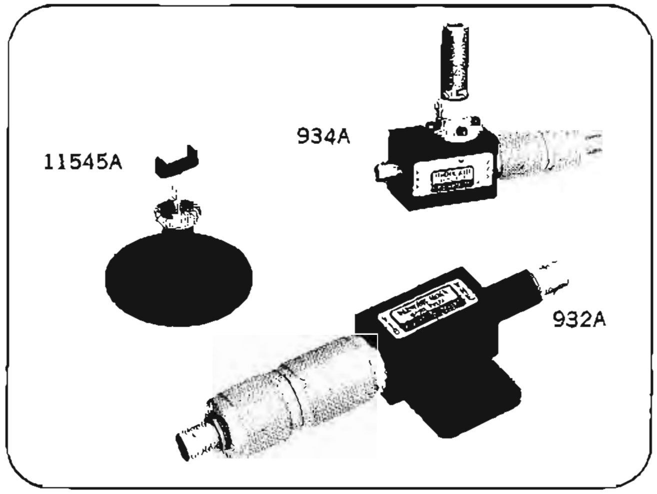
Specifications 281A,B

HP Model	SWR	Frequency Range (GHz)	Waveguide Size EIA	Coaxial Connector	Length (in.)	Length (mm)	Price
S281A	1.25	2.60-3.95	WR284	N Female	2½	64	$65
G281A	1.25	395-5.85	WR187	N Female	2⅛	54	$50
J281A	1.25*	5.30-8.20	WR137	N Female	2	51	$45
H281A	1.25	7.05-10.0	WR112	N Female	1⅝	41	$40
X281A	1.25	8.20-12.4	WR90	N Female	1⅜	35	$35
X281B	1.25	8.20-12.4	WR90	APC-7**	1⅜	35	$70
P281B	1.25	12.4-18	WR62	APC-7**	15/16	24	$85

*1.3 from 5.3 to 5.5 GHz.
**Option 13, Furnished with stainless steel N-female connector, less $15.00.

Specifications 292A,B

HP Model	SWR	Length (in.)	Length (mm)	Frequency range (GHz)	Price
HX292B	1.05	1½	38	8.20 to 10.0	$40
MX292B	1.05	2⅜	60	10.0 to 12.4	$50
MP292B	1.05	2⅜	60	12.4 to 15.0	$40
NP292A	1.05	2⅜	60	15.0 to 18.0	$40
NK292A	1.05	2⅜	60	18.0 to 22.0	$40



934A, P932A Harmonic Mixers

HP 934A, P932A speed and simplify frequency measurements from 2 to 18 GHz. They are also excellent as RF mixers in phase-stabilized signal sources. Both feature high sensitivity, yet require no tuning.

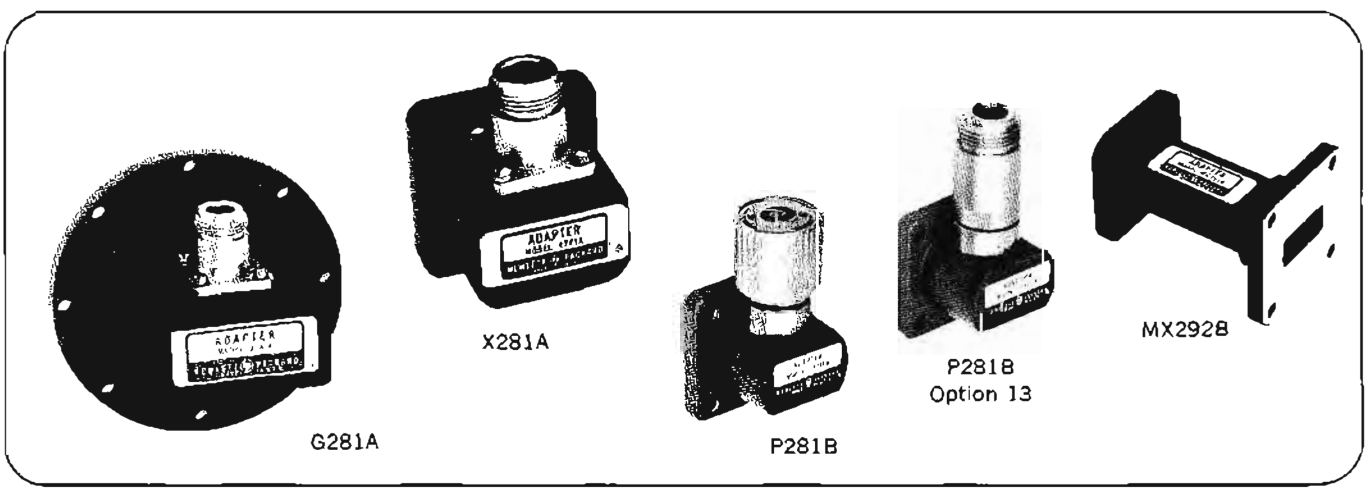
Specifications 934A, P932A

Model	Frequency Range (GHz)	Maximum Input	Typical Sensitivity	Min. video output*	Price
934A	2 to 12.4	100 mW	−48 dB at 3.5 GHz −25 dB at 10 GHz	1.4 mV p-p	$150
P932A	12.4 to 18	100 mW	−10 dB	0.4 mV p-p	$250

*With 0 dBm input signal.

Waveguide Stand, Waveguide Clamps

The 11540A Waveguide Stand locks HP Waveguide Clamp at any height from 2¾" to 5¼" (70 to 133 mm). The stand is 2½" (64 mm) high, and the base measures 4¾" (121 mm) in diameter. Price: 11540A, $3. The Waveguide Clamps are offered in eight sizes to hold waveguide covering frequencies from 2.6 to 40 GHz (see pages 276-281 for individual listings). They consist of a molded plastic cradle with a center rod. Price: 11541A-11548A, $3 each.



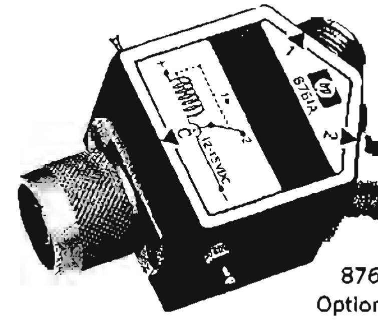
COAXIAL SWITCH
Economical, versatile, broadband switches
Model 8761

8761 Coaxial Switch

The HP 8761 is a single-pole, double-throw coaxial switch with low standing-wave ratio, low insertion loss, and good isolation from dc to 18 GHz. Mechanically, the switch is a break-before-make type controlled by a latching solenoid. Solenoids are available in 12- and 26-volt ratings and can be operated by dc or pulsed signals.

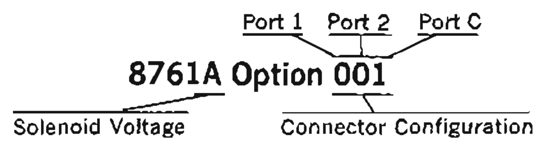
For maximum utility, any of seven coaxial connectors, or a 50-ohm termination, may be specified for each port. Connectors may be chosen from Type N jack, Type N plug, precision 7-mm plug, precision 7-mm jack, precision 7-mm jack for semirigid coax, 3-mm jack, and 3-mm plug. Type N connector dimensions conform to MIL-C-39012, and the 3-mm connectors are compatible with the OSM[1] series. The three precision 7-mm connectors are space-saving versions of the APC-7[2]. Two of these, the jack and plug, mate with the standard APC-7 connector. The third is compatible with the connector used on 0.250-inch outside diameter semirigid (UT-250[3]) coaxial cable. The 7-mm jack has a fixed, threaded coupling sleeve whereas the 7-mm plug has a narrow, hexagonal nut and no coupling sleeve.

[1] Amphenol RF Division, Danbury, Connecticut.
[2] Omni Spectra Inc., Detroit, Michigan.
[3] Uniform Tubes, Inc., Collegeville, Pennsylvania.


8761A
Option 001

Ordering information

Specify solenoid voltage and connectors (including built-in 50Ω termination) by the alphabetic suffix on the switch model number and the appropriate three-digit option number.



A: 12 - 15 V
B: 24 - 30 V

Option Code	Connector Type	Option Code	Connector Type
0	N Jack*	4	7-mm for UT-250 Coax
1	N Plug	5	3-mm Jack
2	7-mm Jack	6	3-mm Plug
3	7-mm Plug	7	50Ω Termination

*"Jack" identifies the connector with fixed threads; "plug" identifies the connector with the coupling nut.

Specifications

Characteristic impedance: 50Ω.

Frequency range: dc —18 GHz.

Standing-wave ratio: looking into one of the connected ports with 50Ω on the other; third port open.*

	Frequency	Connector Type		
		7-mm	N	3-mm
8761	DC-12.4 GHz	<1.15	<1.20	<1.25
	DC-18 GHz	<1.20	<1.25	<1.30

Looking into one of the connected ports with the built-in termination on the other; third port open.*

	Frequency	Connector Type		
		7-mm	N	3-mm
8761 with built-in termination	DC-12.4 GHz	<1.20	<1.25	<1.30
	DC-18 GHz	<1.25	<1.30	<1.35

Insertion loss:

DC - 12.4 GHz: <0.5 dB.

DC - 18.0 GHz: <0.8 dB.

*These specifications apply when connected ports are of the same connector type; for mixed connector types, the larger of the two VSWR's applies. N-connector VSWR specifications apply to Option 4 connectors.

Isolation:

DC - 12.4 GHz: >50 dB.

DC - 18.0 GHz: >45 dB.

Power: safely handles 10 W average, 5 kW peak without built-in termination; built-in termination rated at 2 W average, 100 W peak.

Switching energy: 1.5 W for 20 ms (permanent magnet latching).

Solenoid voltages: (dc or pulsed)

8761A: 12 - 15 V.

8761B: 24 - 30 V.

Switching speed: 35 - 50 ms (includes settling time).

Life: >1,000,000 switchings.

Dimensions: 1.6″ x 1.5″ x 1.5″ (41 x 38 x 38 mm), excluding connectors and solenoid terminals.

Weight: net, 5-8 oz (140-220 g); shipping, 8-11 oz (220-300 g).

Price: Model 8761, $150 each, 1-9; $140 each, 10-24.
Model 8761 with built-in termination on any port, add $35 each.
Prices on request for larger quantities.

NOISE FIGURE METERS; SOURCES

Automatic noise figure measurements to 18 GHz

Models 340B, 342A; 343A, 345B, 347A, 349A

In microwave communications, radar, etc., the weakest signal that can be detected is usually determined by the amount of noise added by the receiving system. Thus, any decrease in the amount of noise generated in the receiving system will produce an increase in the output signal-to-noise ratio equivalent to a corresponding increase in received signal. From a performance standpoint, an increase in the signal-to-noise ratio by reducing the amount of noise in the receiver is more economical than increasing the power of the transmitter.

The quality of a receiver or amplifier is expressed in a figure of merit, or noise figure. Noise figure is the ratio, expressed in dB, of the actual output noise power of the device to the noise power which would be available if the device were perfect and merely amplified the thermal noise of the input termination rather than contributing any noise of its own.

The Hewlett-Packard system of automatic noise figure measurement depends upon the periodic insertion of a known excess noise power at the input of the device under test. Subsequent detection of noise power results in a pulse train of two power levels. The power ratio of these two levels contains the desired noise figure information. Hewlett-Packard noise figure meters automatically measure and present this ratio directly in dB of noise figure.

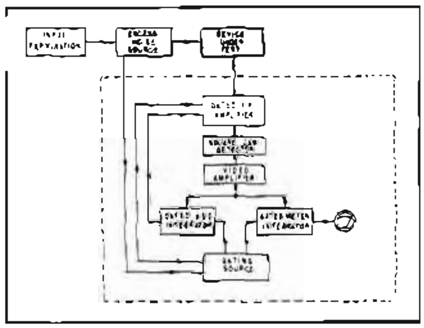


Figure 1. Automatic noise figure measurement system.

Noise figure is discussed in detail in Hewlett-Packard Application Note 57, which is available from your local Hewlett-Packard field office upon request. Application Note 57, "Noise Figure Primer," derives noise figure formulas, describes general noise figure measurements and discusses accuracy considerations. One of the measurement systems discussed in Application Note 57 is shown in Figure 1. The portion of the diagram within the dashed box is a simplified block diagram of the HP 340B and 342A Noise Figure Meters, and the excess noise source could be any of the noise sources described on these pages.

Advantages:

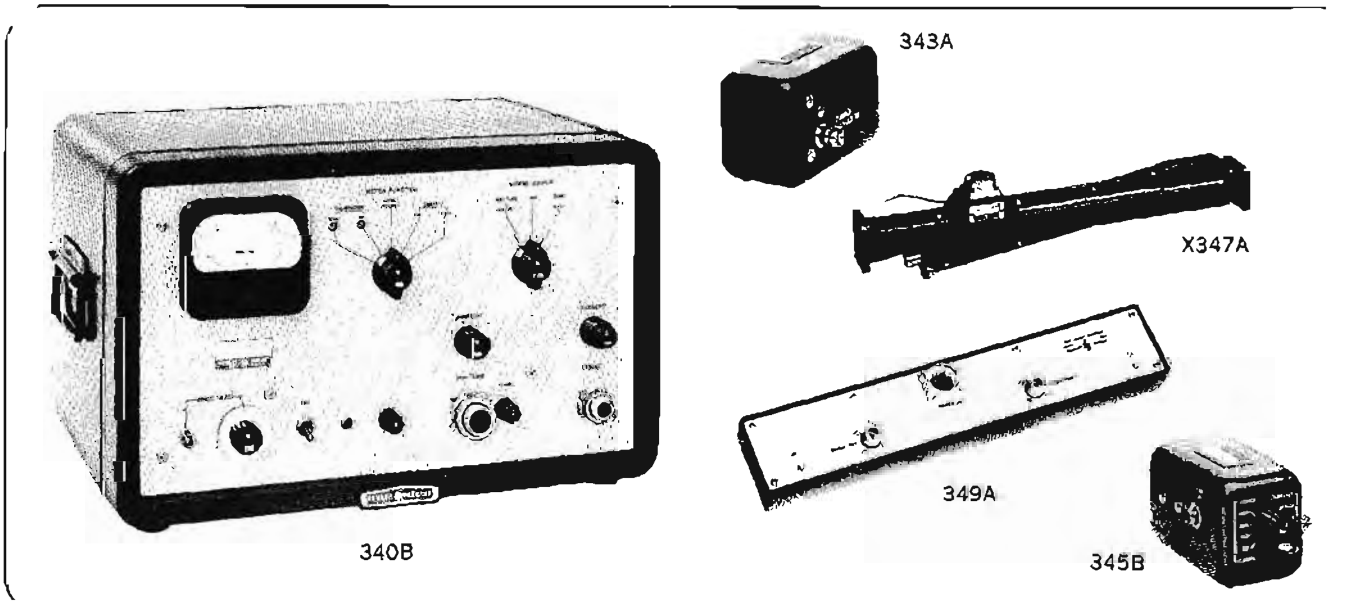
Reads noise figure directly in dB
Completely automatic measurement
Easily used by nontechnical personnel
No periodic recalibration needed
Fast response; ideal for recorder operation

Uses:

Measure noise figure in microwave or radar receivers, RF and IF amplifiers
Compare unknown noise sources against known noise levels
Adjust parametric amplifiers for optimum noise figure

HP noise figure meters and noise sources offer time-saving and cost-reducing advantages. Their ease of operation and continuous, automatic metering of noise figure reduce the time required for alignment and adjustment and simplify measurements so that they can be done by nontechnical personnel. No periodic recalibration of the meters is needed, and accurate alignment is easy, so high-level, on-line performance is assured.

In operation, a noise source is connected to the input of the device under test. The IF output of the device is connected to the 340B or 342A. The noise figure meter gates the noise source on and off. When the noise source is on, the noise level is that of the device plus the noise source. When the noise source is off, the noise level is that of the



device and its termination. The noise figure meter automatically compares the two conditions and displays noise figure directly in dB. Power to operate the noise source is supplied by the noise figure meter. Simply connect the noise source, adjust drive current using the controls and meter on the 340B or 342A, and the noise source is ready for operation.

Noise figure meters

Model 340B Noise Figure Meter, when used with an HP noise source, automatically measures and continuously displays noise figure for frequencies of 30 and 60 MHz. On special order up to four custom frequencies between 10 and 70 MHz, and some frequencies outside this range, can be supplied.

Model 342A is similar to Model 340B, except that it operates on five frequencies: 60, 70, 105, 200, and the basic tuned-amplifier frequency of 30 MHz. Up to six custom frequencies between 10 and 200 MHz, including 21.4 MHz, are available on special order.

Noise sources

Hewlett-Packard 343A VHF Noise Source: Specifically for IF and RF amplifier noise measurement, a temperature-limited diode source with broadband noise output from 10 to 600 MHz with 50-ohm source impedance and low SWR.

Hewlett-Packard 345B IF Noise Source: Operates at either 30 or 60 MHz, as selected by a switch; another selector permits matching 50-, 100-, 200-, and 400-ohm impedances.

Hewlett-Packard 347A Waveguide Noise Source: Argon gas discharge tubes mounted in waveguide sections; for waveguide bands 2.6 through 18 GHz, they provide uniform noise throughout the range; maximum SWR is 1.2.

Hewlett-Packard 349A UHF Noise Source: Argon gas discharge tubes in Type N coaxial configuration for automatic noise figure readings, 400 to 4000 MHz.

Specifications, 340B and 342A

Noise figure range: 5.2 dB noise source, 0 to 15 dB, indication to infinity; 15.2 dB noise source, 3 to 30 dB, indication to infinity.

Accuracy (excluding source accuracy): noise diode scale: ±0.5 dB, 0 to 15 dB; gas tube scale: ±0.5 dB, 10 to 25 dB; ±1 dB, 3 to 10 dB and 25 to 30dB; (for stated accuracy with 343A S, H, X and P347A and 349A Noise Sources, correction factor equal to the difference between specified excess noise and 15.2 dB must be applied to meter reading).

Input frequency: 340B: 30 or 60 MHz, selected by switch, 342A: 30, 60, 70, 105, and 200 MHz, selected by switch. Other frequencies available; prices and details on request.

Bandwidth: 1 MHz minimum.

Input requirements: −60 to −10 dBm (noise source on): corresponds to gain between noise source and input of approximately 50 to 100 dB for 5.2 dB noise source and 40 to 90 dB for 15.2 dB noise source.

Input Impedance: 50 ohms nominal.

AGC output: nominal 0 to −6 V from rear binding posts.

Recorder output: 1 mA maximum into 2000 ohms maximum.

Power input: 115 or 230 volts ±10%, 50 to 60 Hz, 185 to 435 watts, depending on noise source and line voltage.

Power output: sufficient to operate 343A, 345B, 347A or 349A Noise Sources.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14½" deep (527 x 324 x 368 mm); rack mount: 19" wide, 10-15/32" high, 13⅞" deep behind panel (483 x 266 x 353 mm).

Weight: net 44 lb (19.8 kg), shipping 55 lb (24,8 kg) (cabinet): net 37 lb (16,7 kg), shipping 51 lb (22,9 kg) (rack rount).

Accessories furnished: one 340A-16A Cable Assembly, connects noise figure meter to 347A or 349A Noise Source.

Price: HP 340B, $815 (cabinet); HP 340BR, $800 (rack mount); HP 342A, $915 (cabinet); HP 342AR, $900 (rack mount); not available in all countries.

Specifications, 343A

Frequency range: 10 to 600 MHz.

Excess noise ratio[1]**:** 10 to 30 MHz, 5.20 dB ±0.20 dB; 100 MHz, 5.50 dB ±0.25 dB; 200 MHz, 5.80 dB ±0.30 dB; 300 MHz, 6.05 dB ±0.30 dB; 400 MHz, 6.30 dB ±0.50 dB; 500 MHz, 6.50 db ±0.50 dB; 600 MHz, 6.60 dB ±0.50 dB.

Source impedance: 50 ohms.

Reflection coefficient: <0.091 (1.2 SWR), 10 to 400 MHz; <0.13 (1.3 SWR), 400 to 600 MHz.

Noise generator: temperature-limited diode.

Dimensions: 2¾" wide, 2½" high, 5" deep (70 x 63 x 127 mm).

Weight: net ¾ lb (0,34 kg); shipping 2 lbs (0.9 kg).

Price: HP 343A, $125.

Option 01.: spare noise diode(s) calibrated and supplied with instrument, add $40 each.

Specifications, 345B

(same weight and dimensions as 343A)

Spectrum center: 30 or 60 MHz, selected by switch.

Excess noise ratio[1]**:** 5.2 dB.

Source impedance: 50, 100, 200 or 400 ohms, ±4%, as selected by switch; less than 1 pF shunt capacitance.

Noise generator: temperature-limited diode.

Price: HP 345B, $125 (operation at any two frequencies between 10 and 60 MHz in lieu of 30 and 60 MHz available on special order).

Specifications, 347A

HP Model	Range (GHz)	Excess noise ratio[1,2]	Approx. length (in.)	(mm)	Price
G347A	3.95— 5.85	15.2 ±0.5	19	483	$310
J347A	5.30— 8.20	15.2 ±0.5	19	483	$300
H347A	7.05—10.0	15.6 ±0.5	16	406	$275
X347A	8.20—12.4	15.7 ±0.4	14¾	375	$225
P347A	12.4 —18.0	15.8±0.5	14¾	375	$275

Reflection coefficient for all models, fired or unfired, 0.091 (SWR 1.2) max. (source terminated in well-matched load).

Specifications, 349A

Frequency range: 400 to 4000 MHz, wider with correction.

Excess noise ratio[1]**:** 15.6 dB ±0.6 dB, 400 to 1000 MHz; 15.7 dB ±0.5 dB, 1000 to 4000 MHz.

SWR: <1.35 (fired), <1.5 (unfired) up to 2600 MHz; <1.5 (fired or unfired), 2600 to 3000 MHz; <2.0 (fired), <3.0 (unfired) 3000 to 4000 MHz.

Dimensions: 3" wide, 2" high, 15" long (76 x 51 x 381 mm).

Weight: net 3¼ lb (1,4 kg); shipping 6 lb (2,7 kg).

Price: HP 349A, $325.

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[1] $\text{ENR (dB)} = 10 \log \frac{k(T - T_o)B}{kT_oB}$

where kTB = available noise power,
and kT_oB = available noise power 315 with noise source at 290° K.

[2] Includes factor for insertion loss.

DELCON DIVISION

Cable fault locators

Ultrasonic translator detectors

Special ordering information

U.S.A. Customers: The Delcon Division products listed on this page are sold directly to the customer from the manufacturing division. Please direct all orders and inquiries to:

DELCON DIVISION
333 Logue Avenue
Mountain View, California 94040
Telephone (415) 969-0880

Customers Outside the U.S.A.: Orders should be directed to your local Hewlett-Packard distributor or representative.

Cable Fault Locators

Model 4904A

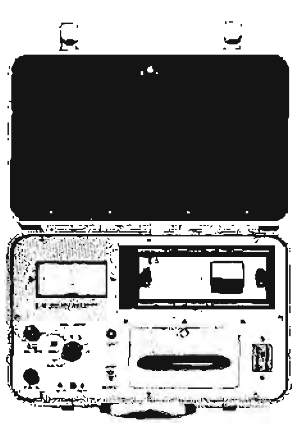
Pulsed tone system for locating shorts, crosses and grounds in direct buried, underground (ducted) and aerial utilities cable. Also, accurately locate path and determine depth of buried cables and pipes. Sensitive narrow bandwidth receiver rejects ac hum and permits locating high resistance faults. Tone transmitter unit also has built-in ohmmeter for analyzing faults. Complete with transmitter, receiver, search wand, cables and ground rod. $995.

Model 4901A

Similar to Model 4904A except limited to locating path, depth and low resistance faults. Built-in ohmmeter. $765.

Model 4900A

Identical to Model 4901A except without ohmmeter. $655.



Model 4904A

Model 4910B

Locates opens in telephone exchange cable, coaxial cable and other cable types having constant mutual capacitance. Reads distance to fault directly in feet* by sampling mutual capacitance. $635.

**Metric calibration available on special order.*

Model 4910B

Ultrasonic Translator Detectors

Model 4905A

Locates leaks in pressurized communication cable and other pressure and vacuum vessels by detecting release of ultrasonic energy. Also detects friction in moving machinery and electrical corona. Special accessory for detecting leaks in cable ducts available. Self-contained speaker and logging meter. Provision for headphones (not included). $595.

Model 4916A

Identical to Model 4905A, except without speaker and meter. Includes headphones. $525.

Model 4917A

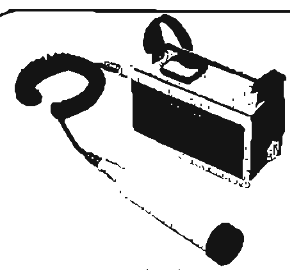
Identical to Model 4905A, except without speaker. Includes headphones. $575.

Model 4918A

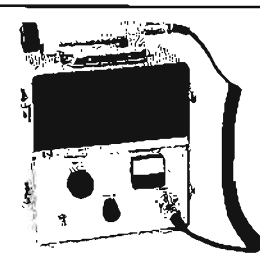
Industrial Ultrasonic Translator Detector. Listed under Re-examination Service of Underwriters Laboratories, Inc. as intrinsically safe for use in hazardous locations, Class I, Group D. $850.

Model 4950A

Embodies special alarm circuitry to actuate relay whenever ultrasonic intensity exceeds present limits. Can be used on bench or rack mounted. Self contained speaker and level meter; oscilloscope and recorder output jacks. AC powered. $1475.



Model 4905A



Model 4918A

The telegraph was the first method of electrical communication. In 1844 the first message was sent over a circuit; shortly after this, the telephone was invented. Since then, electrical communications have been changed to electronic communications. Hewlett-Packard has designed equipment specifically for testing communication systems. The following information pertains only to test equipment designed to simplify and expedite communications service.

These objectives have been accomplished several ways: 1) One instrument, or combination of instruments in one carrying case, will perform the duties of several previous instruments. 2) One function may be transferred to another by merely changing a switch position. 3) Battery-operated test equipment permits operation in the field. 4) A number of standard Western Electric terminals connected in parallel permit connection to different types of line equipment.

Generally, in the United States, subscribers' loops are of nominal 900-ohm impedance. 600 ohms is an accepted trunk and tollboard impedance and is found in the many miles of open-wire carrier still in use. The CCITT* does not recognize 900 ohms as a subscriber-loop impedance but recommends 600 ohms. Wire-cable carrier, typically short-haul, uses 135-ohm cable. Many higher capacity systems use 135 ohms as an interface impedance on a group or super-group basis. The CCITT equivalent of this impedance is 150 ohms. Long-haul coaxial-cable carrier systems use 75 ohms in the United States and in the CCITT recommended systems.

Since a holding function is desirable in many measurements, a holding coil is provided which may be switched into the circuit on the 600 Hold and 900 Hold position. This provides an off-hook condition to hold the dialed line.

Connections are provided for attaching a lineman's handset for dialing. Once the connection has been established, the test instrument may be switched to one of the Hold positions. This will maintain the dialed connection but will remove the talking function and substitute the measuring circuit. The input and output jacks accept standard 241, 309 and 310 Western Electric plugs, as well as the special connectors to receive the lineman's handset and dual banana binding posts for attaching wires.

The theory of message-circuit noise measurement is based on a relative interfacing effect of the noise on the subscriber's hearing. Because of the frequency response of the telephone subset and the fact that the human ear responds differently to noise of various frequencies, a weighting function is assigned to each frequency in proportion to its contribution to the interfering effect.

The weighting curve currently accepted as a U.S. standard is the Bell System C-Message weighting (see Figure 1). The unit used to define noise measured in this manner is dBRNC, meaning deciBels above Reference Noise, C-Message weighted. Reference noise is −90 dBm at 1 kHz. The CCITT recommendation is psophometric weighting, which has a slightly different curve and is referenced to 800 Hz. The measuring units for this weighting are picowatts psophometric, or pWp. A flat weighting refers to the broadband or flat voltmeter function, and a 3 kHz flat weighting provides for

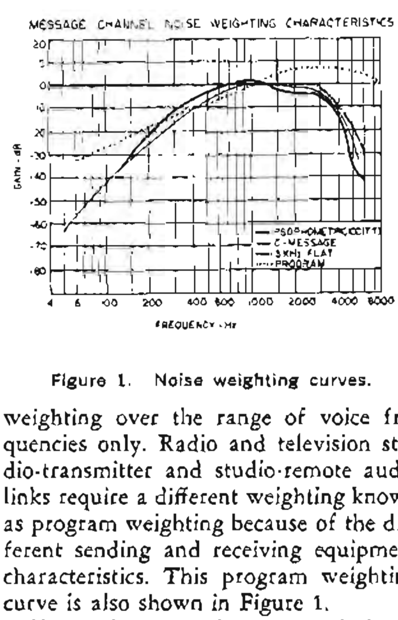


Figure 1. Noise weighting curves.

weighting over the range of voice frequencies only. Radio and television studio-transmitter and studio-remote audio links require a different weighting known as program weighting because of the different sending and receiving equipment characteristics. This program weighting curve is also shown in Figure 1.

Since noise-measuring sets are designed to duplicate the response of the ear, the dynamic response time and the law of combination of tones should be the same. This requires a 200 ms meter-response time and rms response. Average-responding meters will read 1.05 dB low compared to an rms meter on Gaussian noise (providing no overload occurs on the peaks).

The CCITT recommendation specifies rms response for noise measurements and calls out a method for testing meters for rms response.

In addition to the quantitative measurement of noise, it is important to identify the source of the noise. Some indication of this can be obtained by noting the difference in noise on the 3 kHz flat and the C-Message weighting functions. A substantially higher reading in the 3 kHz flat mode usually indicates excessive power-line noise. Aural monitoring of the noise using a headphone is also used.

The noise meter should also be a level meter, as these two measurements are most frequently made. Since field use accounts for a major part of the service of such a device, portability and battery operation are essential. Rugged case construction, able to withstand the rigors of outside operation, is desired. Monitor and recorder outputs for aural monitoring and long-term recording of noise and level should be provided along with a damping switch to lengthen the integrating time constant of the meter for rapidly fluctuating noise.

The Hewlett-Packard Telephone Test Meter incorporates these important features.

3555B Telephone Test Meter

The HP Model 3555B Telephone Test Meter combines the functions of a broadband level meter and a message-circuit noise meter. As a broadband rms-level meter, a frequency range of 20 Hz to 3 MHz is covered with a maximum sensitivity of 0 dBrn and −90 dBm. It is fully balanced with impedances of 75 ohms unbalanced, 135 or 150, 600 and 900 ohms balanced both bridging and terminated (Figure 2). The balanced input impedances are accomplished by a high impedance repeat coil. This technique gives impedances of over 100 kΩ bridging with less than 0.05 dB bridging loss. Provisions are made for dial-through and hold.

As a noise-measuring set, the 3555B contains filters which perform the C-Message, 3 kHz Flat, 15 kHz Flat and Program weighting functions (CCITT weighting filters and European connectors are available on the Model 3556A). The meter circuit contains an rms detector which adds the noise voltages on a power basis. Indication of noise levels down to 0 dBrn as well as noise-to-ground and noise-metallic measurements can easily be made. The amplifier output may be connected to a recorder for long-term noise records or will allow aural monitoring of the character of the noise.

This instrument in a rugged, portable carrying case features internal battery operation as well as CO battery or ac power. It operates reliably over a 0°F to +120°F temperature range at humidi-

*Consultative Committee on International Telephone and Telegraph.

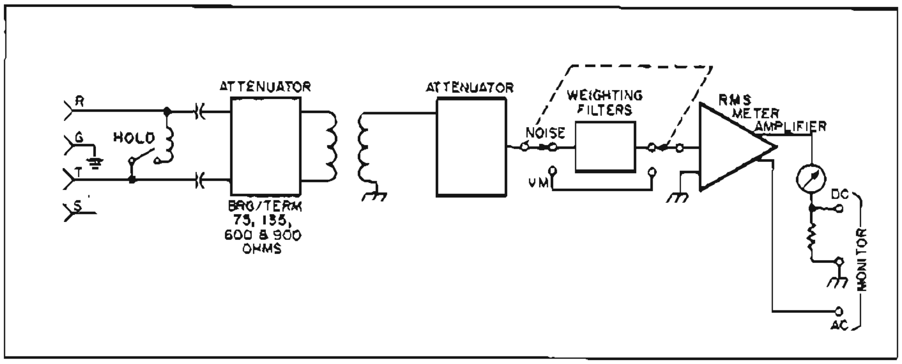


Figure 2. 3555B simplified block diagram.

ties up to 95% R.H. An interlock turns the power switch off when the cover is replaced.

Using the 3555B Telephone Testmeter in conjunction with the HP-236A Telephone Test Oscillator makes a universal transmission test set that can be used for all types of telephone equipment.

236A Telephone Oscillator

The HP Model 236A Telephone Oscillator has all of the above-mentioned Western Electric connectors for dialing and output. It incorporates the holding function for 600- and 900-ohm output impedances. It provides a 50 Hz to 20 kHz frequency range in the 600- and 900-ohm balanced output and a 5 kHz to 560 kHz frequency range on the 135-ohm balanced output. Its power source may be a 115/230 V ±10%, 50 to 400 Hz external source or a 45 V dry cell internal battery.

An interlock turns the power switch off when the cover is replaced. The oscillator's output level is adjustable from +10 to −31 dBm in 0.1 dB steps. The attenuator precedes the output transformer so the output impedance is not affected by the attenuation.

The HP 236A consists of an oscillator-amplifier, attenuator, power supply, meter circuit and a selective output circuit. Figure 3 shows the block diagram of this instrument.

The oscillator-amplifier operates as a typical solid-state HP RC oscillator (refer to page 368 of the oscillator section of this catalog). The front-panel output calibrator adjustment controls the output amplitude. Accurate metal-film resistors are used to insure exact attenuations.

The output circuitry consists of a low- and a high-frequency output transformer, a holding coil, and parallel Western Electric output and dial connectors to insure a proper connection to any line equipment.

3550B Portable Test Set

The HP 3550B Portable Test Set was designed specifically for transmission-line testing and for such applications as alignment and maintenance of multi-channel communication systems. The test set consists of a wide-range oscillator, an electronic voltmeter and a patch panel containing attenuators and line-matching transformers. The instruments are operated from a rechargeable battery power source, making it usable in the field.

The heart of this test set is the 353A Patch Panel which adapts the oscillator and voltmeter to specific telephone usage. The patch panel has input and output sections acting as a source and receiver for the transmission line. The output section has an attenuator and both sections have an impedance-matching device which matches the oscillator and voltmeter 600-ohm impedance to 135, 600 and 900 transmission-line impedances. The center-tapped transformers give balanced outputs and inputs with bridging or terminated capabilities. The accurate attenuator gives 110dB attenuation in 1dB steps.

The H20-204C Option 02 Oscillator frequency is 5 Hz to 1.2 MHz in six ranges, and the 403B Option 01 Voltmeter has ranges from 0.001 to 300 V full scale in 12 ranges. Thus, a complete telephone measuring set is contained in one portable package.

The H02-353A Patch Panel has special telephone jacks which will accommodate Western Electric 309 and 310 plugs. The Hold function is included along with a selectable 23dB attenuation position.

The H03-353A Patch Panel will accommodate Western Electric 309-310 and 241 plugs, and a lineman's handset. The Hold function is included along with a 23 dB attenuator.

Analyzers

The H05-332A and H05-334A are standard HP Models 332A and 334A Distortion Analyzers modified for use in the broadcast industry. The front-panel voltmeter reading is in dBm, and a switchable low-pass 30 kHz filter is added.

312A/313A Selective Voltmeter

The low noise and wide dynamic range of the 312A Selective Voltmeter makes it useful for many telephone applications including measurement of system flatness, analysis of distortion and intermodulation (cross-talk) in carrier systems, and measurement of noise levels. Input impedances of 50, 60, 75, 124, 135, 150, and 600 ohms or bridging, balanced or unbalanced, are selectable at the front panel. Amplitude response vs. frequency can be measured when using the Model 313A Tracking Oscillator. Semi-automatic plots of amplitude vs. frequency can be made using the Model 297A Sweep Drive and an X-Y recorder.

Noise on coaxial telephone lines restricts dynamic range, which often must be as high as 70 to 90 dB. The measurements are usually made with a selective voltmeter that has a 200 hertz window. This reading is normalized to that of a 3 kHz window, which covers the standard voice-channel width, adding a complicated correction factor to compensate for the difference in bandwidths, weighting factors, and rms response.

A selective voltmeter with a 3 kHz bandwidth would be better to measure noise. Until recently, the shape factor of the 3 kHz bandwidth was such that the carrier frequencies were only partially suppressed.

The HP 312A Option 01 provides carrier-system operators with a filter that allows channel noise measurements with a 3 kHz bandwidth. Two notches are superimposed 2 kHz away from the center frequency. Better carrier rejection is obtained, as can be seen in Figure 4. If the carrier frequency is known, the HP 312A Option 01 need only be tuned to 2 kHz above or below the carrier frequency, and the carrier frequencies adjacent to the voice channel are attenuated 45 dB before they are detected.

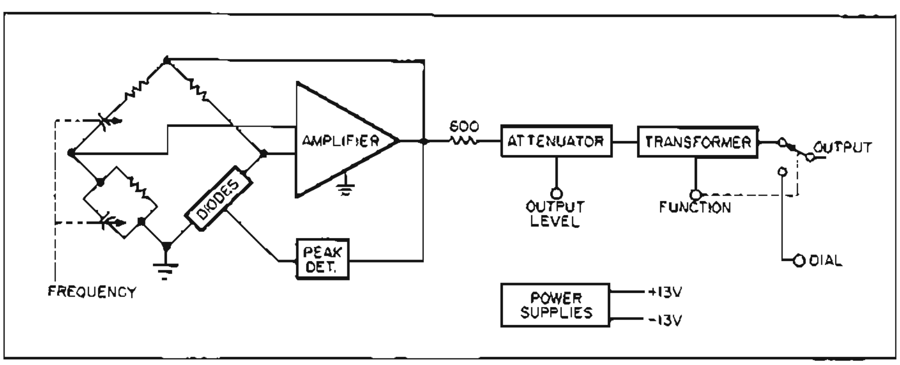


Figure 3. 236A block diagram.

The indication is a much truer representation of channel noise. Refer to pages 446 and 447 for additional information.

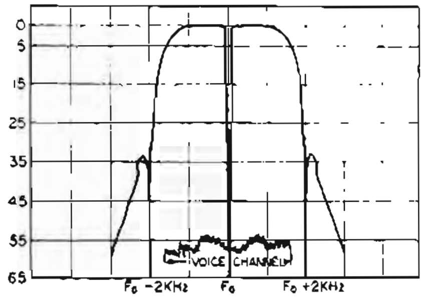


Figure 4. Bandpass for the 312A Selective Voltmeter.

3591A Selective Voltmeter

The HP 3591A Selective Voltmeter with a Sweeping Local Oscillator Plug-in is a modified 3590A Wave Analyzer that is specialized for communication testing.

The balanced input impedances are 75, 135, 150, 600 ohms and 100 k-ohms bridging. The meter has an illuminated scale with high resolution.

The input functions selected by the function switch are: 1) "dBm" with levels calibrated in dBm for each of the selected input impedances. 2) "ABS VM" which is the absolute value calibrated in volts. 3) "Rel" which is relative values in 10 dB steps with an adjustable reference level for an arbitrary starting point for relative measurement. 4) "Cal" which gives a 100 kHz full scale calibration signal.

The outstanding dynamic range of this instrument is shown in Figure 5. For additional information refer to the 3590A technical pages 437 and 438, and for plug-in information, refer to page 443. The 3591A specifications are given on page 324.

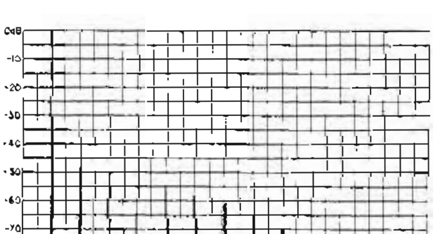


Figure 5. HP 3591A/3594A sweeps a signal showing the dynamic range of the instrument.

Alignment in local video loops

Equalizer alignment in local video loops has typically been a complicated procedure requiring considerable time and effort on the part of the technician or craftsman. He has had to carry four bulky pieces of test equipment to the site, interconnect them with seemingly endless patch cords and then become a nimble-fingered wizard adjusting a myriad of controls to produce a flat video response. A frequency range of more than 5 decades is required to faithfully transmit television signals. This necessitates an impressive array of equipment to maintain the required response.

The classical test equipment used at the sending end for setting the receive equalizers consists of a Western Electric 61C Signal Generator supplying test frequencies from 300 kHz to 10 MHz and a Hewlett-Packard 200CD Oscillator for supplying the 300 kHz reference. For test frequencies below 300 kHz, the 200CD is used as the test frequency generator and the 61C supplies the reference. Since neither generator is capable of supplying accurate amplitude signals with a flat frequency response over the wide range required, a Western Electric 70B Power Meter is used to monitor the generator outputs. The 70B is a highly accurate thermocouple-type meter and consequently is subject to burnout or error when overloaded. Its time constant is slow in making rapid amplitude adjustments difficult. A Western Electric 1AP Comparing Set is used to switch between the test and reference frequencies and contains a power splitter arrangement to allow the 70B to monitor the power level simultaneously while transmitting the signal. The receiving level indicator is also a 70B Power Meter.

There are several sources of error to be considered in making these accurate measurements. Since the 70B Power Meter responds to the total power generated by the test oscillator, any oscillator distortion generated will also be measured. If the distortion is not constant, the total power indicated will vary. Near the high frequency end of the system response the oscillator distortion products will fall outside the band resulting in an apparent change in total power. Impedance accuracy is important as mismatches will cause part of the power to be reflected and consequently change the total level. Thus the return loss of the test equipment, which is a measure of its impedance accuracy, must be high. Amplitude transients occurring when the test frequency is changed must be minimized to avoid damage to the thermocouple in the 70B Power Meter. The oscillator frequency must be accurate since the loss of the equalizers varies with frequency. Frequency inaccuracy would result in the equalizer being set improperly.

In some installations the 1AP Comparing Set and 70B Power Meter are replaced with a Western Electric 38A Transmission Measuring Set which automatically performs the switching and comparing function. These 4 classical pieces of test equipment represent a cost of about $5000, weigh 100 lbs. and are rather laborious to carry to remote sites, as well as to operate.

Hewlett-Packard has recently introduced the Model 653A Test Oscillator shown on page 327 which combines into one 21 lb. package costing $990 all the functions previously requiring 4 test sets. The oscillator covers a test frequency range of 10 Hz to 10 MHz and contains a built-in 300 kHz reference oscillator. The output can be switched between the test and reference frequency at any time. The output circuitry supplies a balanced 124Ω or unbalanced 75Ω output flat to within ±0.05 dB over the entire 10 Hz to 10 MHz frequency range. An accurate 1 and 10 dB step attenuator together with an output meter capable of 0.02 dB resolution allows output levels from +10 dBv to −99 dBv to be accurately set. To avoid accidentally applying the +10 dBv power output, causing possible damage to the system under test, a locking switch is used which must be purposely depressed and turned to the +10 dBv position.

The operation of the 653A is simple. The reference frequency is switched on and the system gain is adjusted. Then the switch is set to the test frequency position and the equalizer frequency is set on a large, easy-to-read dial. Once the amplitude of the test frequency is adjusted to equal the reference level on the oscillator output meter, no further adjustments are necessary, since the oscillator is extremely flat over the entire range. The reference test switch is spring-loaded for momentary reference level checks or can be locked in the reference position. The indicating meter used at the receiving end is a 70B Power Meter.

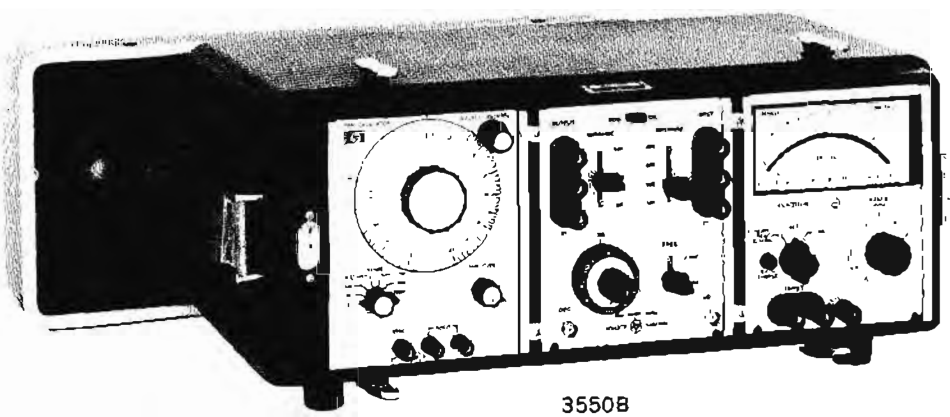
The 653A is equipped with a front cover with carrying handle for protection of the panel controls and a rear cover providing storage space for instruction manual, power cord and output cords.

The 653A represents a modern test set for television system maintenance with unparalleled speed and accuracy. The broadcast technician can make rapid and accurate alignments with this inexpensive, lightweight, and portable piece of test equipment. Refer to page 327 for specifications. For theory of operation refer to the 654A description page 370. The 654A oscillator is similar to the 653A omitting the 300 kHz reference oscillator, and adding a different output circuit calibration in dBm for impedances of 50Ω, 75Ω unbalanced and 135Ω, 150Ω and 600Ω balanced.

Other instruments which can be used in the communications industry are found in the oscillator and voltmeter sections of this catalog.

PORTABLE TEST SET

Model 3550B



3550B

Features:

Oscillator—battery or ac operated.
- 5 Hz to 1.2 MHz. Amplitude variation within ±0.5% 30 Hz to 300 kHz; ±1% 300 kHz to 1.2 MHz.

Voltmeter—battery or ac operated.
- 5 Hz to 2 MHz; reads in volts and dBm from −72 +52 dBm.

Patch Panel (353A)—Matches both oscillator and voltmeter to 135, 600, and 900Ω systems; provides 110 dB attenuation in 10-dB and 1-dB steps.
- (H02 or H03-353A) Holding coils provided.
- 23 dB Attenuator to conform to standard telephone levels of +7 and −16 dBm.
- 135, 600, 900Ω Balanced Input and Output impedances.
- Dial/Talk function switch for use in active telephone circuits.
- Better than 60 dB balanced at 1 kHz for 600 ohm and 900 ohm impedances. Better than 40 dB balance over entire frequency range for 135, 600 and 900 ohms.
- Measure-calibrate switch eliminates insertion loss.
- Accepts standard telephone plugs.
- Hand set may be used in conjunction with Patch Panel.

Uses:

- Align and maintain multichannel communications systems.
- Align and maintain long distance and local telephone circuits, both wet and dry.
- Measure gain, attenuation, and frequency response.
- Measure amplifier characteristics without ground loops.
- Source of balanced μV signals for testing differential amplifiers.

Description

The HP Model 3550B Portable Test Set is designed specifically to measure transmission line and system characteristics such as attenuation, frequency response or gain. It is particularly useful for lineup and maintenance of multichannel communication systems. Model 3550B contains a wide range oscillator, a voltmeter, and a patch panel to match both the oscillator and the voltmeter to 135, 600, and 900 ohm lines. These instruments are mounted in a combining case which is equipped with a splash-proof cover. In addition, the oscillator, voltmeter, and patch panel may be used separately whether they are in or removed from the combining case.

Both the oscillator and voltmeter are transistorized and operate from their internal rechargeable batteries or from the ac line. The batteries provide 40 hours of operation between charges and are recharged automatically during operation from the ac line.

Oscillator

The oscillator of the Portable Test Set is an HP Model H20-204C and has a frequency range of 5 Hz to 1.2 MHz. Its output is fully floating, isolated from the instrument case and powerline ground. Flat frequency response, excellent amplitude and frequency stability and balanced output further enhance its ease of operation.

Voltmeter

The HP Model 403B-Option: 01 Voltmeter, which is part of the Model 3550B Portable Test Set, is a versatile general purpose voltmeter for measurements both in the laboratory and in the field. Its most sensitive range, 1 mV full scale, allows you to measure voltage as small as 100 μV rms from 5 Hz to 2 MHz and a dB scale allows you to measure in dBm from −72 dBm to +52 dBm. Accuracy is within 2% of full scale over a temperature range of 0°C to +50°C for frequencies from 10 Hz to 1 MHz. The dB scale is placed at the top of the meter scale to provide increased resolution for dB measurements.

Patch panel

HP Model 353A Patch Panel contains a precision attenuator, variable in 1-dB steps to 110 dB, and two sets of impedance matching transformers.

The calibrate position of the Meas-Cal switch connects the output of the oscillator to the voltmeter via the attenuator and both sets of transformers to calibrate out the insertion loss of the impedance matching transformers when making loop-back measurements. Insertion loss should be considered when making single-ended or straightaway measurements.

One set of transformers matches the oscillator to 900-ohms, 600-ohms, or 135-ohms lines. The other set of transformers terminates the line in 900 ohms, 600 ohms, 135 ohms or in 10K for bridging measurements. In all positions except Bridging, the voltmeter reads dBm directly. Bridging is on a 1:1 impedance and voltage basis.

Available telephone patch panels

The H02-353A has jacks for Western Electric 309 and 310 plugs which may be switched to either the input or output function of the patch panel. Special clip posts accept a Western Electric 1011B lineman's handset for the dial and talk function. A single-step 23-dB attenuator is provided to facilitate setting standard levels of +7 and −16 dBm.

The H03-353A has jacks for Western Electric 241, 309, 310 and 347 plugs at both input and output permitting loop-back measurements. The dial/talk and hold functions along with the 23 dB attenuator are identical to the H02-353A.

Specifications

Oscillator H20-204C

Frequency range: 5 Hz to 1.2 MHz in 6 ranges. Vernier.

Dial accuracy: ±3% of setting.

Frequency response: +5% −1% 5 Hz to 30 Hz. ±0.5% 30 Hz to 300 kHz. ±1% 300 kHz to 1.2 MHz.

Output impedance: 600 ohms.

Output: 10 milliwatts (2.5 V rms) into 600 ohms; 5 V rms open circuit. Completely floating (isolated).

Output control: continuously adjustable bridged "T" attenuator with 20 dB minimum range.

Distortion: less than 1% −5°F to +120°F. Less than 0.1% 30 Hz to 200 kHz 32°F to 120°F.

Hum and noise: less than 0.01%.

Power supply: 4 rechargeable batteries (furnished). 40-hour operation per recharge (20 hours at −20°C), up to 500 recharging cycles (expected battery life of 20,000 hours). Recharging circuit is self-contained and functions automatically when instrument is connected to ac line (115 or 230 V ±10%, 50 to 400 Hz, approximately 3 watts).

Temperature range: −5°F to 120°F.

Dimensions: (Std. 1/3 module) 6-3/32" high, 5⅛" wide, 8" deep (155 x 130 x 203 mm).

Voltmeter 403B Option 01

Range: 0.001 to 300 V rms full scale (12 ranges).

Frequency range: 5 Hz to 2 MHz.

Accuracy: within ±0.2 dB of full scale from 10 Hz to 1 MHz; within ±0.4 dB of full scale from 5 Hz to 10 Hz and 1 MHz to 2 MHz, except ±0.8 dB 1 to 2 MHz on the 300 V range (0°C to +50°C).

Meter: individually calibrated, taut band. Responds to average value of input waveform and is calibrated in the rms value of a sine wave.

Nominal input impedance: 2 megohms; shunted by 50 pF on 0.001 V to 0.03 V ranges, 25 pF on 0.1 V to 300 V ranges.

DC isolation: signal grd. may be ±500 V dc from chassis grd.

Price: HP 403B Option 01, $335 when purchased separately.

Patch Panel, 353A (apply with oscillator and voltmeter)

Input (receiver)

Frequency range: 50 Hz to 560 kHz.

Frequency response: ±0.5 dB, 50 Hz to 560 kHz.

Balance: better than 70 dB at 60 Hz for 600 ohms and 900 ohms; better than 60 dB at 1 kHz for 600 and 900 ohms; better than 40 dB over entire frequency range for 135, 600 and 900 ohms.

Impedance: 135, 600, 900 ohms and Bridging (10 k); center-tapped.

Insertion loss: less than 0.75 dB at 1 kHz.

Maximum level: +22 dBm (10 V rms at 600 ohms).

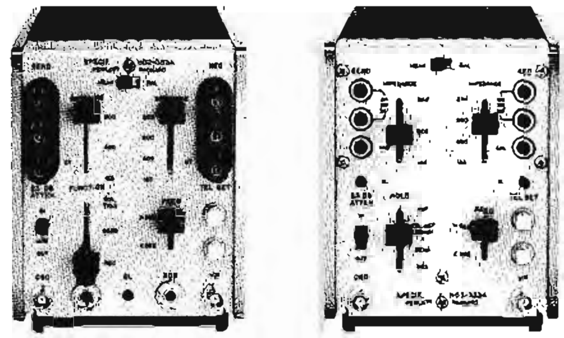
Output (source) includes all receiver specifications:

Attenuation: 110 dB in 1 dB steps.

Accuracy: 10 dB section, <±0.25 dB per step. 100 dB section, <±0.5 dB per step.

Accessories available: 11075A Carrying Case (page 227), $45.

Price: HP 353A, $260 when purchased separately.



H02-353A H03-353A

Available Telephone Patch Panels

Patch Panel H02-353A (Same as Model 353A except as indicated below)

Attenuator: 23 dB ±0.5 dB (1-step slide switch).

Hold circuit (Send terminals)

Frequency response: 300Hz to 3 kHz ±0.5 dB, 1 kHz refer.

DC resistance: 240 ohms NOMINAL.

Maximum dc current: 100 mA.

Maximum dc voltage: 150 volts.

Connectors: special telephone jacks to accept Western Electric No. 309 and 310 plugs. Sleeve jack is connected to sleeve of jacks 309 and 310.

Price: HP HO2-3550B (H20-204C Option 02, HO2-353A, and 403B Option 01), $1270. HO2-353A, $380.

Patch Panel HO3-353A (Same as Model 353A except as indicated below)

Hold circuit (Rec terminals)

Frequency response: 300 Hz to 3 kHz ±0.5 dB, 1 kHz ref.

DC resistance: 240 ohms NOMINAL.

Maximum dc current: 100 mA.

Maximum dc voltage: 150 volts.

Attenuation: 23 dB ±0.5 dB (1-step slide switch).

Hold circuit (Send terminals)

Frequency response: 300 Hz to 3 kHz ±0.5 dB, 1 kHz ref.

DC resistance: 240 ohms NOMINAL.

Maximum dc current: 100 mA.

Maximum dc voltage: 150 volts.

Connectors: special telephone jacks to accept Western Electric No. 309, 310 and 241 at Send and Rec terminals. Sleeve jack is connected to sleeve of jacks 309 and 310.

Price: HP HO3-3550B (H20-204C Option 02, HO3-353A and 403B Option 01), $1270. HO3-353A, $380.

General

Power: (identical specifications in both voltmeter and oscillator): 4 rechargeable batteries (furnished); 40-hour operation per recharge, up to 500 recharging cycles; recharging circuit is self-contained and functions automatically when instrument is operated from ac line (115 or 230 volts ±10%, 50 to 400 Hz, approx. 3 watts).

Dimensions: 8⅜" high, 19¼" wide, 13¼" deep (with cover installed) (213 x 489 x 367 mm).

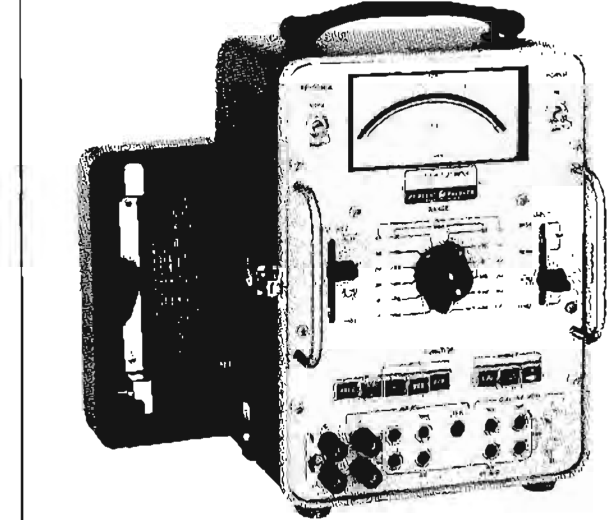
Weight: net 30 lbs (13,5 kg); shipping 40 lbs (18 kg).

Accessories furnished: detachable power cord; two 11035A Cables (1 foot long, dual banana-plug-to-BNC); splash-proof cover and storage compartment.

Accessories available: 10503A Cable, BNC-to-BNC, $7; 11002A Test Leads, banana-plug-to-alligator clip, $8.

Price: HP 3550B (H20-204C Option 02, 353A and 403B Option 01) $1150.

TELEPHONE TEST METER
Transmission Test Set with 236A Oscillator
Model 3555B



3555B

Uses

Measure transmission and noise on voice, carrier and radio systems

Description

The HP Model 3555B Telephone Test Meter is a combination transmission and noise measuring set designed especially for telephone plant maintenance. The 3555B measures voice frequency level, carrier frequency level and noise measurements for both noise metallic and noise-to-ground. Its wide range of sensitivity, selection of input impedances and variety of weighting filters make it a universal tool for virtually all telephone level and noise measurements.

The 3555B comes in a rugged, splash-proof, compact case. This, with a selection of ac line, internal battery or 24/48 V CO battery operation, and a convenient selection of input connectors makes the instrument ideally suited for use inside or outside plant applications. Combined with the 236A Telephone Test Oscillator, this 3555B makes a complete transmission test set. Refer to pages 317 and 318 for additional information.

Tentative Specifications

Voice frequency level measurements
Range: −80 dBm to +30 dBm full scale.
Level accuracy: ±0.2 dB, 100 Hz to 5 kHz; ±0.5 dB, 20 Hz to 10 kHz.
Temperature range: 0°F to 120°F.
Input impedance: terminated, 600 or 900Ω, balanced; bridging, 100 kΩ balanced.
Noise measurements
Range: 0 dBrn to +110 dBrn.
Weighting: 3 kHz flat, C-message, 15 kHz flat, program.
Input impedance:
Noise: metallic - terminated—600 or 900Ω, balanced bridging—100 kΩ balanced.
Noise-to-ground: 80 kΩ across line; 100 kΩ to ground.
Carrier frequency level measurements
Range: −50 dBm to +30 dBm full scale.
Level accuracy:
135Ω and 600Ω: ±0.2 dB, 10 kHz to 100 kHz; ±0.5 dB, 5 kHz to 600 kHz.
75Ω: ±0.2 dB, 100 Hz to 1 MHz; ±0.5 dB, 20 Hz to 3 MHz; +20 and +30 dBm ranges limited to 600 kHz.
Input impedance: terminated: 600 or 135Ω balanced; 75Ω unbalanced. Bridging: 100 kΩ balanced on 600 or 135Ω; 100 kΩ unbalanced on 75Ω.
General
Meter indication: indicates rms value of input signal.
Meter response: 200 ms ±50 ms to +0 dBm (norm), 500 ms ±100 ms to +0 dBm (damp).
Input balance: >70 dB, 30 Hz to 30 kHz; >60 dB, 30 kHz to 100 kHz; >40 dB, 100 kHz to 600 kHz.
Max. input voltage: tip to ring, 150 V peak; tip or ring to ground, 200 V peak (NOTE: this is maximum instantaneous voltage and includes both ac and dc.) Input circuit will withstand 48 V dc CO battery with superimposed 90 V rms 20 Hz ringing voltage, or ±130 V carrier supply.
Max. longitudinal input level: 200 V rms.
Hold circuit: 600, 900, Ng only, 100 Hz to 10 kHz, 700Ω dc resistance, 60 mA max current.
AC monitor: 1.4 V rms with 10 kΩ output impedance (output available at DIAL/AC MONITOR jacks).
DC monitor: −1 V for 0 dBm on meter scale. Jack accepts 310 plug.
Input jacks: accepts Western Electric 241, 309, 310, 358 plugs. Binding posts accept banana plugs, spade lugs, phone tips or bare wires. Removable shorting bar between sleeve and ground binding posts.
Dial jacks: accepts standard 289, 310, 347 plugs. Clip posts accept Western Electric 1011B lineman's handset clips.
Power requirements
Line: 115 or 230 V ±10%, 50 to 400 Hz, <1 W.
Internal battery: single NEDA 202 45 V "B" battery (included)* 24/48 V CO battery: 310 jack (tip negative), <10 mA.
Expected battery life: 150 hr on a 3 hr/day duty cycle at 77°F.
Dimensions: 7¾" wide, 10½" high, 8" deep (197 x 267 x 203 mm).
Weight: net 12 lbs, 8 oz (5,6 kg); shipping 15 lbs (6,8 kg).
Complementary equipment available: HP Model 236A Telephone Test Oscillator, $600 (refer to page 323).
Price: HP Model 3555B, $625.

HP 3556A Telephone Test Meter

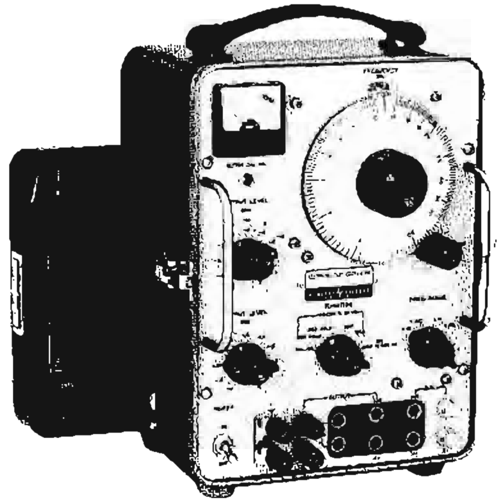
The HP 3556A is identical to the 3555B Telephone Test Meter except it is designed for European operation. The front panel connectors are of the Siemens type. The weighting filters consist of CCITT (psophometric) weighting, CCITT program weighting and the standard 3 kHz flat and 15 kHz flat. Refer to the Data Sheet for detailed information and specifications.

*Rechargeable battery supply available on special order.

TELEPHONE OSCILLATOR

Wide range telephone test oscillator

Model 236A



236A

The solid-state HP 236A Telephone Test Oscillator is designed specifically to deliver transmission test signals. It is particularly useful for line-up and maintenance of telephone voice and carrier systems.

Any frequency between 50 Hz and 560 kHz may be selected in four ranges to an accuracy of ±3%. Frequency response is flat over the entire range at any attenuator setting. The oscillator is fully transistorized, and internal heat production is small, resulting in unusually low warmup drift. Advanced feedback techniques insure excellent frequency and amplitude stability even under temperature extremes. Its output is fully floating and balanced, isolated from power-line ground and instrument case. Low-current drain, solid-state circuitry results in exceptionally long battery life with hum and noise 65 dB below total output.

Output jacks are standard telephone types to facilitate patching into standard test boards. A front-panel switch selects 135, 600 or 900-ohm output impedance. These outputs are balanced to ground and the impedance of each is controlled over the specified frequency range. The phase angle of the output impedance is low to maintain a true resistive source.

The output circuit includes two transformers preceded by step attenuators which, together, adjust output power over a 41 dB range (+10 to −31 dBm), in 10 dBm, 1 dBm, and 0.1 dBm steps having an overall accuracy of 0.1 dB over the entire range.

A front-panel control permits calibration of the output power level. Frequency response of the instrument is better than ±0.3 dB.

A front-panel meter monitors the 45 volt dry cell battery or the 115/230 V ac regulated power supply. The dry cell will provide in excess of 180 hours of operation of the oscillator on a 3 hr/day discharge cycle at 70°F.

Uses:

- Align, test and maintain telephone circuits, both wet and dry
- Align, test and maintain carrier systems
- Test manual switchboards and PBX systems
- Make accurate and reliable measurements even at temperature and humidity extremes
- Balanced signal source for bridges

Features:

- Flat frequency response 50 Hz to 560 kHz
- Calibrated −31 to +10 dBm output in .1 dBm steps
- Balanced 135, 600 and 900 ohm outputs
- Standard telephone output jacks
- Dial and hold provisions
- Operates from battery or ac line

Specifications

Frequency range: 50 Hz to 560 kHz.

Frequency dial accuracy: ±3% of setting.

Frequency response (60°F to 80°F operating temperature):*

	50 Hz — 20 kHz
600Ω & 900Ω outputs	±0.3 dB*

	5 kHz — 560 kHz
135Ω output	±0.3 dB*

*Response is ±0.5 dB from 32°F to 60°F and 80°F to 120°F.

Output level: −31 to +10 dBm in 0.1 dBm steps.

Output level accuracy: ±0.2 dBm from −31 to +10 dBm (1 kHz reference), when operating into selected output impedance.

Distortion: at least 40 dB below fundamental output.

Noise: at least 65 dB below total output or −90 dBm, whichever noise is greater.

Output circuit: balanced and floating. Can be operated up to ±500 V dc above case (earth) ground.

Output impedance: 600 and 900 ohms ±5%. 135 ohms ±10%.

Output balance: 70 dB at 100 Hz (600 and 900 ohm outputs). 55 dB at 3 kHz (600 and 900 ohm outputs). 50 dB at 5 kHz (135 ohm output). 30 dB at 560 kHz (135 ohm output).

Output jacks: accepts Western Electric 241, 309 and 310 plugs. Binding posts accept banana plugs, spade lugs, phone tips or bare wires. Removable shorting bar between sleeve and ground binding posts.

Dial jacks: accepts Western Electric 309 and 310 plugs. Clip posts accept Western Electric 1011B lineman's handset clips.

DC holding coil: 700Ω ±10% dc resistance; 60 mA maximum loop current at 100 Hz. (600 and 900 ohm outputs only).

Power requirements: line: 115/230 V ±10% ac, 50 to 400 Hz, 1 W.

Internal battery: single NEDA 202 45 V "B" battery (included).

Battery life: 180 hr on a 3 hr/day duty cycle at 70°F.

Dimensions: 7¾" wide, 10½" high, 8⅛" deep (197 x 267 x 205 mm).

Weight: net 13.5 lbs (6,1 kg); shipping 16 lbs (7,2 kg).

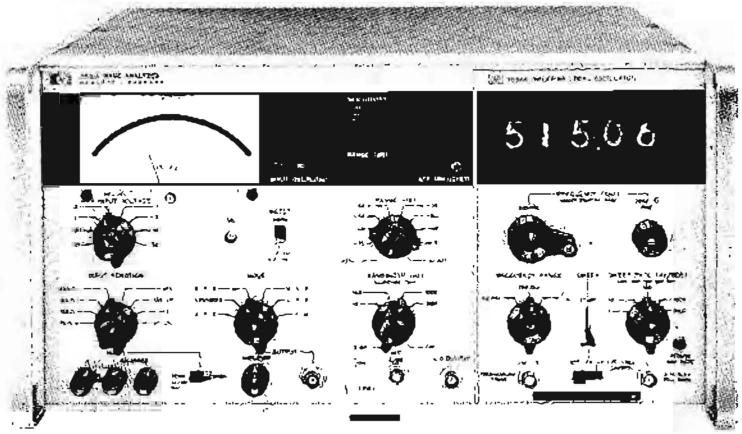
Complementary equipment available: HP Model 3555B Telephone Test Meter, $525.

Price: HP 236A, $600.

PLUG-IN SELECTIVE VOLTMETER

Balanced inputs of 75Ω to 600Ω and bridging

HP 3591A/3594A



3591A with 3594A Plug-in

The HP Model 3591A Plug-in Selective Voltmeter is designed specifically for communications systems. The input balanced impedances and the input functions, in addition to all of the features of the 3590A, make it outstanding as a communications test instrument.

Tentative Specifications

Frequency range: 20 Hz to 620 kHz.

Amplitude ranges: 3 μV to 30 V full scale in 15 ranges.

Amplitude accuracy

Meter switch in normal position: overall accuracy: ±0.5 dB or ±5% of reading, including:

Frequency response flatness: ±0.2 dB or ±2%; Meter tracking: ±0.1 dB or ±1% of reading, 0 dB to −10 dB indication.

Meter switch in linear dB position: overall accuracy: ±1 dB.

Internal calibrator: frequency, 100 kHz ±10 Hz; Amplitude, full scale on 0 dB range in CAL mode; Amplitude accuracy, ±0.1 dB.

Dynamic range: (IM and harmonic distortion products).

>85 dB below zero dB reference level when ABSOLUTE measurements are being made (>70 dB 20 Hz 50 Hz).

>80 dB below zero dB reference level when RELATIVE adjustment is used (>70 dB for 20 Hz to 50 Hz).

Residual responses

>80 dB below zero reference (>70 dB for 20 Hz to 50 Hz).

Return loss: 100 Hz to 620 kHz, 600Ω >30 dB; 5 kHz to 620 kHz, 150Ω, 135Ω, 75Ω, >35 dB.

Noise level:

Bandwidths	Input noise level (600Ω input impedance)
10 Hz and 100 Hz	−125 dBm or 0.436 μV
1 kHz and 3.1 kHz	−115 dBm or 1.38 μV

Rejection	Bandwidths 10 Hz	100 Hz	1 kHz	3.1 kHz
3 dB	10 Hz	100 Hz	1 kHz	3.1 kHz
60 dB	35 Hz	320 Hz	3.1 kHz	9.6 kHz

Input functions

dBm: levels calibrated in dBm for impedances selected.

Abs Vm: level calibrated in volts.

Rel: input level can be set arbitrarily to 0 dB Ref. (10 dB set level range)

Cal: 100 kHz full-scale 0 dB cal signal.

Input impedances*

Resistances: 75Ω, 135Ω, 150Ω, 600Ω terminated; 50 kΩ (single ended bridging) and 100 kΩ (balanced bridging).

Capacitance (each terminal to ground): 10 mV, 30 mV ranges <55 pF; 100 mV to 30 V ranges <40 pF.

Common mode rejection: 20 Hz to 620 kHz, >40 dB; 50 Hz to 1 kHz, >50 dB.

Automatic ranging: 8 ranges, 0 dB to −70 dB. Ranging rate proportional to bandwidth.

Output: amplitude: adjustable 0 to 1 V rms open circuit.

BFO frequency response flatness: ±0.2 dB or ±2%.

Resistance: 600Ω.

L.O. output: frequency, 1.28 MHz to 1.90 MHz (1.28 MHz + tuned frequency); amplitude, 0.65 V rms ±20% open circuit; resistance, 250Ω.

Recorder outputs:

X-Axis (3593A/3594A only)	Plug-In Frequency Ranges 62 kHz	620 kHz
X-axis linear output: (1 kΩ source resistance)	0 to −12.4 V (200 mV/kHz ±5%)	0 to −12.4 V (20 mV/kHz ±5%)
X-axis log output: (1 kΩ source resistance)	5 V/decade ±5% (50 Hz - 62 kHz)	5 V/decade ±% (500 Hz - 620 kHz)

Y-Axis:

Linear Y axis output: +10 V dc ±2% for full scale meter indication, 1 kΩ source resistance.

Log Y axis output: +1 V to +10 V dc, proportional to linear dB meter indication (−90 to 0 dB, 0.1 V/dB) ±1 dB, 1 kΩ source resistance.

Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <70 W.

Dimensions: 16¾" wide, 8¼" high (without removable feet), 16⅜" deep (425 x 210 x 416 mm).

Weight: net 37 lbs (16.8 kg); shipping 47 lbs (21,3 kg).

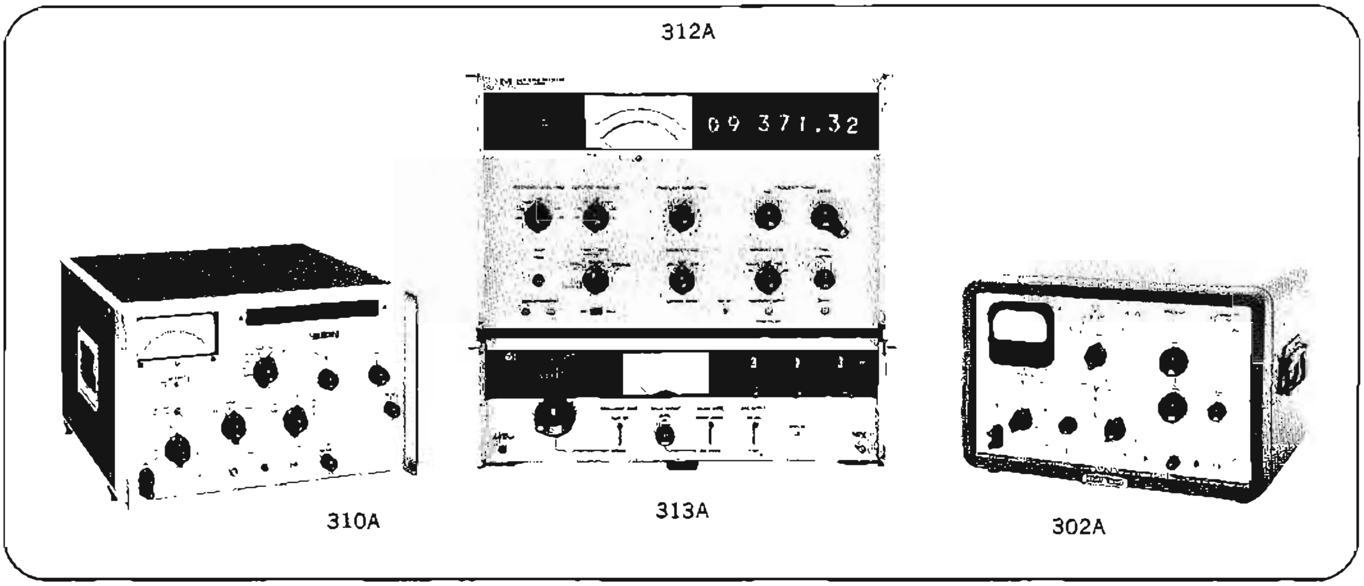
Accessories furnished: rack mounting kit for 19" rack. (Refer to page 443 for plug-in information. The 3591A must have a plug-in to operate.)

Price: HP 3591A, $3350.

Plug-Ins: HP 3592A, $80; HP 3593A, $1100; HP 3594A, $1600.

*Other terminations available on special order.

SELECTIVE VOLTMETERS
Choice of frequencies and bandwidths
Models 302A, 310A, 312A/313A



Description

These Hewlett-Packard Selective Voltmeters are particularly useful for testing multiplex communications systems. The 302A with its narrow (7 Hz) bandwidth is particularly useful for measuring power-line frequency noise components and narrow-spaced, voice-band telegraph and telemetry signals. The 310A is useful in multiplex systems up to about 300 channels. The 312A is useful in multiplex systems up to about 3600 channels. The 312A is a versatile measuring set with time-saving features (special 312A instruments are listed in the table below).

Specifications, 302A

Frequency range: 20 Hz to 50 kHz.

Level ranges: −120 dB to +50 dB full scale (15 ranges).

Residual FM and hum: 75 dB down

Selectivity (bandwidth): 7 Hz; >80 dB down at ±70 Hz.

Input impedance: 100 kΩ/<100 pF to 1 MΩ/<20 pF (unbalanced).

Restored-frequency output: 1 V across 600Ω unbalanced (FS). (For complete specifications, refer to page 444.)

Price: HP 302A (cabinet) $1900; (rack mount) $1885.

Specifications, 310A

Frequency range: 1 kHz to 1.5 MHz (200 Hz bandwidth), 5 kHz to 1.5 MHz (1000 Hz bandwidth), 10 kHz to 1.5 MHz (3000 Hz bandwidth).

Voltage range: −130 dB to +40 dB V full scale in 10 dB steps.

Noise and spurious response: at least 75 dB below a full scale reference on 0 dB position of range switch.

Selectivity (3 IF bandwidths): 200 Hz, 1000 Hz and 3000 Hz.

Input impedance: 10 kΩ/100 pF to 100 kΩ/50 pF unbalanced.

Restored-frequency output: 0.25 V across 135Ω unbalanced (FS). (For complete specifications, refer to page 445.)

Price: HP 310A, $2500.

Specifications, 312A/313A

Frequency range: 10 kHz to 18 MHz in 18 overlapping bands, usable to 1 kHz with 200 Hz bandwidth.

Amplitude range: −97 to +23 dBm FS (−107 to +13 dBm for 600Ω impedance), 3 μV to 3 V FS; selected in steps of 10 dB or 3, 1 V sequence.

Noise level, referred to input: 50 to 150Ω, −120 dBm (200 Hz bandwidth); 600Ω, −130 dBm (200 Hz bandwidth).

Selectivity (3 IF bandwidths): 200 Hz, 1000 Hz and 3000 Hz.

Input impedances: 50, 60, 75, 124, 135, 150, 600Ω or bridging; input capacitance <18 pF balanced, <35 pF unbalanced.

Automatic frequency control

Dynamic hold-in range: ±3 kHz. Tracking speed: 100 Hz/s.

Frequency readout: 7 digits with 10 Hz resolution.

Frequency range: (313A Tracking Oscillator): usable to 3 kHz; tracks 312A tuning or 10 kHz to 22 MHz in one band.

Output: 0 or +10 dBm max.; attenuator, 0 to 99.9 dB in 0.1 dB steps. (For complete specifications, refer to page 446 and 447.)

Price: HP 312A, $3900; HP 313A, $1300.
HP 312A, Option 01 (measurement of channel noise in C message units "dBrnc" at carrier frequencies), add $100.

Special *312A Instruments for Communications

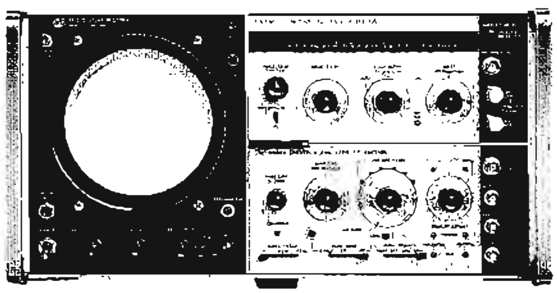
Special	Frequency Range	Input Z	Connectors Input	Connectors Output	Price
C01–312A	10 kHz to 18 MHz 18 bands	Same as Std. 312A	WE-465C	WE-477B	$3975
H01–312A	10 kHz to 22 MHz, 22 bands	75Ω or 10 kΩ bridging (unbalanced)	WE-477B	2 Std. Phone-jacks	$3850
H05–312A	10 kHz to 22 MHz 22 bands	50Ω or 10 kΩ bridging (unbalanced)	female BNC	female BNC	$3800
H10–312A	10 kHz to 22 MHz, 22 bands	75Ω or 10 kΩ bridging (unbalanced)	female BNC	female BNC	$3800

*Same as standard instrument except as designated.

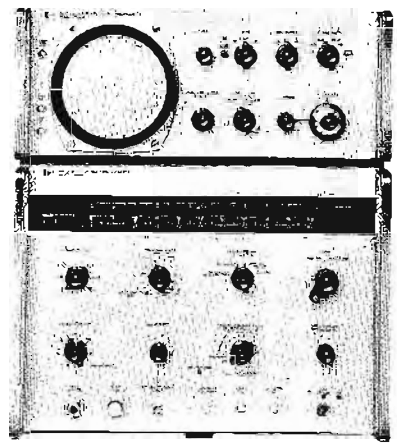
SPECTRUM ANALYZERS

Swept Analysis—Baseband to Carrier

Models 8553L/8552A/141S 8551B/851B



8553L/8552A/141S



8551B/851B

Spectrum analysis provides a rapid means of evaluating the performance of communications systems; the spectrum analyzer is useful for monitoring, as well as testing and alignment. Important measurements such as distortion, percent amplitude modulation, carrier and sideband suppression in SSB systems, carrier and pilot levels and calibration of FM deviation meters by the carrier null technique are easily made. Other uses include equalization and distortion adjustments of the tape recorder systems used in telemetry systems.

Hewlett-Packard spectrum analyzers provide frequency coverage from 1 kHz to 40 GHz—measurement capability from baseband through microwave. Variable persistence/storage display units are available for all Hewlett-Packard spectrum analyzers for flicker-free spectral display even with high resolution, slow sweep rates.

For complete specifications and accessory information on these spectrum analyzers, refer to pages 450 through 460.

Model 8553L/8552A/141S

This spectrum analyzer provides high resolution coverage from 1 kHz to 110 MHz, a range covering baseband, commercial and military communications broadcast, as well as navigation systems and the common IF's. All functions are calibrated: scan widths from 2 kHz for modulation and stability analysis to 100 MHz for monitoring out-of-band signals such as RFI or carrier distortion components.

Outstanding features of the 8852A/8553L are

Absolute amplitude calibration: −130 dBm to +10 dBm or 0.07 μV to 0.8 V.

70-dB display dynamic range: free of analyzer distortion products.

High sensitivity: to −130 dBm (0.07 μV).

Frequency response flatness: ±0.5 dB.

50-Hz resolution: to separate closely spaced signals.

High stability: residual FM less than 20 Hz p-p when stabilized.

Automatic stabilization for narrow scan widths: no complicated phase-locking procedure.

Variable persistence display: a necessity for low-frequency, high resolution, *flicker-free* displays. This is the breakthrough that makes low frequency spectrum analysis *practical;* the *spectrum,* instead of a slowly moving CRT spot, can be seen.

8551B/851B

RF and microwave frequency coverage with the 8551B/851B allows easy measurement of system power, flatness, gain, and spurious emissions. This spectrum analyzer can display as much as 2 GHz of any portion of the spectrum from 10 MHz to 40 GHz.

Outstanding features of this analyzer are

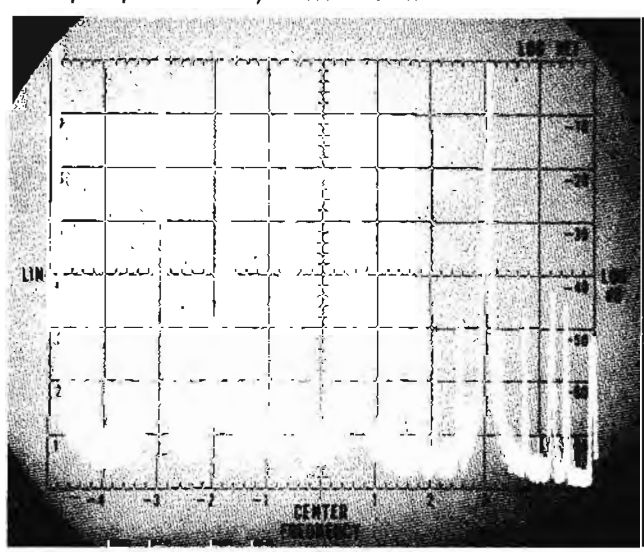
2-GHz spectrum width: presents a wide, easy-to-interpret display.

60-dB display range: signals, differing widely in amplitude, are easily compared.

Flat frequency response: a *must* for accurate comparison of signals of different frequencies.

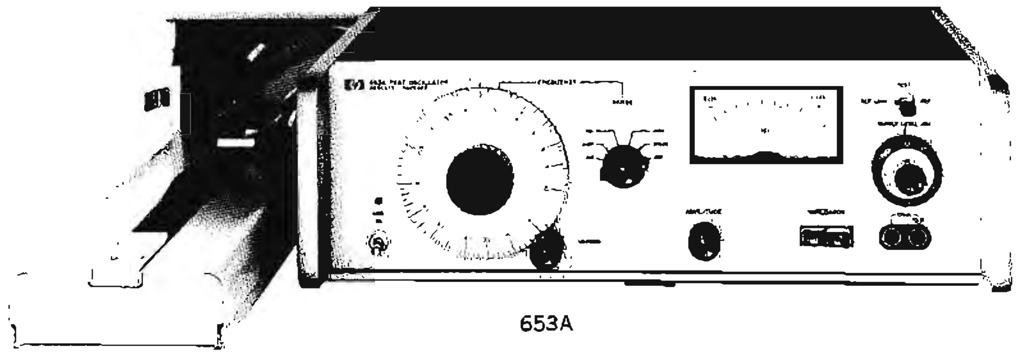
High sensitivity: to let you see very low level signals.

Simple operation: for your convenience.



Telemetry system baseband carriers. SCAN WIDTH PER DIVISION is 50 kHz. Center frequency is 250 kHz. Test shows IM distortion (more than 40 dB below carriers). Carrier #5 is disabled to measure any IM products from other carriers that occur in Channel 5. Swept analysis with 70-dB dynamic range makes such tests easy. Response at far left of display is zero-frequency marker.

VIDEO TEST OSCILLATOR
Balanced, unbalanced outputs calibrated in dBV
Model 653A, 654A



653A

653A Description

The 653A Test Oscillator is a lightweight, portable, solid-state signal source primarily used in the measurement and adjustment of transmission characteristics of television video loops. For this measurement, the HP 653A Test Oscillator replaces the Western Electric 61C Signal Generator, HP 200CD Reference Oscillator, Western Electric 70B Power Meter at the sending end, and the Western Electric 1AP or 38A Transmission Comparing Set and associated cabling.

Adjustable test frequencies from 10 Hz to 10 MHz cover the complete video frequency range. The internal 300 kHz reference oscillator, conveniently selected by a front-panel switch for comparison masurements, eliminates the need for a separate reference oscillator. Amplitude stability, accuracy, and frequency response, good for 90 days from calibration, eliminate the need for the power meter at the sending end.

Front and rear covers provide protection and convenient cable storage space during transportation and periods when not in use. The test set can be operated vertically on the floor or ground.

653A Tentative Specifications

Frequency range: 10 Hz to 10 MHz in 6 bands.

Test frequency accuracy: (20°C to 30°C) ±1% at 4.5 MHz; ±2%, 100 Hz to 5 MHz; ±3%, 10 Hz to 5 MHz; ±4%, 10 Hz to 10 MHz.

Reference accuracy (0 dBV)
Frequency: 300 kHz ±2%.
Level: ±0.1 dB for 90 days.

Output Impedance: 75Ω unbalanced, 124Ω balanced.

Return loss: on 0 dB V range and below: >40 dB, 10 Hz to 5 MHz; >30 dB, 10 Hz to 10 MHz.

Output level: +11 dBV max to −90 dBV, 10 dB and 1 dB steps with adjustable ±1 dB meter range into 75Ω unbalanced or 124Ω balanced.

Amplitude control: >2 dB

Overall attenuator accuracy: ±0.15 dB except 1 dB at output levels below −60 dBm at frequencies >300 kHz.

Meter resolution: 0.02 dB.

Meter range: ±1 dBV full scale.

Meter tracking: ±0.05 dB.

Frequency response (0 dBV, at end of recommended 6 ft cables): ±0.05 dB, 10 Hz to 10 MHz.

Balance: >50 dB, 10 Hz to 1 MHz; >40 dB, 10 Hz to 10 MHz.

Distortion (THD): >40 dB below fundamental, 10 Hz to 5 MHz; >34 dB, 10 Hz to 10 MHz.

Hum and noise: >70 dB below full rated output.

Output jacks: accepts WE 358A and 408A plugs. Max dc voltage which can be applied to the output jacks: <±3 V p.

Counter output: >0.1 V rms into 50Ω, BNC connector.

General

Operating temperature: 32°F to 130°F.

Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, 30 W nominal, 35 W max.

Dimensions covers installed: 16¾" wide, 5" high (without removable feet), 16" deep. (425 x 127 x 406 mm).

Weight: net 21 lb (9,5 kg); shipping 26 lb (11,8 kg).

Accessories furnished: rack mount kit 00653-84401, HP Part No. 5060-0827 front cover, rear cover HP Part No. 00653-62201, 7.5 ft yellow power cord.

Recommended accessories: (not available from Hewlett-Packard). Cord 75Ω, P2BJ 6 ft; cord 124Ω, 6 ft made with 754E type cable or equivalent 124Ω cable.

NOTE: If P3AH cord is used frequency response will roll off 0.03 dB at 5 MHz and 0.1 dB at 10 MHz. As the P3AH is not 124Ω this mismatch will also degrade return loss.

Price: HP 653A, $990.

654A Description

The 654A Test Oscillator is similar to the 653A except it is a general purpose test oscillator. The internal 300 kHz reference oscillator is deleted. It has BNC output connectors, and the meter is calibrated in dBm. For additional technical information refer to pages 370 and 382.

654A Tentative Specifications

The 654A specifications are similar to the 653A specifications with these additions:

Output impedance: 50Ω, 75Ω unbalanced; 135Ω, 150Ω, 600Ω balanced (10 Hz to 1 MHz for balanced outputs).

Output level: 11 dBm max., calibrated for each impedance.

Meter range: ±1 dBm full scale.

Output connectors: BNC (max dc voltage applied ±3 Vp).

Price: HP 654A, $875.

TV WAVEFORM OSCILLOSCOPE

Precision Measurement of VITS and Video Signals

Model 191A

Displaying the TV video waveform and the new test signals, and making accurate measurements of them, calls for an oscilloscope with special capabilities, plus unusual accuracy and stability. These requirements are met by the HP Model 191A Television Waveform Oscilloscope which displays and measures black-and-white and color TV video signals and VITS.

Video and test signals

TV picture information occurs at a rate of 30 pictures, or frames, per second, each frame consisting of two fields of 262½ lines each. Lines 1 to 21 of each constitute the vertical blanking interval, which produces the black areas between frames on a TV receiver. The other lines contain the picture signals. Each line consists of a horizontal sync pulse of maximum carrier amplitude followed by the picture signals, which are used to intensity modulate the electron beam (or beams, in color receivers) of the TV picture tube.

Precision measurements with 1% accuracy

The Model 191A is a precision instrument of advanced design. It is capable of measuring signal amplitudes with 1% accuracy, which is a capability not usually found in oscilloscopes of any type. It produces bright, sharp displays of fast pulses that have low repetition rates. Its frequency response and phase characteristics are carefully controlled not only within the nominal bandwidth, but also on the roll-offs or skirts of the response curves. Its differential input amplifier has high common mode rejection over an unusually wide frequency range. Transient response is also controlled to insure high-fidelity reproduction of the test signals.

The 1% accuracy of the Model 191A is achieved by means of stable, wideband amplifiers and passive filters of special design; by a mesh-type CRT with extremely constant deflection sensitivity over the entire display; by an internal graticule with a new type of flood gun illumination; and by an advanced CRT gun structure which produces a sharper spot. Brightness is 7.5 times that of most oscilloscopes, made possible by the new gun structure, which delivers more current to the screen in a sharper spot, and by the mesh structure, which makes it possible to use a 20 kV accelerating potential without losing deflection sensitivity.

The Model 191A displays VITS and video signals without discernible jitter. This results from the use of logic circuits for positive selection of the portion of the waveform to be displayed, and from the use of a special synchronizing circuit which works well even with very noisy input signals.

Front panel controls permit easy selection of the displays that are needed in television testing. Discrete selection is provided for the parts of the video signal which contain the VITS. Five special vertical-amplifier gain-filter combinations are available for distortion tests using VITS waveforms.

For minimum size and weight and maximum reliability, the oscilloscope is all solid-state except for the CRT. It is designed to operate at temperatures between −20°C and +65°C and at high altitudes, so that it can be used in hot locations which are crowded with electronic equipment or in mountain-top radio relay stations.

TV waveform oscilloscopes like the Model 191A are used in the Television Operating Centers of the intercity TV network where video signals are adjusted and switched to the proper channels. Television broadcasting stations also use TV waveform oscilloscopes in their master control consoles, in video tape recorders, in adjusting both black-and-white and color cameras, and in monitoring incoming network programs.

Specifications

Vertical amplifier

Input circuit: loop through type.

Terminated: 75 ohms unbalanced; 124 ohms balanced.

Unterminated: 12.5 k ohms unbalanced; 25 k ohms balanced.

Power off-on transient: less than 5 mV.

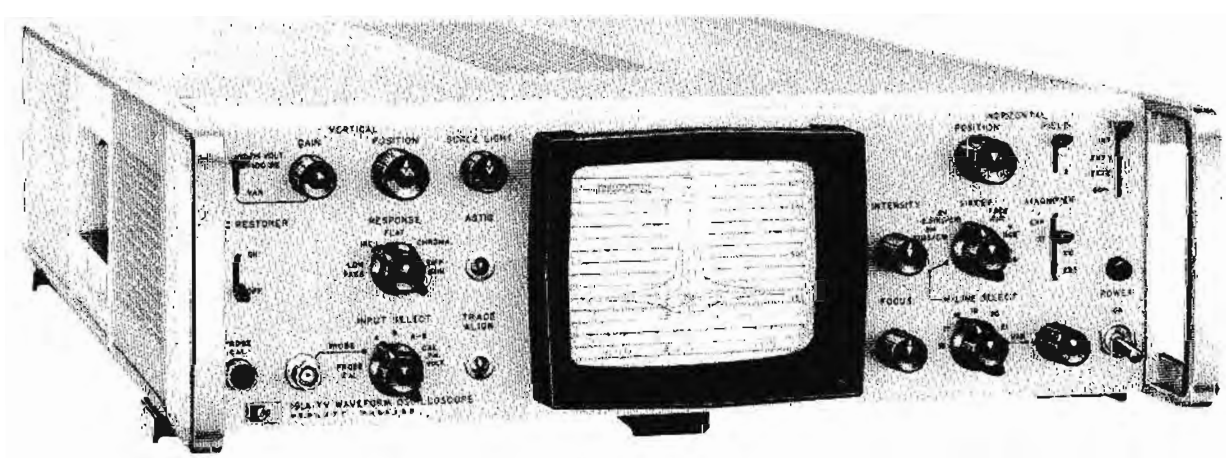
Transient protection: 100 V with rise time no less than 1 μs.

Common mode rejection: −40 dB from 0 to 2 MHz: decreasing at 6 dB/octave from 2 MHz to 20 MHz.

Gain control: selectable, fixed or variable; variable provides 140 IRE deflection for composite TV video signal from 0.2 V to over 2 V pk-pk amplitude.

DC restorer: On, restores to the back porch, color burst effect on the display will be less than 2 IRE; Off, restores to the average value of the input signal.

Calibrator: with input switch set to Cal, automatically switches vertical channel to flat filter mode, horizontal



191A

sweep to 2 V mode, and applies a 120 Hz, 0.714 volt ±1% signal to the vertical amplifier.

Probe input: input RC, 1 megohm shunted by 25 pF; when used with X10 attenuation probe, 10 megohms shunted by 10 pF.

Filters

Flat: +15°C to +35°C: ±0.05 dB from 100 Hz to 1.5 MHz decreasing to −0.05 ±0.05 dB at 4.5 MHz; −20°C to +65°C: decreasing to ±0.15 dB from 100 Hz to 1.5 MHz, −0.1 ±0.2 dB at 4.5 MHz, −3 dB at 10.5 MHz, and −20 dB at 20 MHz; rise time less than 50 nsec; less than 1% tilt on 60-Hz square-wave with dc restorer off.

IRE: standard roll-off as specified by IRE (1958 IRE Journal, page 23.S1); 20 dB down at 3.58 MHz.

Chrominance: band-pass filter with Q of 4 and center frequency of 3.58 MHz.

Differential gain: same response as Chrominance with 14 dB additional gain.

Low pass: more than 30 dB down at 0.500 MHz ±0.015 MHz; 40 dB down at 1.5, 2.0, 3.0, 3.6, and 4.2 MHz; less than 2 dB down at 0.15 MHz.

Horizontal sweep

Internal sweep:

2 V (2.5 ms/cm): ±5% for X1, X10, and X25 magnification.

2H (10 μs/cm): ±3% for X1 and X10; ±5% for X25 magnification.

H-Line select (10 μs/cm): discrete line selection for lines 16 through 21; variable line selection for all lines in the entire field.

Free run (10 μs/cm): envelope display for video setup.

External inputs: two inputs to sync oscilloscope to external TV sync generators; staircase input to accept a 4-step staircase for WRGB (may be modified to accept a 3-step staircase).

RGB operation:

H-RGB: displays 3 or 4 line parade.

V-RGB: displays 3 or 4 field parade.

Expand mode allows 10-cm overlay display.

Field select: positive selection of either field; circuit is insensitive to noise pulses.

Blanking: decoupled to remove trace with no signal input.

Linearity: ±1.0% of full scale.

CRT display

Cathode-ray tube: post-accelerator, 20 kV accelerating potential; aluminized P31 phosphor; high writing rate for viewing of sine-squared T/2 pulse.

Graticule: 8 cm x 10 cm parallax-free internal graticule; 140 IRE units = 7 cm; vertical and horizontal trace alignment controls; external graticules available for sine-squared pulse-and-bar, video modulation, etc.

Bezel: provision for external transparent plate with graticule markings; provision for illuminating both internal and external graticules.

General

Design: all solid-state (except for CRT) on plug-in printed circuit boards.

Power: 115 or 230 volts ±10%, 50 to 400 Hz; approx. 70 W (no fan).

Temperature: operating range from −20°C to +65°C unless otherwise noted.

Environmental: meets Bell Telephone Laboratories KS-19763 environmental specifications.

Altitude: operates at 15,000 feet above sea level.

Line bright output: supplies both video and line bright gate to the associated picture monitor; line bright gate pulse is supplied in variable H-line select only.

Accessories supplied: two plug-in extender boards for servicing, and rack-mount kit.

Dimensions: 16¾″ wide, 5¼″ high, 21½″ deep overall (426 x 133 x 546 mm); hardware furnished for quick conversion to 5″ x 19″ (127 x 483 mm) rack mount.

Price: HP Model 191A, $1475.

Special order: chassis slides and adapter kit; fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0720, $37.50; slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40.

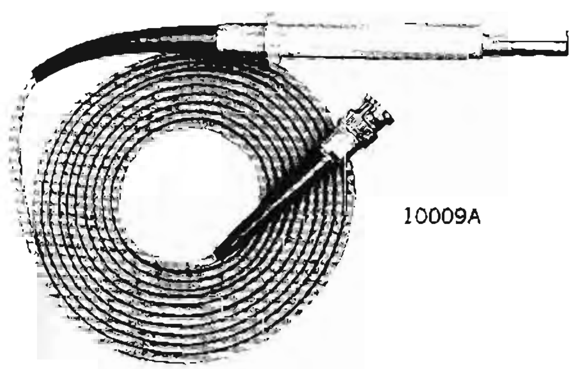
Accessories available

Camera: HP Model 197A Camera mounts direct, adapters available for other cameras. Model 197A, $540.

Front panel cover: cover attaches to front of scope for protection during storage or transportation, order HP Part No. 5060-0437, $25.

Amplifier boards: consists of three printed circuit boards for calibration of the Model 191A vertical amplifier, order HP Part No. 00191-69501, $240.

Model 10009A probe: probe tip is WECO Type 477B connector; input RC, 10 megohms shunted by 10 pF; when attached to Model 191A Probe Input, input signal at 0.2 V to 4 V will provide 140 IRE display; probe combined with X10 gain input amplifier in the Model 191A gives unity gain, ±10%; (other standard X10 probes may also be used with the Model 191A): price, Model 10009A, $50.



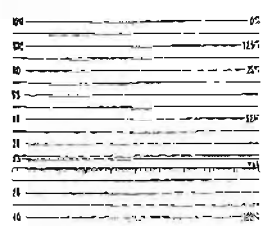
10009A

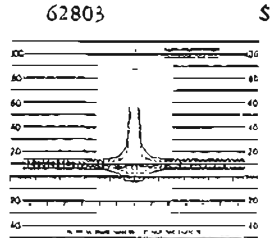
External graticules:

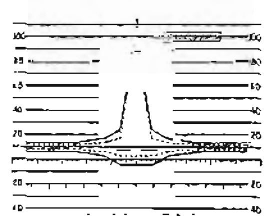
2T-4 MHz, HP Part No. 00191-62801 $10

2T-8 MHz, HP Part No. 00191-62802 $10

Dual, HP Part No. 00191-62803 $10







PRECISION RASTER DISPLAY

Visual displays convey information to a viewer from various signal sources, such as television cameras, magnetic storage devices, or computers. By providing proper signal conversion to the Hewlett-Packard precision Raster Displays, one can achieve high-resolution images from these signal sources.

A television raster presentation is an array of lines formed by an intensified CRT beam. It consists of a frame of horizontal scanning lines which are displayed in two interlaced fields. Information is presented by intensifying the beam of the cathode ray tube in a synchronous manner to produce a desired image. Since a raster consists of a finite number of scan lines, the image of the display is broken into pieces (quantized). Each horizontal scan line can also be represented by a quantization factor determined by the video amplifier bandwidth and the cathode ray tube spot diameter.

A raster display is therefore a sampling device. Since it is generally necessary that the display device be capable of reproducing a specified amount of image detail, it is important that the parameters affecting image quality be specified and understood.

Geometric Distortion—The degree to which elements of the reproduced image are maintained relative to each other.

Resolution—The degree to which fine image detail can be reproduced is termed resolution and can be expressed as: lines per inch; spot diameter; or spatial cycles per inch.

Vertical resolution is basically dependent on the CRT spot diameter and the number of active horizontal scan lines. Sequential scanning or interlaced scanning modes of operation may be achieved by providing sync signals with proper characteristics. However, when the raster image consists of two interlaced fields, the registration of the fields is important to image quality. The scan lines from the first field should lie exactly halfway between the lines of the second field. When this occurs, the raster is perfectly interlaced and maximum vertical resolution is obtained. Scan line pairing degrades resolution and a completely "paired" raster effectively has only half the maximum possible resolution.

Horizontal resolution is determined by the CRT spot diameter, the video amplifier bandwidth, and phase characteristics. Excellent image reproduction is achieved if transient and phase responses are carefully controlled. Phase response is particularly important since the human eye's tolerance to delay distortion is very small.

The video amplifier in Hewlett-Packard raster displays has carefully controlled transient, amplitude, and phase responses thereby maintaining display acuity at a high level. The unretouched computer generated alphanumeric presentation reproduced on this page demonstrates the excellent small area contrast characteristics made possible by these video amplifier parameters.

Brightness—The display brightness required for satisfactory viewing is dependent on the ambient light level. Hewlett-Packard displays are supplied with a polarized neutral gray filter overlay thus improving contrast ratio.

The absolute brightness level through the neutral gray filter is more than adequate for satisfactory viewing in office and laboratory environments. Comfortable viewing, by human factors standards is maintained. Also important is the fact that high resolution characteristics are maintained throughout the range of required brightness levels.

Applications

The most common usage of raster displays has been for broadcast and CCTV applications. However, the use of raster displays for presenting synthetically generated images and alphanumerics is rapidly growing in computer/data processing industries. Along these lines computer aided instruction terminals are used in great numbers. Some typical applications are listed below.

High-resolution display applications

BROADCAST

CLOSED CIRCUIT T.V. (CCTV)

INDUSTRIAL PROCESS CONTROL

EDUCATIONAL T.V.

COMPUTER AIDED INSTRUCTION

COMPUTER GRAPHICS

DATA RETRIEVAL TERMINALS

MEDICAL
- X-RAY W/SPECIAL CAMERA
- OPERATING ROOM OBSERVATION
- PHOTOMICROGRAPHY
- PATIENT MONITORING

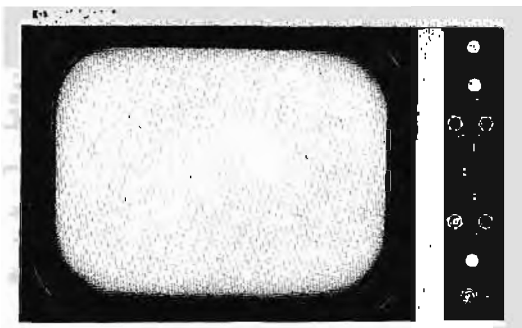
TELEMETRY & SATELLITE STATIONS

Unretouched photo of computer-generated alphanumeric readout on Model 6964A Precision Raster Display. Letter matrix here is typical 5 x 7 format, which means that height of letter uses only 7 raster lines, and 5 equivalent spaces are used in defining width of characters.

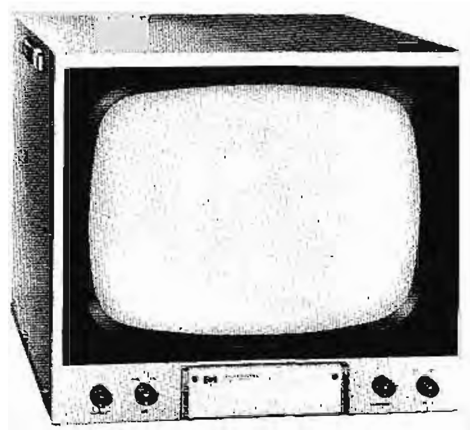
PRECISION RASTER DISPLAYS

Unexcelled picture quality

Models 6946A, 6947A



6947A
14-inch Model



6946A
17-inch Model

Advantages:

- All-silicon solid state circuitry
- Unity interlace
- Greater than 1000 line resolution
- Constant-delay wideband video amplifier
- Excellent stability—feedback employed in video, horizontal, and vertical circuits
- Less than 1.5% geometric raster distortion (Less than 1% over center 80% of screen)
- Circularly polarized safety glass
- Display size reduction—switchable to 80% for examination of raster edges (without affecting linearity)
- Maintains all specifications throughout operating temperature range of −20°C to +55°C
- Operates at 50 or 60 Hz field rate, 625 or 525 lines
- Sync pulse cross display (standard on 6947A; optional on 6946A)

Description

The Precision Raster Displays comprise two models, the 17″ Model 6946A and the 14″ Model 6947A. These units are electronically identical in performance, which is to say that they are high-quality, all solid-state instruments that offer excellent resolution, definition, and precision in a raster display. Applications—traditionally found in exacting video and broadcast monitoring use—have more recently spread to include similar requirements in closed circuit and computer graphics applications.

The quality of the components used in the Precision Raster Display and the conservative design assure excellent reliability. The display has less than 1% geometric distortion over the center 80%, and 1.5% geometric distortion over the entire picture area. These displays achieve this linearity by retaining feedback control over the entire usable sweep. In addition, display linearity is independent of size and centering adjustments.

The all solid-state video amplifier employs feedback over the entire bandwidth. The response is flat up to 4.5 MHz with controlled attenuation increasing slowly and smoothly (monotonic) to 3 dB at 11.6 MHz and 18.5 dB at 20 MHz. The controlling element is a passive network designed to insure a linear phase signal characteristic to beyond 16 MHz. With constant-delay performance, a 62.5 nanosecond video pulse applied to the input remains symmetrical and undistorted at the control element of the picture tube.

Unity interlace factor is automatically obtained by deriving the vertical sweep from the stabilized AFC horizontal oscillator. No vertical or horizontal hold controls are required for either U.S. or CCIR standard. In fact, horizontal and vertical sync are maintained with a composite picture signal-to-noise ratio of 12 dB.

Circularly polarized safety glass covers the picture tube face to improve the reproduced contrast ratio of the displayed pictures. It is easily removed to clean the face of the picture tube.

Specifications

Video circuits

Input circuit: 6946A: 75 ohms unbalanced to ground; UHF connectors with loop-through facility. 124 ohms balanced to ground; UHF connectors with loop-through facility. Return loss greater than 40 dB from dc to 4.5 MHz. Protection for up to 100 V peak transients appearing on input

Unexcelled picture quality
Models 6946A, 6947A

Specifications (continued)

balanced line. Input impedance (unterminated) —12 K ohms. 6947A: Identical, but with BNC connectors; the UHF connectors are optional.

Input level: 0.25 to 2 Volts peak to peak for 50-Volt signal at kinescope.

Common mode rejection (longitudinal balance): 46 dB from 0 to 2 MHz; decreasing at 6 dB/oct from 2 MHz to 20 MHz.

Frequency response: flat up to 8 MHz (±0.25 dB); less than —1 dB at 10 MHz decreasing smoothly to —3 dB at 18 MHz.

Signal-to-noise ratio: rms visible noise is greater than 50 dB below p-p signal present at picture tube when a 0.25 Volt sinusoid is applied to the input.

Differential gain: less than 3% over specified input level (0.25 to 2 V p-p).

DC restoration: keyed back-porch clamp. Black level shift: Less than 1% for a full change in input signal level.

Horizontal deflection circuits

Horizontal AFC: locks on either 525 or 625 line systems. Horizontal sync is maintained with a composite picture signal-to-noise ratio of 24 dB.

Horizontal width: more than 5% overscan of the usable visible area of the kinescope; horizontal width control range is 15% of horizontal dimension.

Vertical deflection circuits

Field rate: vertical lock and interlace is automatic. Front panel switch maintains the picture aspect ratio for either 50 or 60 Hz field rate. Vertical sync is maintained with a composite picture signal-to-noise ratio of 12 dB.

Vertical height: more than 5% overscan of the usable visible area of the kinescope; vertical height control range is 15% of vertical dimension.

Display

Display size: switchable from 100% to 80% of full picture size with no change in linearity.

Geometric raster distortion: less than 1.5% overall; less than 1% safe title area (80% of full picture size).

Interlace factor: unity (equal spacing between raster lines) maintained with signal-to-noise ratio of 24 dB.

Line brightening: separate raster line brightening input: A line brightening gate produced by a TV Oscilloscope can brighten any selected raster line (1-525).

Picture tube: 6946A: 17" rectangular tube, type 17DWP4 with medium short persistance P-4 phosphor, aluminized; 6947A: 14" rectangular, medium short persistance P-4 phosphor, aluminized. (Bonded faceplate is optional, see below.)

Safety glass: circularly polarized laminated safety glass is standard on all units. Polarization increases reproduced picture contrast.

Spot size: 6946A: .010 inch (10-mil) at 30 foot lamberts. 6947A: .007 (7-mil) at 30 foot lamberts.

General

External sync inputs: sync switch selects one of the external sync inputs (rear panel jacks) or internal sync input. Sync input range is —1 V to —8 V.

Temperature ratings: operating: —20°C to +55°C. Storage: —20°C to +75°C.

Altitude: operating: up to 15,000 ft. Storage: up to 50,000 ft.

Controls: 6946A: front-panel, exposed: off-on ac switch, contrast, brightness, size switch. Front-panel, concealed: 50/60 Hz field rate switch, focus, height, width, sync switch. 6947A: Front-panel, concealed; off-on ac switch, contrast, brightness, size switch, pulse-cross switch, 50/60 Hz field rate switch, focus, height, width, sync switch, and video input selector switch.

Input power: 115 V ac ±10%, 50-400 Hz, 75 W nominal.

Dimension: 6946: 17-7/16" (44,3 cm) W x 15½" (39,4 cm) H x 20⅛" (51,1 cm) D; 6947A: 17" (43,1 cm) W x 10½" (26,6 cm) H x 20⅝" (52,3 cm) D.

Weight: (net/shipping: 6946A: 63.5 lbs/83.5 lbs (30,6 kg/37,8 kg); 6947A: 43.8 lbs/64.4 lbs (19,8 kg/27,8 kg).

Accessories: standard rack brackets come with both units, for special rack kits, see p. 561 for 14526A, 14528A, 14529A.

Options: pulse-cross is standard on 6947A; Option 46 for 6946A. Option 28 is available for both models (see p. 561) —$10; Option 33 (UHF Connectors) for 6947A—$30.

Price: $1,050 (for either model).

CUT COST ON CABLE INSTALLATION AND MAINTENANCE

Quick location of faults

Time domain reflectometry (TDR) speeds maintenance by locating faults such as shorts, opens, loose connectors, troublesome tap-offs, mismatched terminations, and poor cable splices. The information is presented on a cathode-ray tube and discloses both the location and nature of each discontinuity. Problems of locating smashed or water damaged sections of underground cable are quickly resolved. Troubles are isolated to specific locations on the line.

Improve picture quality

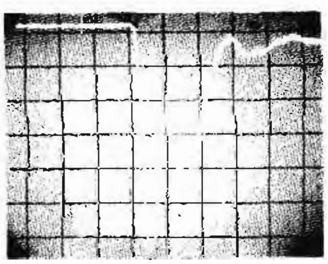
TDR reveals the quality of the transmission system by directly measuring reflection. Since reflection ghosts are an even greater annoyance to color TV viewers than to monochrome viewers, color transmission requires a higher degree of precision. CATV transmission is subject to reflection anywhere along the cable, at connectors, tapoffs, and terminations. The high sensitivity of the Model 1415A TDR plug-in can locate even the smallest ghost-causing reflection.

Time domain reflectometry principle

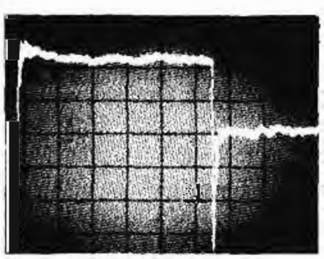
TDR employs a closed loop radar method to examine cables. Cables can be easily tested in the same way a transmitted signal would see it. By sending a step voltage through the cable and measuring the reflected voltage with a high-speed sampling oscilloscope, a time profile is obtained revealing the characteristics of each point along the cable.

Checks cables to 3000 feet

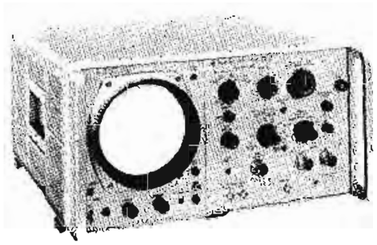
The CRT is calibrated directly in distance for air and polyethylene dielectric cables.



WET CONNECTOR: Highly magnified display of a wet connector. Multiple reflections from the faulty connector cause a reflection coefficient of −0.4.



IMPEDANCE MISMATCH: Reflection caused by cables of different impedance. With the vertical calibrated in .02 ρ/cm and the first cable known to be 75Ω, the second cable is quickly found to be 69Ω using the TDR slide rule. From scope readout, the mismatch is located 55 ft down the 75Ω cable.



The Model 1415A can test polyethylene cable to 600 feet with 5% accuracy. The long line version, Option 14, will test to 3000 feet. A special slide rule is furnished to convert the distance scale to other dielectrics. Special techniques can double the range and pinpoint discontinuities at long distances. If both ends are accessible, measurements can be taken at each end permitting 6000 feet to be checked. Accuracy can be improved two ways. The first is to close in on the fault by measuring at successively closer connections. The other is to compare distances to a standard cable connected in parallel. With these techniques, faults can be isolated within inches of the trouble spot. The 150 ps (1 ps = 10^{-12} s) step rise time of the Model 1415A is great enough to resolve nearby discontinuities that are less than an inch apart. The high resolution is useful to examine faulty connectors.

50 ohm system TDR plug-in

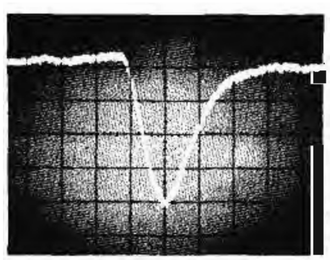
(Refer to page 530 for details)

Distance scale is calibrated to relate centimeters of CRT display to centimeters of transmission cable. For polyethylene line with a dielectric constant of 2.25, the CRT is calibrated to represent 200, 500, 1000, or 2000 cm line/cm display. The long line version, Option 14, will extend the range to 1000 cm line/cm display. For air line with a dielectric constant of 1, the calibration is 300, 750, 1500 or 3000 cm line/cm display. Option 14 extends calibration to 15000 cm line/cm display. Also, each calibrated display can be magnified X1 to X200 in 1, 2, 5 sequence with 5% accuracy.

75 ohm system

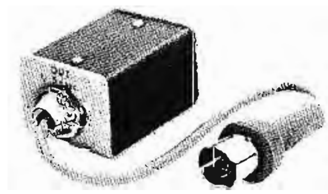
(Refer to page 530 for details.)

The E75-140A is a special system for checking and analyzing 75 ohm coaxial cable systems. This system uses an H08-1415A which is calibrated to read directly in feet of polyethylene or polyfoam coaxial cable. This system includes, in addition, a 140A Oscilloscope mainframe with P7 phosphor. This phosphor has a long persistence that is quite useful in reducing flicker when scanning the line in detail. This system includes a 50 to 75 ohm adapter and is calibrated at the factory for 75-ohm systems. Also included in this system are: an application note on TDR measurements; 75 ohm overlays for direct reading of different resistance cables; and a TDR slide-rule for rapid conversion to distance in different dielectric cables.



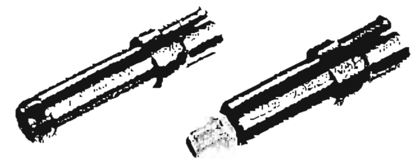
PINCHED CABLE: Magnified display of a pinched cable resulting from sharp radius of curvature. The calibrated CRT indicates a reflection coefficient of −0.04.

Rise time converters

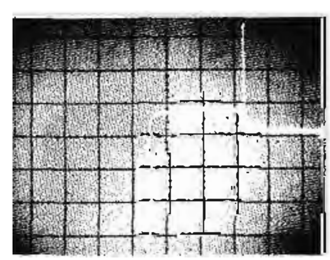


Models 10452A through 10456A Rise Time Converters slow down the step from the Model 1415A in order to eliminate reflections caused by frequencies beyond the bandwidth of interest. Rise times are 0.5, 1, 2, 5, and 10 ns. Refer to page 531 for complete specifications.

75-ohm adapters

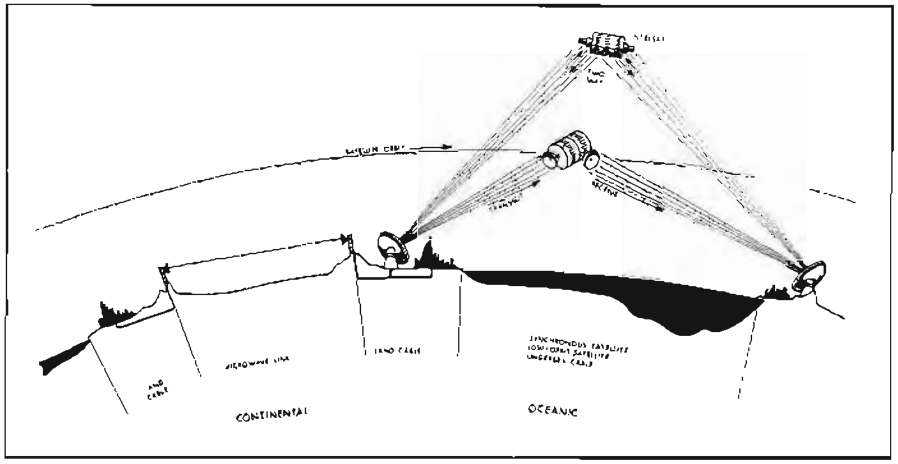


Models 10457A and 10458A Adapters convert the Model 1415A output connector to 75-ohms systems. Refer to page 531 for complete specifications.



SYSTEM PROFILE: Reflection pattern as seen by looking down a transmission system. The pattern reveals a low impedance cable (off screen) connected to a 69Ω cable. 27 ft from the connector is an inductive defect; 20 ft farther along is a capacitive defect from a pinched cable; 8 ft from the pinch is a 67Ω termination.

MICROWAVE LINK TESTING



The seventh decade

Communications systems have been planned, and are being commissioned now which will make multi-national communications in the 1970's the most rapid and of the highest quality ever achieved. Hewlett-Packard recognizes the vital role that the complex communication systems of the seventies will play in the continuing endeavor for better understanding between nations and ultimate World peace.

Increasing complexity

These communication systems encompass every possible means of communication and embrace many fields of technology. Typically these systems include telephone and telegraph equipment, multiplex and data-handling racks, overland and undersea cables, microwave links, broadcast radio and VHF, and special active communications satellites. Many different branches of information are passed by communication systems including telephony, datel, monochrome and color TV, Press Wire Photo, and international news messages. For example, during the Olympic Games in Mexico City in the late summer 1968, continuous daily Radio and TV broadcasts were relayed live to many countries throughout the World. Sportsmen throughout the World could follow their country's progress at the Games, with TV and up-to-date sports news services far in excess of the coverage available four years before at the Tokyo Olympics.

Accepted as the leading supplier, and famous in the design of electronic measuring instruments for the engineer, Hewlett-Packard has more recently become an important source of communications test equipment.

International standards

With improvements in solid-state electronics, and microwave equipment in particular, coupled with the rising costs of cable-laying and maintenance, the Microwave Link has gradually yet successfully replaced the use of cable for long-haul overland communications. Development and maintenance of these microwave links requires specialized equipment. Hewlett-Packard recognizes this need and developed the Microwave Link Analyzer, Models 3701A, 3702A, 3703A, to meet this need. The Analyzer is designed to the CCIR recommendations on international standards for radio relay equipment, which includes 70 MHz IF, 75 ohms standard impedance, and standardized test deviations and baseband sensitivity.

Standard link equipment

Microwave Link equipment embraces three main areas of electronics, each very much different from the other and requiring specialized test equipment. These areas are (1) Multiplex at 600 kHz to 9 MHz, (2) FM modulators, demodula-

Figure 1. Communications Test Equipment

Type	Description	Range	Models	Price $
Transmission test set	Transmission line and system characteristics: attenuation, gain, frequency response, line-up; patch-panel 135, 600, 900Ω lines	5 Hz to 560 kHz	3550A/353A 204B/403B	1225/260 350/340
Cable network leak detector	Ultrasonic translator detector which translates detected leaks of ultrasonic energy in cables to audio frequency	36 kHz to 44 kHz	4916A 4905A	525 595
Cable shorts, grounds, crosses	Operating on principle of electromagnetic induction and earth voltage gradients with inductive and conductive loops	990 Hz Pulsed 7 pps	4900A 4901A	655 765
Cable resistance	Resistance measurement for fault location in telephone cable pairs to 30,000 meters	0-3 kHz	4910B/C	635
Telephony oscillator	R-C oscillator with all Western Electric connectors for dialling and output. Holding functions for 600, 900Ω outputs.	50 Hz-20 kHz 5-560 kHz	236A	600
Telephony analyzer	Selective voltmeter, 7 Hz bandwidth, meter scale in dB, working range −120 to +50 full scale. High impedance.	20 Hz to 50 kHz	302A	1900
Multiplex oscillator	Linear sweeping oscillator, 10 Hz to 32 MHz in one range, 0.15 dB flatness, AM to 1 kHz, FM to 4 kHz, +13 dBm/50Ω	10 kHz to 32 MHz	675A	2250
Multiplex analyzer	Selective voltmeter, digital frequency readout, bandwidth 200 Hz, 1 kHz, 3 kHz, sensitivity −97 dBm to +23 dBm, 75Ω	10 kHz to 22 MHz	312A	3900
Microwave link IF analyzer	Transmission generator provides 45-95 MHz swept IF with baseband FM. Output range +10 dBm to −89 dBm. IF flatness ±0.1 dB. Demodulator display extracts FM from 45-95 MHz IF, will display IF flatness, linearity, group delay, Bessel Zero, TVSC differential phase and gain at 3.50 and 4.50 MHz, return loss, 75Ω system	IF 45-95 MHz BB 83.3-500 kHz TVSC 3.5-4.5 MHz	3701A 3702A 3703A	2700 3750 750
TV waveform oscilloscope	Displays of TV test signals are multiburst frequencies, sine-squared pulse and bar, modulated stairstep. Checks quality of monochrome or color TV signal channel in routing equipment or Microwave links. 75Ω input. Chrominance filters at 3.58 MHz.	Monochrome and Color TV	191A 193A	1475 1550
Attenuator	75Ω push-button unbalanced impedance. 0-99 dB in 1 dB steps. Insertion loss less than 0.6 dB. Accuracy ⎓ ±0.5 dB to 79 dB, ±1 dB to 89 dB, ±2 dB to 99 dB ∼ ±1 dB to 79 dB, ±2 dB to 89 dB	DC— to 100 MHz to 200 MHz	3750A	95
Accessories	75Ω impedance, 6 dB Hybrid Accessory kit includes 75Ω loads, cables, 17 dB standard mismatch	DC— to 100 MHz	15520A 15526A	80 140

tors and IF at 70 MHz, (3) Up- or down- converters at 3-10 GHz. The Microwave Link Analyzer is specially designed for analyzing IF equipment, but can do a number of tests at baseband (BB). Figure 1 shows how typical telephone signals get transfererd by frequency division multiplex (FDM) into the multiplex band. 1800 telephone channels, each allocated 4 kHz, occupy about 8.4 MHz, with spacing for test frequencies.

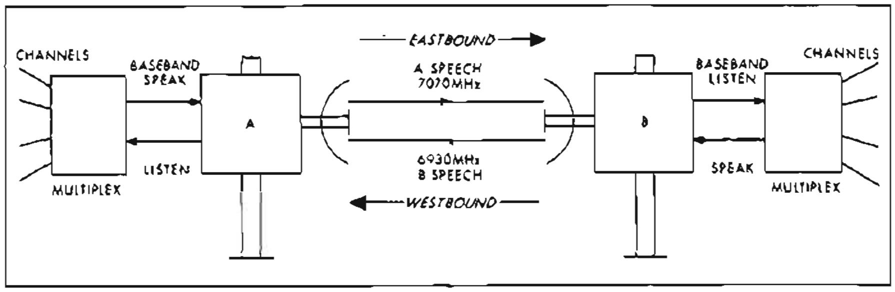


Figure 2. Simple microwave link, like the one above, can provide two-way communication for up to 1800 voice channels over a 'hop' of less than 30 miles. Most links employ the system shown where a common aerial system is used to transmit and receive simultaneously the two microwave carriers at different frequencies.

Figure 2 shows in simplified form the concept of a microwave link. The BB signals are applied to an FM modulator centered at 70 MHz. Frequency modulation is used because it offers a significant improvement in signal/noise ratio and is more resistant to fading effects than

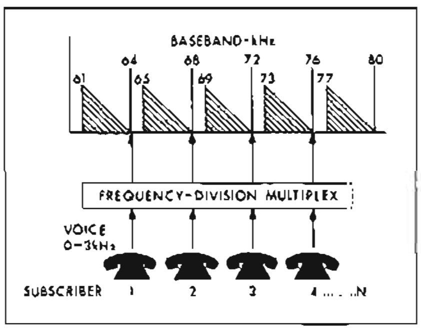


Figure 1. Voice channels are shown conventionally as triangles stacked by the multiplex (FDM) in the frequency spectrum. Each channel is 3 kHz-wide lower sideband (LSB) amplitude modulation on the appropriate multiplex carrier.

amplitude modulation.

The modulator is followed by an up-converter where the 70 MHz band signals are converted to the GHz band, generally around 3-10 GHz. The same parabolic dish and aerial system is used for both the EASTBOUND and WESTBOUND carriers which are separated slightly in frequency; for example A speech at 7070 MHz, B speech at 6930 MHz. A simple 'hop' like the one shown can span a maximum of about 30 miles.

Figure 3 shows in simplified form the basic microwave link terminal. The input signals (BB) at A are applied to an FM modulator centered at 70 MHz. The input frequencies extend up to 8.4 MHz and the deviation rates generally used create sidebands which extend from about 55 MHz to 85 MHz. This 30 MHz band IF is amplified and filtered before being applied to the up-converter where it is converted to, typically, 7070 MHz. The incoming signal is at some different frequency, say 6930 MHz, and the use of ferrite circulators and waveguide filters prevents breakthrough of the 7070 MHz and 6930 MHz signals into unwanted channels.

Distortion problems

Principal causes of distortion in the handling of the baseband input to the modulator arise at the IF sections. The IF signal for an 1800 channel telephony system extends from about 55 MHz to 85 MHz and is densely packed with channel information. All these channels are in particular amplitude and phase relationship to each other and any changes in amplitude sensitivity or phase are evident as distortion, crosstalk and intermodulation.

Distortion at IF is caused by the inability of modulators, IF amplifiers, filters, attenuators and demodulators to handle the IF with constant sensitivity, group delay and return loss across the IF band. The Microwave Link Analyzer measures IF sensitivity, FM linearity, group delay and return loss of any BB/IF, IF/IF or IF/BB item. For checking IF sections, the Analyzer provides a swept IF output from 45 MHz to 95 MHz flat to within ±0.1 dB. A special feature about this IF is that the sweep is sinusoidal at 70 Hz (Figure 5) with distortion products better than 30 dB down on sweep level. The general measurements required by link engineers are shown in Figure 4.

Sinusoidal sweep

Hewlett-Packard employs classical methods of sweep-testing with pure sinusoidal sweep-envelopes because these methods are inherently noise-free and offer the most accurate and reliable solutions to the problems of distortion measurement.

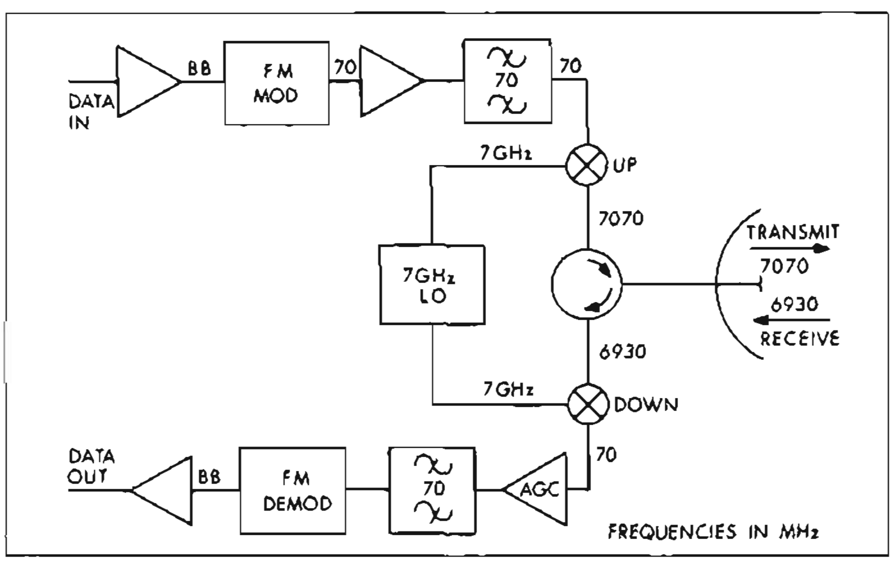


Figure 3. Simplified concept of a microwave link terminal. The main information encoder is the frequency modulator where input data is modulated by FM onto a 70 MHz carrier. This carrier, or IF, is up-converted to frequencies 3-10 GHz. In-coming transmissions are down-converted to 70 MHz and the data extracted in a frequency demodulator. Many links now in service have entirely solid-state electronics.

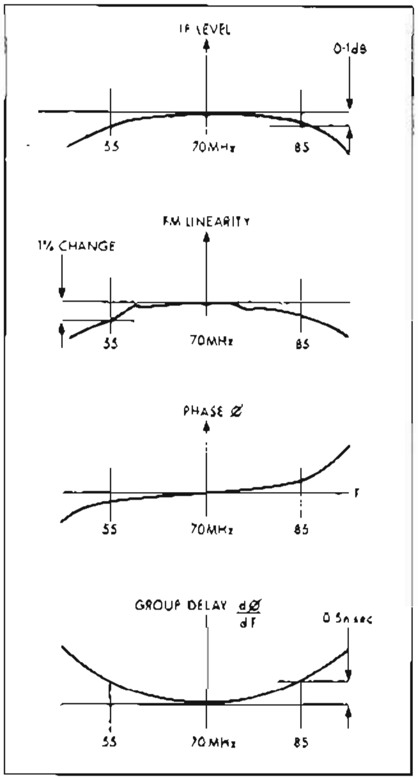


Figure 4. General measurements required at IF. Phase/frequency is not displayed directly, but the effects, mainly of envelope delay on the IF carrier are measured as group delay, the derivative of phase/frequency.

IF level, FM linearity

The IF level sensitivity is detected from the signal IF in a linear detector and displayed as level (dB) against a base of swept frequency. For the measurement of FM linearity on modulators, a modulation frequency is added to the sweep frequency and the resultant IF with FM is demodulated in an FM demodulator. The resultant demodulated frequency is detected and the level measured. This level is displayed (% change in level) against a base of swept frequency. For measurement of group delay, the phase of the detected modulation, which contains the information on envelope delay, is extracted in a phase detector, converted to dc and displayed (nsec delay change) against a base of frequency.

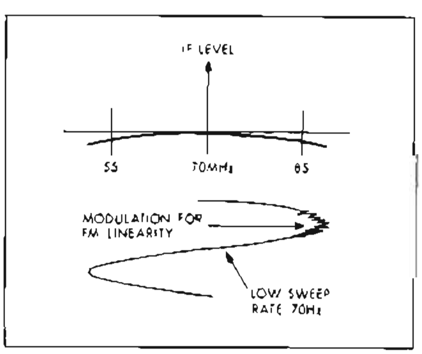


Figure 5. Sinusoidal sweep methods are inherently noise-free and simple in operation. Baseband modulation frequencies are added to sweep so that modulators can be sweep-tested over the working band at constant modulation level. For checking IF sections and demodulators an IF in the band 45-95 MHz is available, modulated with the same baseband + sweep.

Simultaneous display

These bandwidth measurements of IF level, FM linearity and group delay are fundamental to the continued operation and acceptability of the link. To aid setting-up commissioning procedures, the display of IF level and group delay, two quantities which can be mutually interfering, can be viewed simultaneously; group delay can also be viewed simultaneously with FM linearity and return loss. Other measurements performed include BB gain, insertion loss, IF gain, insertion loss and return loss at IF.

Return loss

The return loss, or impedance match, of all connectors and cables at IF is critical. Poor impedance matching results in high VSWR (greater than 1.10:1 is not acceptable) with consequent distortion caused by the standing wave ripple at IF level, and the classic phase ripple on IF group delay. Hewlett-Packard provides two fundamentally different methods of measuring return loss, each with its own advantages and disadvantages, 1) Hybrid method using hybrid power divider and sensitive IF detector to measure return loss power 2) Long cable method where incident power is compared to return loss power by relative attenuation and a long cable.

1) The Hybrid method has the advantage that actual return loss can be seen across the band and compensated for at frequencies where it is excessive. Hewlett-Packard provides a direct-coupled display calibrated at 1 dB/cm so that the threshold can be set, and return loss better than this can be seen. Initial calibration and matching of the hybrid to the measurement system is achieved using the HP Model 15521A 17 dB Standard Mismatch.

2) The long cable method compares the return loss power with the incident power by means of an accurate attenuator. Principal requirement is that IF is detected to display VSWR ripple, and ripple with cable open-ended is attenuated to match ripple with cable terminated. Twice the attenuation applied is the return loss figure.

Calibration

An important feature of the Analyzer is the calibration facilities offered. For relative amplitude of IF, including return loss, a 0.1, 0.3 or 1 dB setting can be used where the calibration selected is the spacing between the double lines on the display. Also, for linearity measurements, where percentage change in modulation level is required, 1, 3 or 10% setting can be selected between the double lines. Similarly, for group delay measurements, 1, 3 or 10 nsec can be selected between the double lines. Guaranteed sensitivities are 0.1 dB/cm, 0.25%/cm and 0.33 nsec/cm.

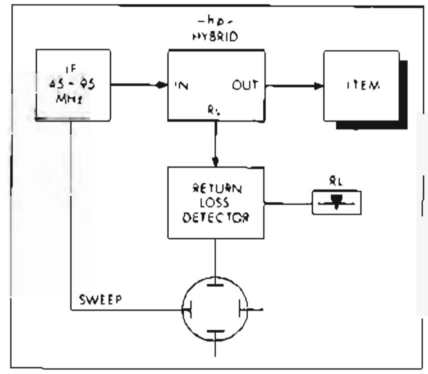


Figure 6. Hybrid method of return loss measurement has return loss detector with −54 dBm IF sensitivity. Initial calibration requires HP Model 15521A Standard Mismatch 17 dB and simple setting-up.

Accurate pin-pointing of non-linearities, relative to the IF band 45-95 MHz, is possible by means of the MARKER OFFSET dial which positions two sliding markers, one each side of 70 MHz, at a spacing up to 26 MHz offset from 70 MHz. These markers are generated by a highly-linear voltage-tuned oscillator output mixing with a stable, accurate crystal reference to produce a center marker at 70 MHz and two sliding markers. For accurate interpolation, offset frequency up to 26 MHz is available at rear panel for digital display.

A further refinement on the Analyzer is a simple Spectrum Analyzer function where the frequency band 67-73 MHz can be investigated for the analysis of deviation. Bessel Zero's, with FM at 83.3 kHz and deviation of 140 kHz rms, are easily displayed, allowing deviation measurement to 1 kHz. The Spectrum Analysis function has a sweep rate of 70 Hz and a separate crystal-derived marker at 70 MHz.

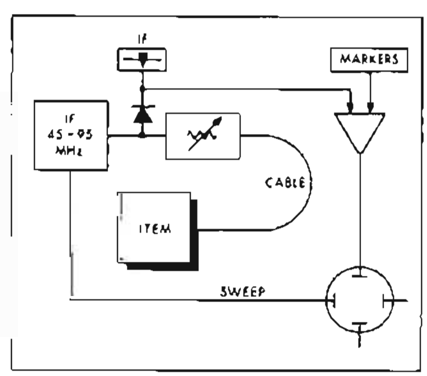


Figure 7. Long cable method of return loss measurement has IF level second-harmonic balanced detector, two-way attenuator and 15 ft. or more of 75 ohm cable. Ripples caused by VSWR of item are noted on display, the item is disconnected, and ripples caused by open-ended cable are attenuated to match the previous ripples. Twice the attenuation applied is the return loss figure.

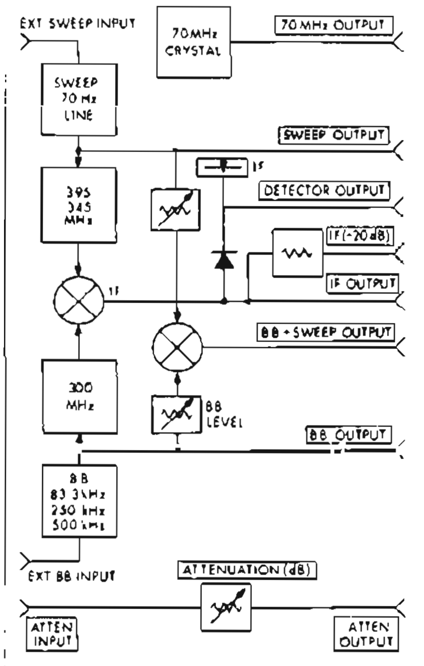
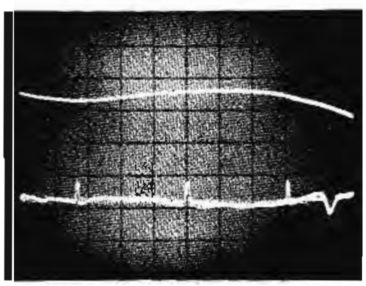
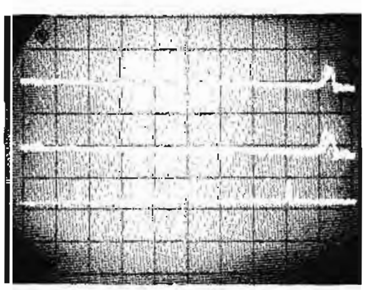


Figure 8. 3701A block diagram.



Simultaneous IF response (top) and group delay 0.1 dB/cm and 0.5 nsec/cm



BB linearity. Calibration is at 1% between traces. Lower trace is flatness reference.

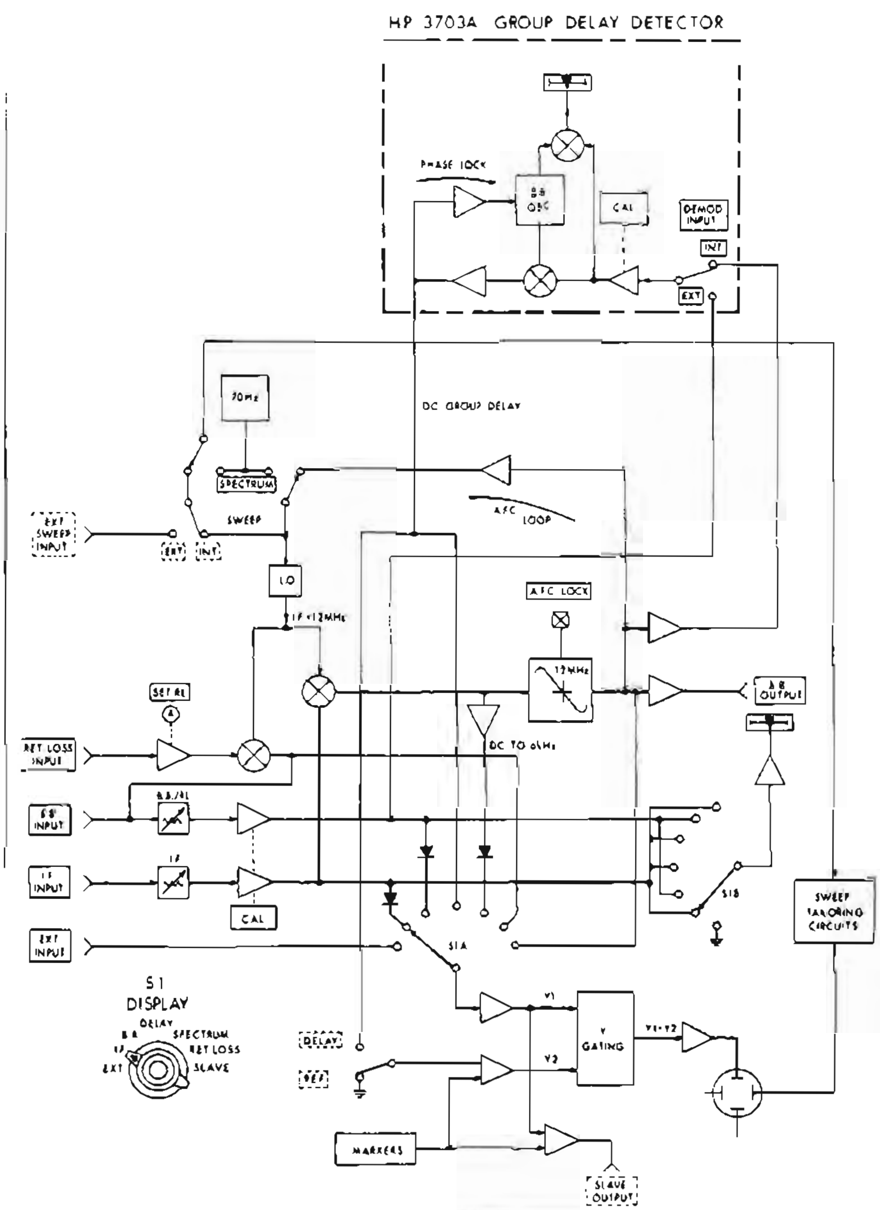
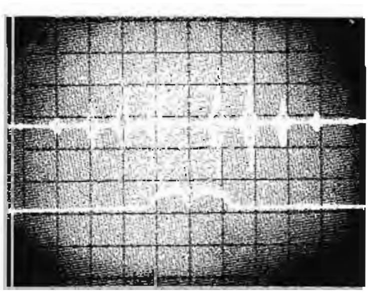


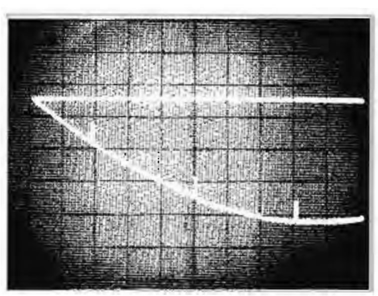
Figure 9. 3702A/3703A block diagram.

Options

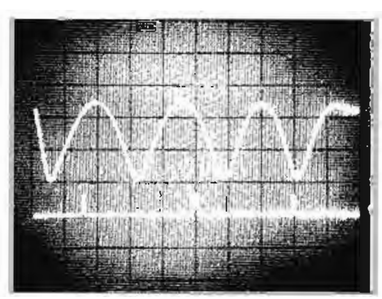
One option offered gives adjustment of phase on the IF sweep, a valuable feature during thru-link tests with slaving for a remote display. Also available as an option, are extra baseband frequencies namely the chrominance sub-carriers for color TV transmission testing, 3.50 MHz or 4.50 MHz. With these frequencies using sinewave methods, the critical measurements of differential gain and phase can be made.



Spectrum display of Bessel Zero 2.4, deviation 423 kHz rms. Center marker is 70 MHz.



DC-coupled return loss 1 dB/cm. Horizontal line is 30 dB limit. Trace below this line is better than 30 dB.

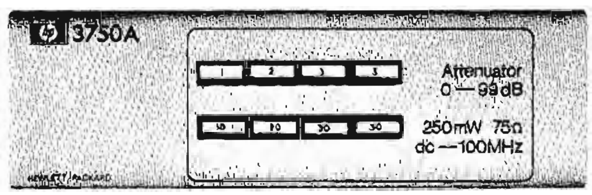


VSWR ripples with long line. Ripples with long cable open-ended are attenuated to match this.

Oscillograms made with the Microwave Link Analyzer Models 3701A/3702A/3703A show performance over 45-95 MHz swept band with 250 kHz FM, deviation 200 kHz rms, outer markers at 55 and 85 MHz.

ATTENUATORS, ACCESSORIES

Model 3750A, 15526A



3750A

DC to 400 MHz
0 to 99 dB by 1 dB steps
VSWR better than 1.1:1
Up to +24 dBm input
75 ohms impedance

Description

The Model 3750A Attenuator is ideally suited for use as a reliable, accurate general-purpose attenuator operating in the communications bands, dc to 400 MHz. It is particularly suited to large-value attenuation of RF signals during receiver and amplifier design.

A controlled-dielectric strip-line attenuator operated by push-buttons in 1, 2, 3, 3, 10, 20, 30, 30 dB steps forms the basis for the Model 3750A. Connectors are 75 BNC female with outer grounded. Insertion loss is less than 0.6 dB. Input powers up to +24 dBm can be accepted, and either connector can be used as input or output; small size and mounting versatility allows various installation arrangements including stacking, even within other equipments.

Specifications

Attenuation performance

	DC - 100 MHz	100 - 200 MHz	200 - 400 MHz
Units	±0.1 dB	±0.2 dB	±0.2 dB
Tens	±0.2 dB	±1.0 dB	±1.0 dB
Cumulative	±0.5 dB to 79 dB		±2.0 dB to 79 dB
	±1.0 dB to 89 dB	±2.0 dB to 89 dB	Not usable
	±2.0 dB to 99 dB	Not usable	

Impedance: 75Ω

Power dissipation: +24 dBm (250 mW).

Maximum SWR: below 1.1:1.

Maximum insertion loss: 0.1 dB at 10 MHz; 0.4 dB at 50 MHz; 0.6 dB at 100 MHz.

Maximum leakage at 99 dB (100 MHz) is 2 dB.

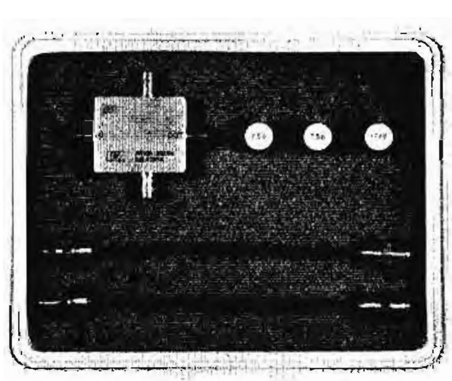
Dimensions: 8″ long x 4″ wide x 2¾″ high (203 mm x 102 mm x 70 mm).

Weight: 2.8 lb (1,27 kg).

Temperatures: operating 0°C to +50°C; storage −40°C to +65°C.

Price: $95 ($80 at factory in Scotland).

Communications Accessories



15525A cable

Description

Constructed from best-quality 75Ω low-loss cable, these cables provide a high standard of connection at nominal cost. Standard cable is 48″ (1220 mm) long with BNC male ends.

Prices

Standard BNC, $8.
Option 02, Siemens 2.5 mm, $10.
Option 03, Siemens 1.6 mm, $10.

15526A accessory kit

Description

Developed for the communications industry, these accessories are supplied standard 75Ω BNC with return loss better than 32 dB, except for Model 15521A 17 dB Standard Mismatch. They are supplied in a useful grey molded PVC case which serves for storage and protection. Options offered include Siemens 75Ω connectors, both large and small types.

Contents

Model 15520A, 6 dB Hybrid.
Model 15521A, 17 dB Standard Mismatch.
Model 15522A, 75Ω Termination (two supplied).
Model 15524A, 75Ω Coupler (two supplied).

Prices

Standard BNC, $140 ($130 at factory in Scotland).
Option 02, Siemens 2.5 mm, add $35.
Option 03, Siemens 1.6 mm, add $35.

MICROWAVE LINK ANALYZER
Checkout 1800 channel systems at IF
Models 3701A, 3702A, 3703A

Description

The Microwave Link Analyzer, Models 3701A, 3702A, 3703A, is an integrated system package which offers a wide range of measurements at both baseband (BB) and 70 MHz IF for BB and IF equipment in Microwave Links. It satisfies the needs of engineers involved in development, commissioning and on-site measurements of Microwave Link equipment.

With the Analyzer comes the ability to performance-check 1800 channel systems through a series of realistic measurements, such as group delay and IF band flatness simultaneously with modulation linearity over the 45-95 MHz band. Sensitivity, group delay and modulation linearity of modulators and demodulators can be measured separately. A special SPECTRUM mode allows analysis of modulation index and hence accurate measurement of deviation (±1 kHz at 83.3 kHz FM) for sensitivity of modulators and demodulators.

Based on CCIR and CCITT recommendations for international standards for Radio Systems, the Analyzer is available as a standard model with 75 ohm BNC connectors. Options offered give differential gain and phase measurements at either 3.50 or 4.50 MHz color TV chrominance sub-carrier frequencies using the Link demodulator; other options give different connectors, including Siemens large and small types.

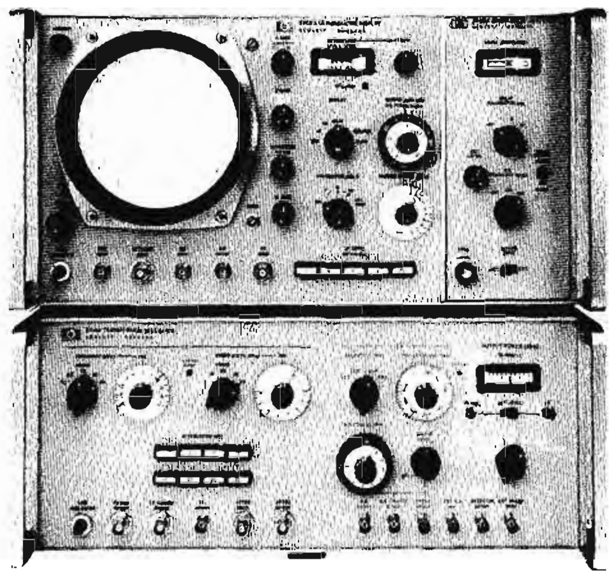
Except for the CRT, the Analyzer is entirely solid-state, having short warm-up and stabilization times, and few regular maintenance requirements. A compatible range of 75 ohm accessories, including a 6 dB Hybrid, are supplied (for further details see page 338).

Operation

The Microwave Link Analyzer is simple to operate. Particular care has been given to logical panel layout and simple cabling set-ups. The Analyzer consists of two principal instruments; Model 3701A Transmission Generator and Model 3702A Demodulator Display. A third instrument, Model 3703A Group Delay Detector is a plug-in for the 3702A and is used in group delay measurements. Figures 8 and 9 show the block diagrams of these instruments, see page 337.

Model 3701A is a BB and IF generator. The highly stable IF is produced by a twin UHF oscillator design, one oscillator fixed at 300 MHz and has FM, the other swept in 70 Hz sinusoidal envelope from 345-395 MHz. Mixing of these two quantities produces a stable 45-95 MHz IF, internally levelled to better than ±0.1 dB, all housed in the same thermal environment to minimize temperature drift. Sweep width is selectable 0-50 MHz continuous, and FM is superimposed at 83.3, 250 and 500 kHz, as selected, with deviation controllable 100 kHz to 500 kHz rms. Options extend the FM to 3.50 or 4.50 MHz. IF output is +10 dBm direct, can be varied in 1 dB steps down to −89 dBm with 99 dB built-in attenuator.

Model 3702A is a 70 MHz demodulator, with automatic frequency lock (AFC) capabilities; the Model 3702A can thus lock and follow swept IF in the range 45-95 MHz, and recover frequency modulation up to 1 MHz, deviations up to 500 kHz rms. IF sensitivity of the 3702A is −10 dBm.



3701, 3702, 3703A

Display modes of the Model 3702A Demodulator Display are selected by the DISPLAY switch as follows:

1. EXT. (input at EXT. INPUT)
2. I.F. (display is IF level)
3. B.B. (display is BB level)
4. DELAY (display is group delay)
5. SPECTRUM (display is sidebands above and below carrier)
6. RET. LOSS (direct hybrid measurement at swept frequencies with marker offset frequency 0-26 MHz available for readout)
7. SLAVE (do test on transmit path, playback display on receive path)

Simultaneous display of IF level, BB linearity, or direct-coupled return loss with group delay is one of the valuable features which speeds-up and simplifies on-site Link performance checks. Other features include a calibration facility where IF, BB and group delay displays can be separately calibrated in dB, % and nanoseconds, and frequency markers are available (with marker offset frequency for digital display) to define both specific non-linearity points and IF frequency band.

Model 3702A has Y1 and Y2 channels operating on a time-sharing basis, with Y1 being the continuous signal channel and Y2 being grounded reference channel with frequency markers, except during simultaneous display, when both channels are used. Particularly useful time-saving features include a 70 MHz crystal-controlled output for checking demodulator crossover and a balanced detector at the IF output which gives a detected IF output including VSWR. This latter feature is invaluable for performing return loss measurements by the 'long cable' method.

Checkout 1800 channel systems at IF
Models 3701A, 3702A, 3703A

System Specifications

1 swept frequency

Measurement	Back-to-back Swept band at 70 MHz			Test Sensitivity
	30 MHz	40 MHz	50 MHz	
IF flatness	±0.1 dB	±0.1 dB	±0.1 dB	0.1 dB/cm
IF group delay	±0.2 nsec	±0.3 nsec	±0.5 nsec	0.33 nsec/cm
Mod/demod group delay	±0.05 nsec	±0.05 nsec	±0.05 nsec	0.33 nsec/cm
Mod group delay	±0.15 nsec	±0.2 nsec	±0.3 nsec	0.33 nsec/cm
Demod group delay	±0.15 nsec	±0.2 nsec	±0.3 nsec	0.33 nsec/cm
Mod/demod linearity	±0.1%	±0.1%	±0.2%	0.25%/cm
Mod linearity	±0.1%	±0.1%	±0.2%	0.25%/cm
Demod linearity	±0.05%	±0.05%	±0.05%	0.25%/cm

2 fixed frequency

Measurement	Max	Min	Accuracy	Frequency band
BB power	−10 dBm	−32 dBm	±0.5 dB	50 kHz to 12 MHz
BB gain	39 dB	0 dB	±0.5 dB	83.3, 250 and 500 kHz
BB insertion loss	43 dB	0 dB	±0.5 dB	83.3, 250 and 500 kHz
IF power	+12 dBm	−10 dBm	±0.5 dB	45 MHz to 95 MHz
IF gain	101 dB	0 dB	±0.5 dB	
IF insertion loss	22 dB	0 dB	±0.5 dB	
Mod sensitivity	−49 dBm 140 kHz	−10 dBm 140 kHz	±0.5 dB ±1 kHz	45 MHz to 95 MHz
Demod. sensitivity	−10 dBm 140 kHz	−32 dBm 140 kHz	±0.5 dB ±1 kHz	45 MHz to 95 MHz
Klystron mod.				
Linearity	—	—	±0.2%	All bands
Mode center	—	—	±1 MHz	

3 return loss

Method	Max.	Min.	Accuracy	Frequency band
Hybrid	10 dB	32 dB	±2.5 dB at 32 dB	45 MHz to 95 MHz
Long cable	0	46 dB	±1 dB	45 MHz to 95 MHz

3701A Transmission generator

Description

Mode switch controls baseband modulation and sweep applied to IF.

Setting	Sweep rate	Baseband (kHz)
Manual	Use I.F. Fine	83.3/250/500/ext.
Auto	70 Hz	–
Line	Line	83.3/250/500/ext.
B.B. +sweep	70 Hz	83.3/250/500/ext.
B.B. +ext. sweep	External	83.3/250/500/ext.

Specifications

IF range: 50, 60, 70, 80, 90 MHz with ±5 MHz on vernier: accuracy ±0.5%, ±0.5 MHz at +25°C, ±1 MHz from 0°C to +50°C.

IF output: +8 dBm to +12 dBm with SET LEVEL; accuracy ±5% levelled to better than ±0.1 dB over 45 to 95 MHz, return loss 30 dB with ±15 MHz sweep, 28 dB with ±25 MHz sweep.

70 MHz output: 10 dBm, adjustable with SET LEVEL; crystal-derived for accurate frequency checking, ±0.01%.

Meter: reads IF or 70 MHz OUTPUT, +8 dBm to +12 dBm, 0.5 dB sub-divisions.

IF sweep rates: power line, 70 Hz, manual (IF FINE) or external; sweep harmonics better than 30 dB down on 70 Hz; internal sweep widths 0 to 50 MHz with step and vernier, centered on IF, accuracy ±2% for internal 70 Hz, ±10% for line sweep 50/60 Hz; external sweep: frequencies 40 Hz to 500 Hz; 5 V peak-peak into 10 kΩ at EXT. SWEEP INPUT maintains sweep calibration.

Baseband: frequencies 83.3, 250, 500 kHz or external; output: +11 dBm ±0.5 dB, return loss 26 dB 50 kHz to 1 MHz; frequency stability: ±5 ppm, 0°C to +50°C; aging rate: ±0.2 ppm per month; external baseband 10 kHz to 12 MHz.

Modulator: sensitivity, −36 dBm ±1 dB/200 kHz rms; linearity: ±0.1% over IF band.

Deviation: range 100 kHz to 500 kHz rms with internal baseband, accuracy ±5 kHz over whole range.

BB + sweep output: baseband frequencies combined with sweep frequency of power line, 70 Hz, or external (40-500 Hz); sweep output variable 0 to 5 V peak continuous, baseband output variable −49 dBm to −10 dBm stepped at 1 dB.

Attenuator: range 99 dB in 1 dB steps; accuracy ±0.1 dB units, ±0.2 dB tens, ±0.5 dB any combination; insertion loss 0.4 dB at 50 MHz, 0.6 dB at 100 MHz frequency range dc to 100 MHz; maximum input +24 dBm.

Detector output: detected level of IF is available for displaying return loss on 3702A Demodulator Display, using 'long cable' method of measurement.

Price: $2700 ($2450 at factory in Scotland).

Options

01: variable phase and amplitude facility on rear panel.
Phase: 0° ±120°, 180° ±120° continuous.
Output: 0 to 6 V peak-peak at 75Ω.
Price: add $100.

02: Siemens 2.5 mm large connectors, 75Ω.
Price: add $75.

03: Siemens 1.6 mm small connectors, 75Ω.
Price: add $95.

04: not assigned.

05: TV color sub-carrier 4.50 MHz.
Price: add $300.

06: TV color sub-carrier 3.50 MHz.
Price: add $300.

3702A demodulator display

Description

Display mode: two channels are displayed on a CRT. In most measurements one channel is the reference channel. Guaranteed CRT sensitivities are 0.1 dB/cm, 0.25%/cm and 0.33 nsec/cm. Signal channel is switched to display seven functions as follows:

Setting	Function Y1	Calibration traces
Ext.	External	50 mV
I.F.	IF amplitude	0.1, 0.3, 1 dB
B.B.	BB amplitude	1, 3, 10%
Delay	Group delay	1, 3, 10 nsec
Spectrum	Spectrum	—
Ret. loss	Return loss	0.1, 0.3, 1 dB
Slave	Slaving	dB, % or nsec

Specifications

Ext. input (Y1): frequency 5 Hz to 80 kHz (3 dB) on Y1 GAIN; sensitivity 5 to 600 mV/cm (Y GAIN), input impedance 1 MΩ in parallel with <50 pf, max. input 6 V peak-peak.

X phase shift: adjusts symmetry of recovered X-axis sweep.

IF range: 45 to 95 MHz at IF INPUT; sensitivity −10 dBm to +12 dBm; 22 dB step attenuator (±0.3 dB) compensates for powers greater than −10 dBm; return loss 30 dB over ±15 MHz sweep, 28 dB over ±25 MHz sweep.

Automatic frequency control: ±1 MHz captive range at 70 MHz; 45 to 95 MHz dynamic hold-in range; sweep rates at 45-85 Hz can be followed.

BB input: feeds detector and meter through 22 dB attenuator; basic sensitivity is −32 dBm, accuracy of power measurement ±0.5 dB; frequency response 80 kHz to 12 MHz.

BB output: baseband frequencies demodulated from IF; internally coupled to 3703A for group delay measurements.

Demodulator: sensitivity −16 dBm ±2 dB/200 kHz rms; frequency modulation up to 1 MHz, deviation up to 500 kHz rms is recovered with distortion loss than ±0.05%.

Meter: center zero, calibrated −0.5 to +0.5 dB with 0.25 dB graduations; when set to read zero by IF ATTENUATOR or BB LEVEL or RETURN LOSS controls, the input power can be read off the control.

Return loss: direct-coupled return loss on display, gives return loss simultaneously with IF level, using the HP 15520A Hybrid. Initial calibration is achieved with HP 15521A 17 dB Standard Mismatch, using the RET. LOSS INPUT; display sensitivity can be calibrated to 1 dB/cm; frequency range 45 to 95 MHz, sensitivity −54 dBm, flatness ±0.5 dB.

Spectrum: display of fixed IF and sidebands, maximum display 67-73 MHz; spectrum sweep is 70 ±5 Hz; minimum width is 1 MHz, with SPECTRUM WIDTH control.

Calibration: amplitude: 0.1, 0.3, 1.0 dB (at IF); 1, 3, 10% (at BB) selected by CALIBRATION control, accuracy ±10%; frequency: selected by MARKER OFFSET, on center marker at 70 MHz (±0.01%) and two sliding markers up to 52 MHz separation; for accurate interpolation, the frequency is available on the rear panel at MARKER OFFSET connector as a clipped sinewave, frequency 0-26 MHz, amplitude 1 V peak-peak minimum.

Price: $3750 ($3400 at factory in Scotland).

Options:

01: not assigned.

02: Siemens 2.5 mm large connectors, 75Ω.
Price: add $100.

03: Siemens 1.6 mm small connectors, 75Ω.
Price: add $110.

3703A group delay detector

Description

Output (internally connected to display channel of 3702A) is dc voltage proportional to instantaneous value of group delay on baseband frequencies of 83.3, 250, 500 kHz and 3.50 or 4.50 MHz (Option 05).

Specifications

Group delay: maximum resolution at 500 kHz: 0.1 nsec, 250 kHz: 0.2 nsec, 83.3 kHz: 0.6 nsec. Resolution limits set by system noise. Above noise is obtained with back-to-back IF tests, 200 kHz rms deviation; minimum measureable phase difference is 0.01°.

Display: total of 80 nsec on Y1 channel, 40 nsec on Y2.

Calibration: 1, 3 or 10 nsec on display, accuracy ±10%.

Phase detector: mean-phase tracking between reference baseband of the 3703A and group delay baseband is achieved by means of a phase-lock loop. The display can be inverted with the NORMAL/INVERT switch. INT/EXT switch gives internal baseband demodulated from IF (INT) in 3702A or requires baseband demodulated externally to be applied to BB INPUT.

Reference baseband: frequency, 83.3, 250 or 500 kHz, crystal-derived, stability and aging same as 3701A baseband.

Meter: indicates phase lock and correct phase detector input level.

Price: $750 ($650 at factory in Scotland).

Options:

01 thru 04: not assigned.

05: modified to measure group delay on TV color sub-carriers 3.50/4.50 MHz.

Price: add $100.

General System Specifications

Connectors: all impedances are 75Ω BNC unless otherwise stated.

Temperatures: operating, 0°C to +50°C.
storage, −40°C to +65°C.

Weights:	net lb. (kg)	Shipping
3701A	31.5 (14.2)	40 (18)
3702A	44 (20)	55 (25)
3703A	3 (1.4)	4 (1.8)

Power:	Volts	Hz	Watts
3701A	115/230 (±10%)	45-100	80
3702A	115/230 (±10%)	45-100	100
3703A	3702A	3702A	3

Dimensions:	wide (mm)	high (mm)	deep (mm)
3701A	16¾" (425)	6⅞" (177)	18⅜" (467)
3702A	16¾" (425)	8⅝" (221)	18⅜" (467)
3703A	3⅝" (92)	8¼" (210)	10⅝" (270)

Accessories furnished:	3701A	3702A	3703A
15520A	—	1*	—
15521A	—	1*	—
15522A	1*	1*	—
15524A	1*	1*	—
15525A	1	2	—
PVC Box	—	1*	—

*Items comprise accessory Kit 15526A. For description see page 338. When system is ordered, 15526A Kit plus three 15525A are supplied.

PULSE AND SQUARE WAVE GENERATORS

Pulse and square wave generators most often are used with an oscilloscope as the measuring device. Waveform shapes as seen by the oscilloscope, either at the output or at pertinent points within a system under test, provide both qualitative and quantitative evaluations of system or device performance.

Square waves or pulses

The fundamental difference between pulse and square wave generators concerns the signal duty cycle. Square wave generators have equal "on" and "off" periods, this equality being retained as the repetition frequency is varied. The duration of a pulse generator "on" period, on the other hand, is independent of pulse repetition rate. The duty cycle of a pulse generator can be made quite low so that these instruments are generally able to supply more power during the "on" period than square wave generators. The HP Model 214A, for instance, supplies up to 200 watts in its output pulse.

Short pulses reduce power dissipation in the component or system under test. For example, measurements of transistor gain are made with pulses short enough to prevent junction heating and the consequent effect of heat on transistor gain.

Square wave generators are used where the low-frequency characteristics of a system are important, such as in the testing of audio systems. Square waves also are preferable to short pulses if the transient response of a system requires some time to settle down.

Pulse generators

In the selection of a pulse generator, the quality of the output pulse is of primary importance. High-quality test

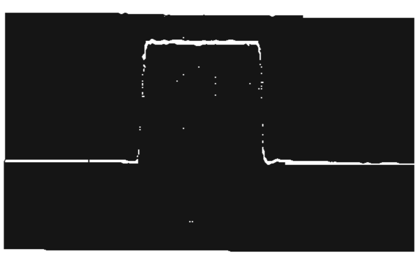


Figure 1. Carefully controlled pulse shapes insure accurate measurements.

pulses insure that degradation of the displayed pulse may be attributed to the test circuit alone.

The pertinent characteristics of a test pulse, shown in Figure 2, are controlled and specified accurately in HP pulse generators. Rise and fall times should be significantly faster than the circuits or systems to be tested. Variable rise time and fall time, available in HP 1900 pulse system, HP Model 8002A, and HP Model 8005A, are useful for testing over a wider range of operating conditions.

Any overshoot, ringing and sag in the test pulse should be known, so as not to be confused with similar phenomena caused by the test circuit.

The range of pulse width control should be broad enough to fully explore the range of operation of a circuit. Narrow pulse widths are useful in determining the minimum trigger energy required by some circuits.

Maximum pulse amplitude is of prime concern if appreciable input power is required by the tested circuit, such as a magnetic core memory. At the same time, the attenuation range should be broad enough to prevent overdriving the test circuits, as well as to simulate actual circuit operating conditions.

The range of pulse repetition rates is of concern if the tested circuits can operate only within a certain range of pulse rates, or if a variation in the rate is needed. The HP Model 216A is capable of rep rates to 100 MHz for testing fast circuits and has a pulse burst feature which allows trains of pulses rather than a continuous output to be used to check systems more thoroughly.

Triggering

The trigger requirements for synchronizing a pulse generator should be evaluated in light of the triggers available in anticipated measurement set-ups. Most Hewlett-Packard pulse generators have versatile trigger circuits similar to oscilloscopes. These circuits synchronize on most waveforms of more than 1 V amplitude.

Hewlett-Packard pulse generators also supply fast rise output triggers for operation of external equipment. The output triggers may be timed to occur either before or after the main output pulse.

Source impedance

Generator source impedance is an important consideration in fast pulse systems. This is because a generator which has a source impedance matched to the connecting cable will absorb reflections resulting from impedance mismatches in the external system. Without this match, reflections would be re-reflected by the generator, resulting in spurious pulses or perturbations on the main pulse.

DC coupling of the output circuit is necessary when retention of dc bias levels in the test circuit is desired in spite of variations in pulse width, pulse amplitude or repetition rate.

Applications of pulse and square wave generators

Pulse generators with fast rise times are widely used in the development of digital circuitry. Teamed with a suitably fast oscilloscope, these generators enable evaluation of transistor and diode switching times.

Variable rise time and fall time pulses are invaluable for testing devices whose output changes with rise time and fall time, such as magnetic memories. Variable transition time pulses are useful in checking logic circuitry where the input signal characteristics must be carefully specified.

Pulse generators are used as modulators for klystrons and other rf sources to obtain high peak power while maintaining low average power.

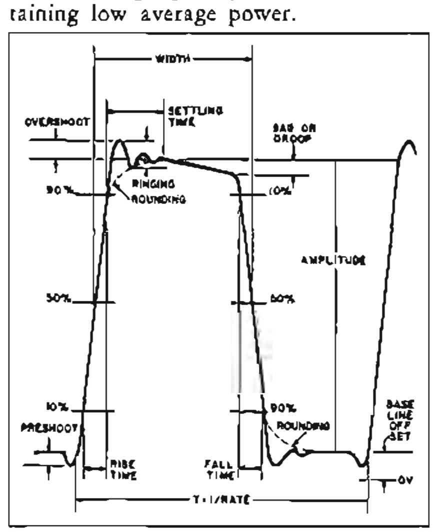


Figure 2. Test pulse description in terms of primary characteristics.

Pulse generators also are used for impulse testing. A very short pulse is rich in harmonic frequency components, so that impulse testing amounts to simultaneous frequency response testing of components or systems.

A relatively new application of fast pulse instruments is the testing of transmission lines. Very fast pulse generators (HP Models 213B, 215A and 1105A/1106A) used with fast oscilloscopes (HP Models 1430A or 1432A) also can measure the stray inductances and capacitances of components.

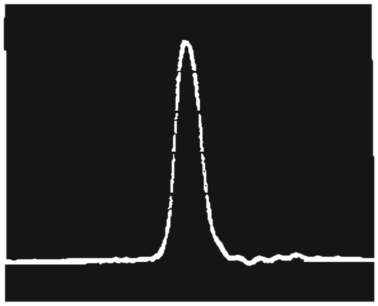
Tests of linear systems with pulse or square wave generators and oscilloscopes

PULSE GENERATOR SELECTION CHART

are dynamic tests which quickly analyze system performance.

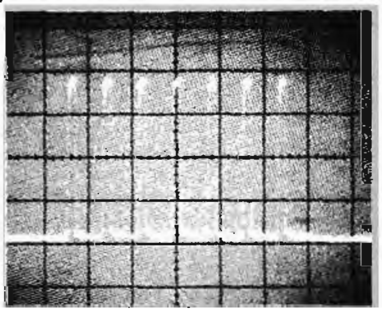
Hewlett-Packard designs pulse generators with the fast rise times (fixed or variable), matched source impedance, flexible pulse width and amplitude control, and versatile triggering capabilities required by a wide range of measurements. Particular attention has been paid to the quality of the output pulse, with all aspects of pulse shape carefully controlled and specified in detail.

The double pulse is useful for testing memory cores, counter circuits and other applications that require a double pulse at a low duty cycle.

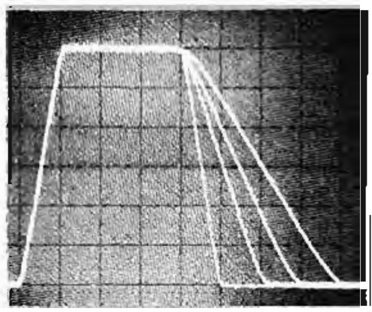


Since the impulse has a wide flat frequency spectrum it is useful in obtaining frequency-domain information.

Fast rise time pulses are used as standards to check the rise time of oscilloscopes, amplifiers, and components. Fast step is also used in Time Domain Reflectometry.



Pulse bursts are used to test many types of logic circuits.

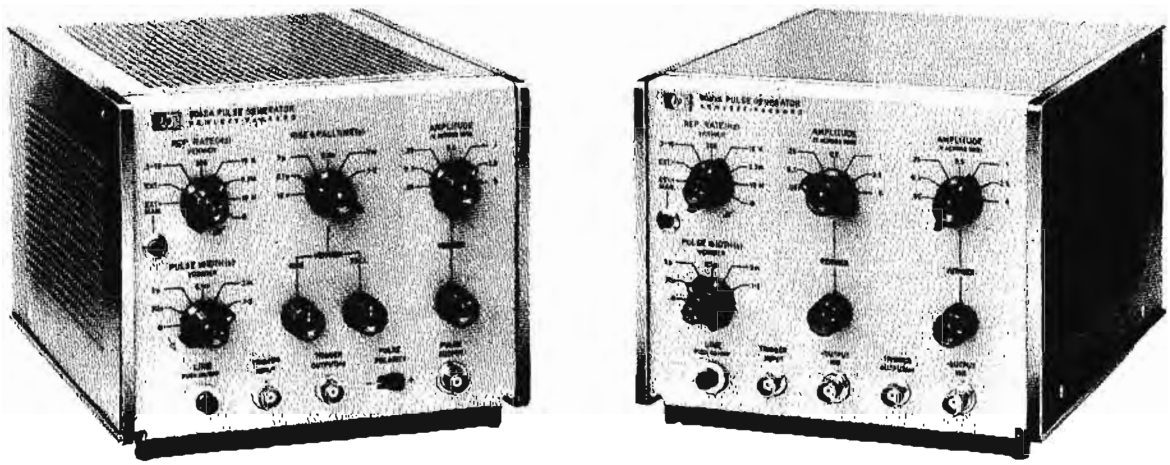


Variable rise and fall times aid checks over wide range of operating conditions.

The square wave is useful in amplifier testing and calibration, and attenuator checking.

Type	Square Wave			Fast Rise Pulse			General Purpose Pulse								
Model No.	211A	211B	220A 221A	213B	1105A/ 1106A	1105A/ 1108A	214A	215A	216A	222A	8002A	8003A	8004A	8005A	1900
Output impedance (ohms)	75/600	50/600	50	50	50	50	50	50	50	50	50	50	50	50	50/5k
	−3.5/ −27	−5/ −30	−5/ +5												
Rise time (ns)	20/100	5/70	10	0.1	0.02	0.06	15	1	2.5	4	10ns – 2 s	5	1	10 ns– 2 s	7 ns– 10 ms
Max rep rate (MHz)	1	10/1	10	0.1	0.1	0.1	1	1	100	10	10	10	10	10	25
Pulse width	sq	sq	sq	fixed	fixed	fixed	var	var	var	var	var	var	var	var	var
Pulse delay							var	var	fixed	var	fixed	fixed	var	var	var
Variable rise and fall											•			•	•
Double pulse							•						•		•
Internal gating									•						
External gating							•	•	•	•	•	•	•	•	•
Programmable												•			•
Price	$400	$450	$195	$250	$750	$375	$875	$1875	$1775	$690	$700	$470	on req	on req	$2750
Page no.	349	348	349	350	350	350	352	353	354	355	344	344	346	346	356

PULSE GENERATORS
Ideal pulsers for general circuit work
Models 8002A, 8003A



8002A 8003A

The Hewlett-Packard 8002A generates pulses with variable rise and fall times over an extremely wide range of repetition rates. These features enable you to test circuits under actual operating conditions rather than conditions dictated by the pulse generator itself. Indeed, in the 8002A you have a high-speed function generator capable of delivering triangular, sawtooth, and trapezoidal shapes as well as pulses and square waves.

Either positive or negative output signals can be selected, giving the pulse generator another degree of flexibility. In addition, the source impedance is a constant 50 Ω for minimum reflections in matched systems. In such systems output amplitude is continuously adjustable from 0.02 to 5 volts with a step attenuator and vernier control. When greater amplitude is required, it can be doubled by switching out the internal 50 Ω terminating resistor (the source impedance then becomes about 300 Ω). In either case the output is protected against damage from a short circuit.

The broad repetition range of the 8002A makes it well suited for driving slow as well as fast circuits. And when the pulses must be synchronized with external signals, the generator can be triggered with sine waves or pulses of either polarity. The 8002A also generates a trigger of its own. This trigger has an amplitude of at least 2 volts and precedes the output pulse by 180 ns. This delay is essential for viewing the pulses on most sampling oscilloscopes. Should this delay be excessive, it can be reduced to about 35 ns by switching out the internal delay line.

A synchronous gating mode is also available. In this mode the generator is "on" for the duration of the gating signal, producing signals with the repetition rate, rise and fall times, etc. selected on the front panel. The first pulse is coincident with the start of the gate; however, the final pulse is always completed even if the gating signal is removed during the time the pulse is on. This mode of operation is extremely useful for testing logic and other circuits requiring pulse trains or bursts.

The 8003A is a highly flexible, general-purpose pulse generator. Except for its fixed rise and fall time of 5 ns, its characteristics are similar to those of the 8002A. The 8003A is well suited for testing analog devices such as wide-band amplifiers, filters, and oscilloscopes. Its ability to generate pulses as narrow as 30 ns at repetition rates up to 10 MHz makes it ideal for fast switching applications.

The combination of fast rise time and long pulse duration means that systems having very broad frequency characteristics also can be tested by these generators. The maximum duty cycle is greater than 90% over most of the repetition range.

Remote programming of repetition rate, pulse width, and amplitude is offered as an option for the 8003A. Contact closure programs the repetition rate, ext. triggering, and pulse width while resistive changes program the vernier adjustments for repetition rate, pulse width, and amplitude. Remote programming makes the 8003A suitable for use in automatic and semi-automatic test systems, saving both time and manpower.

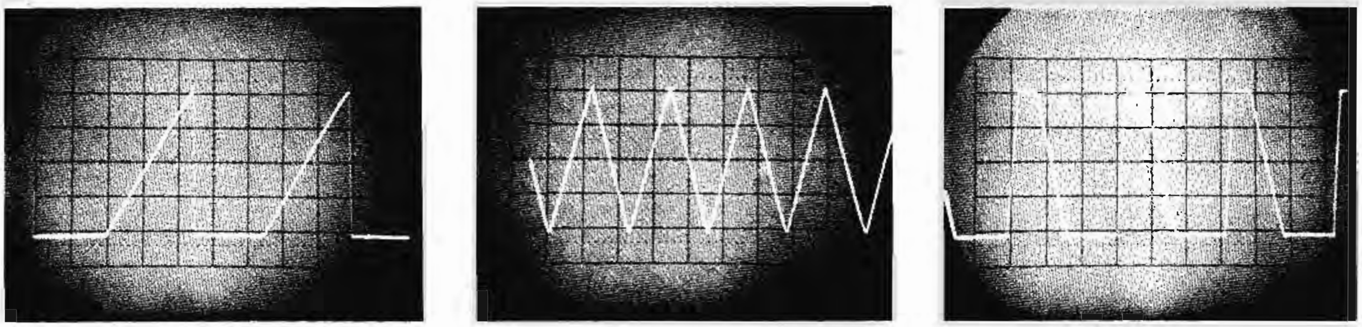


Figure 1. Typical Waveforms produced by the 8002A. Variable Rise and Fall Time Pulse Generator.

Specifications

Source impedance:

8002A: 50Ω ±10% shunted by typically 20 pF at any output voltage.

8003A: 50Ω ±3% shunted by typically 20 pF at any output voltage.

Pulse shape: (measured at 5 V across 50Ω).

Rise and fall time:

8002A: 10 ns to 2 s, 6 ranges, ranges are common for rise and fall times, two verniers for independent control of rise and fall times.

8003A: <5 ns.

Overshoot and ringing: <5% of pulse amplitude.

Preshoot: <5% of pulse amplitude.

Linearity:

8002A: for transition time >20 ns, maximum deviation from a straight line between the 10 and 90% points is less than 4% of pulse amplitude.

Maximum output: 5 V across 50Ω, 10 V across an open circuit. Output circuit protected, cannot be damaged by shorting. With internal load disconnected (switch provided), 10 V across 50Ω (rise and fall time <7 ns for 8003A).

Attenuator: provides 7 steps from 0.05 V to 5 V in a 1, 2.5, 5 sequence (positive and negative output can be set independently on 8003A). Vernier provides continuous adjustment between ranges.

Polarity:

8002A: positive or negative, selectable.

8003A: positive and negative simultaneously within 5 ns.

Pulse width

Range: continuously variable from 30 ns to 3 s in 5 ranges.

Maximum duty cycle: >90% from 0.3 Hz - 1 MHz.
>50% from 1 MHz - 10 MHz.

Width jitter: <0.1% of pulse width at any width setting.

Delay:

8002A: approximately 180 ns fixed delay between trigger and pulse. Internal switch permits removal of delay line, reducing delay to about 35 ns.

8003A: 150 ns fixed delay between Trigger Output and both Pulse Outputs. Slide switch permits switching out the 140 ns delay line.

Internal

Repetition rate: continuously variable from 0.3 Hz to 10 MHz in 5 ranges.

Period jitter: 0.1% of period at any repetition rate setting.

Manual: pushbutton for single pulse.

Triggering

Trigger input: dc coupled. Sine waves, or pulses of either positive or negative polarity, up to 10 MHz.

Sensitivity: sine waves, 2 V p-p minimum.

External pulses: at least 1 V, and at least 15 ns wide.

External trigger delay: approximately 35 ns between leading edge of external input pulse and leading edge of trigger output pulse.

Input impedance: approximately 1 kΩ.

Trigger output pulse (suitable for triggering another Model 8002A or 8003A).

Width: 15 ns ±5 ns at 50% amplitude points.

Amplitude: >2 V across 50Ω.

Polarity: positive.

Synchronous gating: gating signal turns generator "on"; pulse repetition rate, rise and fall time, amplitude, polarity, and width determined by panel control settings; first pulse is coincident with the leading edge of the gate, last pulse is completed even if gate ends during the pulse.

Minimum gating signal: —2 V.

Maximum input: —20 V.

Input impedance: approximately 1 kΩ, dc-coupled.

Power: 115 V or 230 V +10%, —15% +10%, 15%, 50 Hz - 400 Hz, 40 W (8002A), 30 W (8003A).

Dimensions: 6-17/32" high, 7-25/32" wide, 11" deep (166 x 190 x 279 mm).

Weight: net 9 lbs (4 kg); shipping 11 lbs (5 kg).

Price:

Model 8002A, $700 ($620 at factory in West Germany).
Model 8003A, $470 ($420 at factory in West Germany).

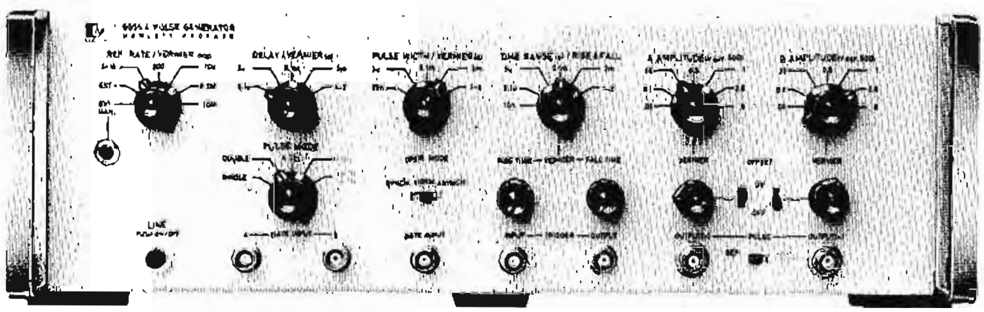
Option 01 (8003A only): remote programming of repetition rate, pulse width, and amplitude. Repetition rate and pulse width programmed by contact closure to ground. Rep rate, pulse width, and amplitude verniers programmed by resistance changes. The amplitude switch is not programmable. Add $70.00.

Manufactured in West Germany by Hewlett-Packard GmbH.

PULSE GENERATOR

Complete control of output waveforms

Models 8005A, 8004A



8005A

8005A Pulse Generator

The Model 8005A combines the capabilities of several pulse generators to give you virtually complete control of the output waveform. Rise and fall times are adjustable from less than 10 ns to 2 s with a ratio of rise to fall or fall to rise of up to 30:1. Both positive and negative pulses are available simultaneously with a variable delay with respect to the synchronizing trigger. The amplitude of each pulse signal is independently and continuously adjustable from 5 V to less than 0.02 V into 50 ohms. Repetition rate and pulse width are variable over wide ranges, and a double-pulse mode effectively increases the maximum repetition rate to 20 MHz. Where non-simultaneous pulses are desired, the delay of either pulse can be fixed while that of the other remains variable. Thus the positive pulse can be delayed from 100 ns to 3 s with respect to the negative pulse or vice versa.

To permit broader utilization of the non-simultaneous pulses, the 8005A permits the two pulse signals to be combined into a single complex signal. Versatile gating possibilities further enhances the utility of the 8005A. Synchronous gating effectively turns the instrument on and off, permitting the generation of pulse trains of various lengths. In the asynchronous gating mode, on the other hand, the repetition rate generator continues to run, so the trigger output is always available. This trigger can then synchronize external gating instruments (e.g. a word generator) which in turn can gate the output pulses on or off. Complex pulse waveforms can be generated in this manner. Signals of even greater complexity can be generated using the A/B gating mode. In this mode the positive and negative pulses are gated independently. Figure 1 illustrates some of the waveshapes and pulse combinations available from the 8005A.

The pulse generator also includes a dc offset that is continuously adjustable from +2 to −2 V. When the output pulses are used separately, the offset of each can be adjusted independently. For combined operation, a single control adjusts the common baseline offset.

Specifications

Pulse characteristics (50Ω source and load impedance).

- **Rise and fall time:** separate outputs: <10 ns to 2 s in six ranges; ranges are common for rise and fall times; independent verniers provide separate control of rise and fall times within each range with a ratio of 1:30. Common outputs: <12 ns to 2 s.
- **Linearity:** for transition time 20 ns, maximum deviation from a straight line between 10 and 90% points is 4% of pulse amplitude.
- **Overshoot and ringing:** <5% of pulse amplitude.
- **Preshoot:** <5% of pulse amplitude.
- **Pulse width:** 20 ns to 3 s in five ranges; vernier provides continuous adjustment between ranges.

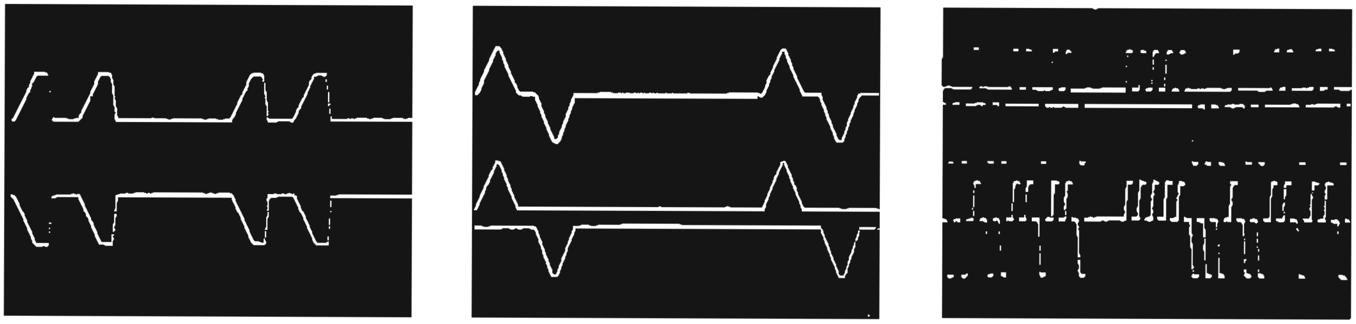


Figure 1. (a) Separates outputs in double-pulse mode. (b) Combined and separate non-simultaneous outputs. (c) A/B gating of combined and separate outputs.

Maximum duty cycle: >90% for repetition rates from 0.3 Hz to 1 MHz; >50% from 1 to 10 MHz.
Width jitter: <0.1% on any width setting.

Amplitude: 5 V maximum (10 V across an open circuit); seven-step attenuator reduces output to 0.05 V in 5, 2.5, 1 sequence; vernier provides continuous adjustment between steps and reduces minimum output to <0.02 V.

Output mode

Separate: positive and negative pulses available from separate connectors simultaneously or with either one delayed with respect to the other. Delay is variable.

Common: both pulses available from a common connector with either one delayed with respect to the other. Delay is variable.

Source impedance: 50Ω ±10% shunted by typically 20 pF.

DC offset: ±2 V across 50Ω load; independent of attenuator and vernier settings; can be switched off.

Pulse delay: 100 ns to 3 s with respect to trigger output; five ranges; vernier provides continuous adjustment between ranges.

Delay jitter: <0.1% on any delay setting.

Repetition rate and trigger

Free running: repetition rate: 0.3 Hz to 10 MHz in five ranges; vernier provides continuous adjustment between ranges. Period jitter: <0.1%.

Double pulse: minimum pulse spacing of 50 ns allows maximum repetition rate of 20 MHz.

External triggering: repetition rate: 0 to 10 MHz; can be triggered with sine waves or pulses of either polarity.

Sensitivity: sine waves, 2 V pp; pulses, 1 V peak at least 15 ns wide; maximum input, ±10 V. Delay: approx 35 ns between trigger input and trigger output. Input impedance: approx 1 kΩ, dc coupled.

Manual: pushbutton for single pulse.

Trigger output: suitable for triggering another 8005A. Amplitude: > +2 V across 50Ω. Width: 15 ns ±5 ns.

Gating

Synchronous gating: gating signal turns pulse "on." Pulse repetition rate, rise and fall time, amplitude, polarity, and width determined by panel control settings; first pulse is coincident with the leading edge of the gate, last pulse is normal even if gate ends during pulse.

Asynchronous gating: gating signal turns output pulse "on." Trigger output always available; last pulse ends with gate.

Gate A/B: independent gating signal for each pulse; last pulse ends with gate.

Gate input: at least −2 V.

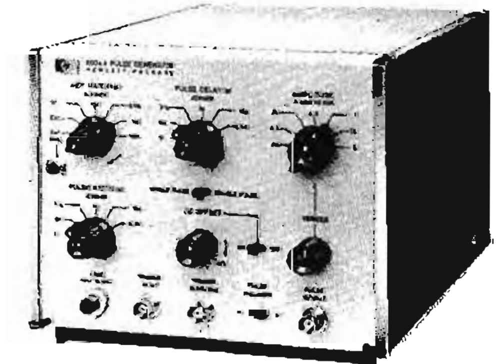
Input impedance: approx 1 kΩ, dc coupled.

General

Power: 115 or 230 V, +10%, −15%, 50 to 400 Hz, 85 W.
Weight: net 16 lb (7 kg); shipping 20 lb (9 kg).
Dimensions: 16¾" wide, 5½" high, 13¼" deep (425 x 140 x 336 mm); hardware furnished for conversion to rack mount 19" wide, 5¼" high, 11¾" deep behind panel (483 x 133 x 298 mm).
Price: $1050 ($925 at factory in West Germany).

PULSE GENERATOR

Model 8004A



8004A

8004A Pulse Generator

The 8004A generates pulses with extremely fast rise and fall times, typically less than 1 ns, yet provides a versatility seldom found in such generators. Pulse width is variable over a wide range. Minimum width is about 2.5 ns at full pulse amplitude; however, pulse width can be reduced to zero with reduced amplitude. The variable pulse delay also can be reduced to zero. A double-pulse mode provides convenient test signals for logic and memory circuits. In addition, the double-pulse mode effectively doubles the maximum pulse repetition rate to 20 MHz. Synchronous and asynchronous gating enables the 8004A to generate a wide variety of pulse trains and "words", and a dc offset permits the pulse baseline level to be set up to ±2 V off ground independent of the setting of the pulse amplitude controls.

Specifications

Pulse characteristics (50Ω source and load impedance)

Rise and fall time: <1.5 ns.
Overshoot and ringing: <5% of pulse amplitude.
Preshoot: <5% of pulse amplitude.
Corner rounding: occurs no sooner than 95% of pulse amplitude.
Amplitude: 5 V maximum across 50Ω; seven-step attenuator reduces output to 0.05 V in 5, 2.5, 1 sequence; vernier provides continuous adjustment between steps and reduces minimum output to <0.02 V. Output short-circuit proof.
Polarity: positive or negative, selectable.
Source impedance: 50Ω shunted by typically 10 pF.
DC offset: ±2 V across 50Ω load; independent of attenuator and vernier settings; can be switched off.
Pulse width: 0 to 1 ms is six ranges; vernier provides continuous adjustment between ranges.
Maximum duty cycle: >50% from 100 Hz to 1 MHz; >25% from 1 to 10 MHz.
Width jitter: <0.1% on any width setting.
Pulse position (with respect to trigger output): 0 to 1 ms delay in 5 ranges; vernier provides continuous adjustment between ranges.
Delay jitter: <0.1% on any delay setting.

Repetition rate and trigger: same as 8005A except:

Free running: repetition rate: 100 Hz to 10 MHz, five ranges.
External triggering: delay: approx 125 ns between trigger input and trigger output.

Gating: same as 8005A except no A/B gate.

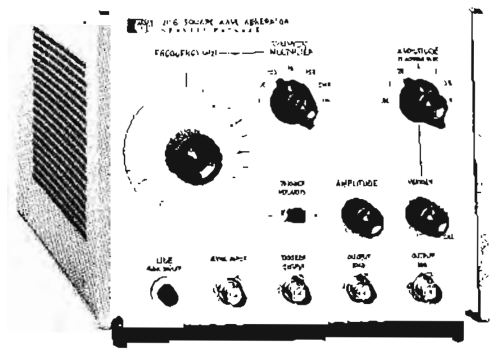
General

Power: 115 or 230 V, +10%, −15%, 50 to 400 Hz, 35 W.
Weight: net 7 lb (3.5 kg); shipping 9 lb (4.5 kg).
Dimensions: 7¾" wide, 6½" high, 11" deep from panel (197 x 165 x 279 mm).
Price: $720 ($620 at factory in West Germany).

SQUARE WAVE GENERATORS

Fast undistorted square waves

Models 211B



211B

Features

- All solid-state.
- 5 V across 50 ohms to 10 MHz, 5 ns risetime.
- 30 V across 600 ohms to 1 MHz, 70 ns risetime.
- Positive or negative trigger output.

Model 211B Square Wave Generator

The Model 211B Square Wave Generator with fast risetime, undistorted squarewaves and a 10 MHz repetition rate is ideal for fast switching application. Two negative-going output pulses are available simultaneously, one from a 50-ohm source with a 5 nanosecond risetime and falltime, the other from a 600-ohm source with a 70 nanosecond risetime and falltime. Phase difference between the two pulses is 180°.

DC coupling prevents baseline shift with rep rate changes. A true 50-ohm output impedance absorbs reflections from load mismatches.

A symmetry control varies the "on" time from 25% to 75% of the rep rate period and the rate jitter has been held to 0.2% of any rep rate period or symmetry setting. Synchronization on external signals is possible through an input trigger circuit. In addition to the output pulse, either a positive or negative trigger pulse is provided so external test equipment can be triggered without loading the circuit. The trigger pulse has an amplitude of 2 volts and coincides with the leading edge of the output pulse.

Specifications, Model 211B

Symmetry control: variable from 25-75% duty cycle.

Polarity: negative.

Source: 50 ohms ±3% shunted by approximately 15 pF.

Pulse Shape: (measured at 5V into 50 ohms).
Rise and fall times: less than 5 ns.

Amplitude:

Peak voltage: 5 V into 50 ohms, 10 V into an open circuit; output circuit protected, cannot be damaged by shorting.

Attenuator: 0.05 to 5 V, in a 1, 2.5, 5 sequence.

Vernier: provides continuous adjustment between ranges.

600 ohm Source: 600 ohms ±10%.

Rise and fall times: less than 70 ns into 600 ohms, less than 140 ns into an open circuit; decreased amplitude setting will improve rise time.

Amplitude:

Peak voltage: at least 30 V into 600 ohms, at least 60 V into an open circuit.

Attenuator: provides continuous adjustment from full output to less than 0.3 V into 600 ohms.

Repetition rate and triggering

Internal:

Repetition rate:

50 ohm output: 1 Hz to 10 MHz, 7 ranges.

600 ohm output: 1 Hz to 1 MHz, 6 ranges.

Period jitter: less than 0.2% at any duty cycle and rep rate setting.

External:

Sync input: sine waves or positive pulses from 1 Hz to 10 MHz; frequency of synchronizing signal must be 105-140% of dial setting.

Sensitivity: dc coupled positive pulses, 2 V peak; sine waves, 4 V peak-to-peak.

Input resistance: approximately 500 ohms.

Trigger output pulse: (suitable for synchronizing with another Model 211B).

Width: 10 (±5) ns at 50% points.

Amplitude: at least 2 V into 50 ohms.

Timing: coincident with leading edge of 50 ohm pulse.

Polarity: positive or negative.

Power: 115 or 230 V +10% −15%; 50 to 400 Hz; 23 W.

Dimensions: 7¾" wide, 6⅛" high, 11" deep overall (190 x 155 x 279 mm).

Weight: net 9 lbs (4 kg); shipping 11 lbs (5 kg).

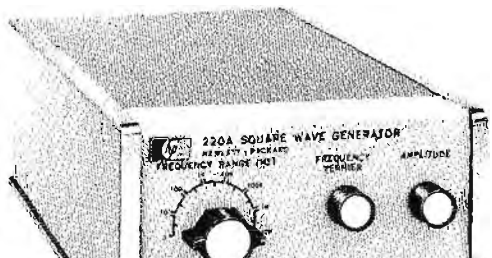
Price: HP Model 211B, $450.

SQUARE WAVE GENERATORS
General purpose testing
Models 211A, 220A, 221A

211A

−55 VOLT OUTPUT

1 Hz to 1 MHz



220A, 221A

ALL SOLID-STATE

1 Hz to 10 MHz

15 ns risetime

−5 V output (220A)

+5 V output (221A)

Model 211A Square Wave Generator

The Model 211A Square Wave Generator is a versatile wide-range instrument particularly designed for testing video and audio amplifier performance, or for use as a trigger generator. It provides complete coverage of all frequencies from 1 Hz to 1 MHz, and has a rise time of 0.02 microsecond. There are two separately variable outputs—a 3.5-volt peak 75-ohm impedance circuit for television measurements, and a 27-volt peak 600-ohm output for a high-level work. The generator may be operated free-running or externally synchronized.

Specifications, 211A

Frequency range: 1 Hz to 1 MHz, continuous coverage.

Low impedance output: −3.5 volts peak across 75-ohm load; −7 volts open circuit, zero level clamped to chassis; rise time less than 0.02 μs.

High impedance output: −27 volts peak across 600-ohm load; −55 volts open circuit, zero level clamped to chassis; rise time less than 0.1 μs.

Relative phase: 180° phase difference between high- and low-impedance output signals.

Amplitude control: low impedance output, potentiometer and 60 dB attenuator, variable in 20 dB steps; high impedance output, potentiometer.

Frequency control: dial calibrated "1 to 10" and decade multiplier switch; six bands.

Symmetry control: allows exact square-wave balance.

Sync input: positive-going pulse or sine wave signal, minimum amplitude 5 volts peak.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 225 watts.

Dimensions: cabinet: 9¾" wide, 15¼" high, 14⅝" deep (238 x 388 x 372 mm); rack rount: 19" wide, 8¾" high, 13⅜" deep behind panel (483 x 222 x 340 mm).

Weight: net 26 lbs (11,7 kg); shipping 29 lbs (13 kg) (cabinet); net 24 lbs (10,8 kg); shipping 35 lbs (15,8 kg) (rack mount).

Price: HP Model 211A (cabinet) or HP Model 211AR (rack mount), $400.

Specifications, 220A and 221A

Source impedance: 50 ohms.

Risetime: less than 15 ns.

Overshoot and ringing: less than 5% at 5 volts into 50 ohms.

Amplitude
- **Model 220A:** continuously variable from 0 to −5 volts into 50 ohms.
- **Model 221A:** continuously variable from 0 to +5 volts into 50 ohms.

Symmetry: variable from approximately 40% to 60%.

Repetition rate
- **Ranges:** from 1 Hz to 10 MHz (7 positions) in decade steps.
- **Vernier:** continuously variable between all ranges.

Frequency programming: −1.2 to −13 volts applied to external input will program the frequency over selected frequency range.

Weight: net, 3½ lb (1,6 kg); shipping, 4½ lb (2,0 kg).

Power: 115 or 230 V ±10%, 50 to 400 Hz, 9 W.

Dimensions: 5⅛" wide, 3-7/16" high, 11⅝" deep (130 x 87 x 295 mm).

Price: Model 220A, $195; Model 221A, $195.

PULSE GENERATORS

Fast rise pulsers

Models 1105A/1106A, 1105A/1108A, 213B

Model 1105A/1106A 20 ps Pulse Generator

The Model 1105A/1106A produces a pulse of 20 ps rise time, ideal for fast circuit testing or high resolution TDR. The pulser is made up of two parts: the Model 1105A Pulse Generator Supply and the Model 1106A Tunel Diode Mount. The Model 1106A may also be used with the Model 1104A Countdown Supply to form an 18 GHz trigger countdown.

Specifications, Model 1105A/1106A

Output

Rise time: approximately 20 ps; less than 35 ps observed with HP Model 1411A/1430A 28 ps Sampler and HP Model 909A 50Ω termination.
Overshoot: less than ±5% as observed on Model 1411A/1430A with Model 909A.
Droop: less than 3% in first 100 ns.
Width: approximately 3 μs
Amplitude: greater than +200 mV into 50Ω.
Output characteristics (Model 1106A):
Mechanical: precision 7 mm (Amphenol APC-7) connector.
Electrical: dc resistance, 50Ω ±2%; source reflection, less than 10%, using a 40 ps TDR system; dc offset voltage, approximately 0.1 V.

Triggering:

Amplitude: at least ±0.5 V peak required.
Rise time: less than 20 ns required; jitter less than 15 ps when triggered by 1 ns rise time sync pulse from Model 1424A or 1425A Sampling Time Base sync pulse; jitter increased with slower trigger rise times.
Width: greater than 2 ns.
Maximum safe Input: 10 volts.
Input impedance: 200Ω, ac coupled through a 20 pF capacitor.
Repetition rate: 0 to 100 kHz; free runs: approximately 100 kHz.

Accessories provided (with Model 1105A): one 6-ft 50Ω cable with male Type N connectors, HP Model 10132A.

Weight:
Model 1105A: net, 3 lbs (1,4) kg); shipping, 8 lbs (3,6 kg).
Model 1106A: net, 1 lb (0,5 kg); shipping, 3 lbs (1,4 kg).

Price: HP Model 1105A, $200; HP Model 1106A, $550.

Model 1105A/1108A 60 ps Pulse Generator

The Model 1105A/1108A is similar to the 1105A/1106A in that the 60 ps rise time pulse can be used for circuit testing and TDR. When used with the 1104A Countdown Supply the 1108A is a 10 GHz trigger countdown.

Specifications, Model 1105A/1108A

Output

Rise time: less than 60 ps
Overshoot: less than ±5%
Droop: less than 3% in first 100 ns
Width: approximately 3 μs
Amplitude: greater than plus 200 mv into 50Ω.
Output characteristics (1108A):
Mechanical: GR-874 connector
Electrical: dc resistance, 50Ω ±2%. Source reflection less than 10%, using a 40 ps TDR dc system. DC offset voltage—approximately 0.1 V.

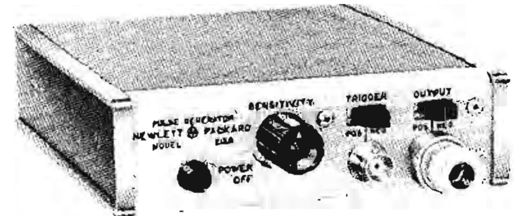
Triggering:

Amplitude: ±0.5 V peak minimum
Rise time: less than 20 ns required. Jitter less than 15 ps when triggered by 1 ns rise time sync pulse from 1424A or 1425A Sampling Time Base. Slow risetimes produce more jitter.
Width: greater than 2 ns.
Maximum safe Input: 10 volts.
Input impedance: 200Ω, ac coupled through 20 pF.
Repetition rate: 0 to 100 kHz; free runs at approximately 100 kHz, nominal.

Accessories provided (with Model 1105A): one 6-ft. 50Ω cable with male Type N connectors, HP Model No. 10132A.

Weight:
1105A: net, 3 lbs (1,4 kg). Shipping, 8 lbs (3,6 kg).
1108A: net, 1 lb (0.5 kg). Shipping, 3 lbs (1,4 kg).

Price:
1105A, $200.
1108A, $175.



Model 213B 100 ps Pulse Generator

The outstanding performance of the Model 213B makes it convenient for many small amplitude pulse test applications ranging from circuit rise time testing and bandwidth determinations to the measurement of transistor switching speeds.

Specifications, Model 213B

Output

Rise time: less than 100 ps.
Top droop: less than 2% in first 100 ns following the rise.
Width: approximately 2 μs.
Amplitude: greater than 175 mV into 50Ω, 350 mV open circuit, either polarity.
Source: 50Ω.
Jitter: less than 20 ps when triggered with the sync pulse from a Model 1424A or 1425A.
Repetition rate: free runs at a rate greater than 100 kHz, or may be triggered.

Trigger input

Amplitude: 0.5 volt peak, either polarity.
Rise time: 20 ns or faster.
Width: at least 2 ns.
Maximum current: 200 mA peak.
Impedance: 200Ω for signals less than 0.75 volt peak; limiting lowers impedance to larger signals.
Repetition rate: 0 to 100 kHz.

General

Power: 115 or 240 V ±10%, 50 to 1000 Hz, approximately 1 W.
Dimensions: 1½" high, 5⅛" wide, 5" deep (38 x 130 x 127 mm).
Weight: net 2 lbs (0,9 kg); shipping, 4 lbs (1,8 kg).
Price: HP Model 213B, $250.

DIGITAL DELAY GENERATOR

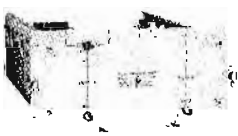
Digitally controlled time intervals, pulses

Model 218AR

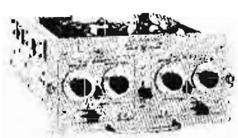
The HP 218AR Digital Delay Generator is designed to generate precise time intervals and single, double or superimposed pulses. It is useful as a general-purpose laboratory pulse generator and because of its versatile plug-in pulse generators, it often can take the place of several special-purpose instruments.

The 218AR consists of (1) a pulsed crystal oscillator which is started in known phase by the initial trigger (start) pulse, eliminating the ±1 count error; (2) a dual-preset digital counter which counts the crystal or externally applied frequency, and operates (3) two preset gates which pass the selected pulses.

Plug-ins include the 219A Dual Trigger Unit to supply trigger pulses for controlling auxiliary equipment, $200; the 219B Dual Pulse Unit to deliver fast-rise-time, high-power pulses that are digitally delayed, $650; and the 219C Digital Pulse Duration Unit, which produces a high-power output pulse whose delay and duration may be digitally controlled. $500. Output pulses of the 219A are identical to the sync output of the 218AR. The 219B pulses are individually adjustable, 0 to ±50 V peak open circuits from a 50Ω source. Pulses from the 219C are 90 V peak (or more), open circuit, from a 500Ω source or adjustable from 0 to 15 V peak from a 90Ω source. The positive excursion of the pulses is clamped to ground, and both positive- and negative-going pulses are available simultaneously.

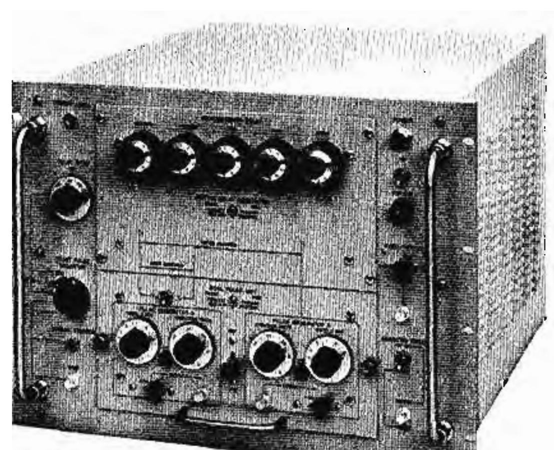


219A



219B

219C



218AR

Specifications

(Plug-in necessary to operate)

Time interval range: (T_0 to T_1 and T_0 to T_2) 1 to 10,000 μs; accuracy ±0.1μs ±0.001% of time interval selected.

Digital adjustment: 1 to 9999 μs in 1 μs steps.

Interpolation: continuously adjustable; adds 0 to 1 μs to digital setting.

Input trigger: internal: 10 Hz to 10 kHz, 3 decade ranges; external: sine wave, 10 to 100 Hz, 5 to 40 V rms, 100 Hz to 10 kHz, 2 to 40 V rms; pulse, 0 to 10 kHz, positive or negative, 2 to 40 V peak; for trigger rise time of 0.05 μs or less, delay between external trigger and T_0 is less than 0.5 μs; manual: pushbutton operation initiates single pulse cycle.

Jitter: 0.02μs or less.

Recovery time: 70 μs or 10% of selected interval, whichever is greater.

Sync output: positive pulse, 50 to 70 V peak, open circuit, 0.1 μs rise time; width more than 1.5 μs; available at T_0, T_1, or T_2 as selected by a switch.

1 MHz output: 1 MHz positive pulses (1 V from 500Ω source) provide timing comb synchronized to start pulses; available at panel connector for duration of longer delay when counting internal 1 MHz oscillator.

External counting: external sine waves, 100 Hz to 1 MHz, 2 V rms minimum; 10 to 100 Hz, 5 V rms minimum, and positive pulses, periodic or random, 0 to 1 MHz, 2 V peak, can be counted instead of internal standard; time interval range becomes 3 to 9999 periods in 1-period steps, and accuracy is ±0.1 μs ±1 period.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 555 W.

Dimensions: 14" high, 19" wide, 21¾" deep behind panel (355 x 483 x 553 mm).

Weight: net 74 lbs (34 kg); shipping 104 lbs (47 kg).

Price: HP 218AR, $2600.00 (requires HP 219A,B,C Series plug-in units).

PULSE GENERATOR
Delivers 200 watts pulse power
Model 214A

The HP Model 214A features 200 watts pulse power, controlled pulse shape, external trigger slope and level selection, and a 50-ohm source impedance for general-purpose lab and production measurements.

The 200-watt (2 amps peak) pulse power is particularly suited for testing current-driven devices such as magnetic memory cores, as well as high-power modulators. At output levels below 50 volts, the pulse generator has a matched source impedance of 50 ohms, eliminating error-producing reflections. The pulse characteristics are carefully controlled, and pulse rate, width and delay jitter are kept to a minimum to insure accurate, dependable test results.

The 214A offers an extremely wide range of trigger control for syncing on external signals. In addition, slope and level may be selected so that triggering occurs at a given point on the trigger waveform. Also provided is a variable delay or advance trigger output signal for use in synchronizing external equipment.

The pulse generator may be gated to provide bursts of pulses. This feature is especially useful for computer logic measurements. Also, a double pulse feature is provided for pulse resolution tests of amplifiers and memory cores.

214A

Specifications

Output pulse

Source resistance: 50 ohms on the 50 V and lower ranges: approximately 1500 ohms on the 100 V range.

Pulse shape:

Rise and fall time: <13 ns on the 20 V and lower ranges and the −50 V range, <15 ns on the +50 V range; typically <10 ns with the vernier set for maximum attenuation, and typically 15 ns on 100 V range.

Pulse amplitude: 100 V into 50 ohms. An attenuator provides 0.2 to 100 V in a 1, 2, 5, 10 sequence (9 ranges); vernier reduces output of 0.2 V setting to 80 mV and provides continuous adjustment between ranges.

Polarity: positive or negative.

Overshoot: <5%, both leading and trailing edges.*

Pulse top variations: <5%.

Droop: <6%.

Preshoot: <2%.

Pulse widths: 50 ns to 10 ms in 5 decade ranges; continuously adjustable vernier.

Width jitter: <0.05% of pulse width +1 nsec.

Pulse position: 0 to 10 ms advance or delay with respect to trigger output (5 decade ranges) continuously adjustable vernier.

Position jitter: <0.05% of advance or delay setting +1 ns (between trigger pulse and output pulse).

Repetition rate and trigger

Internal

Repetition rate: 10 Hz to 1 MHz (5 ranges), continuously adjustable vernier.

Rate jitter: <0.5% of the period.

Manual: pushbutton single pulse, 2 Hz maximum rate.

External

Repetition rate: dc to 1 MHz.

Sensitivity: <0.5 V peak.

Slope: positive or negative.

Level: adiustable from −40 V to +40 V

Delay: delay between input trigger and leading edge of pulse out is approx. 250 ns in Pulse Advance mode (approx. 420 ns minimum in Pulse Delay mode).

External gating: +8 V signal gates pulse generator on; maximum input, 40 V peak.

Double pulse

Minimum spacing: 1 μs on the 0.05 to 1μs pulse width range and 25% of upper limit of width range for all other ranges.

Trigger output

Amplitude: >10 V open circuit.

Source resistance: approximately 50 ohms.

Width: 0.05 μs nominal.

Polarity: positive or negative.

General

Maximum duty cycle: 10% on 100 and 50 V ranges; 25% on 20 V range; 50% on 10 V and lower ranges.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 325 W.

Dimensions: 16¾" wide, 7¼" high, 18⅜" deep overall (425 x 184 x 466 mm); hardware furnished for quick conversion to 7" x 19" rack mount, 16⅜" deep behind panel (178 x 483 x 416 mm).

Weight: net 35 lbs (15,8 kg); shipping 41 lbs (18,5 kg).

Price: HP Model 214A, $875.

*Measured on a 50 MHz oscilloscope

PULSE GENERATOR

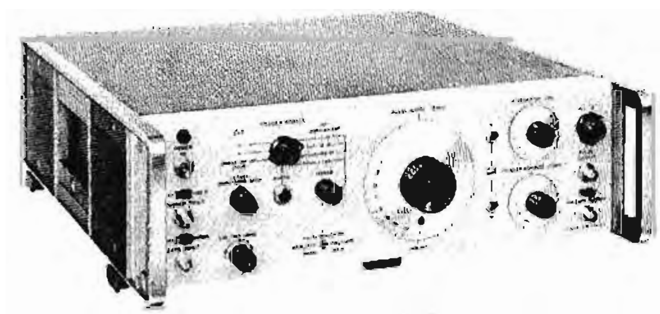
Controlled, fully specified output pulses

Model 215A

The Model 215A Pulse Generator combines in one compact unit the many capabilities desired for fast pulse testing. The fast rise and fall time and extremely low pulse jitter make the Model 215A particularly useful in measuring transition storage times of semiconductors, logic circuits and thin film memory units.

The output pulse of the Model 215A is carefully controlled to approximate an ideal pulse shape and is specified in every respect for accurate, dependable measurements. One nanosecond rise and fall time pulses of either polarity with nearly an ideal pulse shape, combined with calibrated pulse width and delay controls, adjustable pulse amplitude, variable pulse rate to 1 MHz and a true 50-ohm source impedance provide maximum measurement capabilities.

The true 50-ohm source impedance insures clean output pulses, regardless of the load impedance, since any reflection from the circuit under test will be absorbed by the 50-ohm generator impedance.



215A

Specifications

Source Impedance: 50 ohms ±3%; 3% maximum reflection when driven by a pulse with 1 ns rise time from an external 50-ohm system.

Leading edge only
- Rise time: <1 nsec (10 to 90% points).
- Overshoot and ringing: <±5% of pulse amplitude.
- Corner rounding: occurs no sooner than 95% of pulse amplitude.
- Time to achieve flat top: <6 nsec.

Trailing edge only
- Fall time: <1 ns (10 to 90% points).
- Overshoot: <5%.
- Rounding: occurs no sooner than 95% of fall.
- Time to settle within 2% of baseline: 10 to 25 ns, varies with width setting.

Baseline shift: <0.1% under all conditions.

Preshoot: <1%.

Perturbations on flat top: <2% of pulse amplitude.

Peak voltage: >10 volts into 50 ohms; >20 volts open circuit.

Polarity: positive or negative.

Attenuator: 0 to 12 dB in 1 dB steps, absolute accuracy within ±0.1 dB.

Pulse width (between 50% points): continuously adjustable, to 100 ns; dial accuracy within ±5% ±3 ns; width jitter less than 50 ps.

External bias: up to ±100 mA (±5 V dc) may be safely applied to the output; at 0 dB attenuator setting, up to 10 mA (0.5 V dc) may be applied without significant change in pulse shape (5% droop), increasing to 40 mA at 12 dB; in most cases, adjusting the front-panel pulse-shape controls will restore original pulse shape.

Repetition rate sources
- Internal repetition rate: <100 Hz to >1 MHz in 4 ranges, continuously variable between ranges; period jitter <0.3% of one period.
- Manual: pushbutton single pulse.

Trigger timing: adjustable from 10 ns delay to 140 ns advance with respect to leading edge of output pulse; dial accuracy within ±10% ±5 ns; jitter <50 ps.

External triggering: ac coupled, sine waves from 10 Hz to 1 MHz; pulses from 0 to 1 MHz, either positive or negative slope.
- Trigger level: external trigger level continuously variable, from approximately +8 to −8 volts.
- Sensitivity: 1 V peak to peak min.; external pulses must be at least 30 ns wide; max. input 50 V peak, 0.5 W max. average power.
- Input resistance: approx. 50 ohms or High Z available by front-panel switch; High Z is approx. 100 kΩ for negative slope setting approx. 5 kΩ for positive slope setting.
- Countdown: counts down from frequencies to 100 MHz, 2 V rms amplitude; resulting pulse repetition rate is always <1.3 MHz; jitter is <10% of one period of the triggering signal.
- External trigger delay: approximately 250 ns between leading edge of trigger pulse (2 volt step, 2 ns rise time into 50 ohms) and leading edge of output base; <50 ps jitter.
- External gating: gates on with a +1 volt pulse; maximum input 50 V peak, 20 V rms.

Trigger output pulses
- Width: 50 ns, nominal.
- Amplitude: >1 volt peak into 50 ohms.
- Rise time: <6 ns.
- Polarity: positive or negative.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 60 W.

Dimensions: 5½" high, 16¾" wide, 18⅜" deep (175 x 425 x 466 mm); hardware furnished for quick conversion to 5¼" x 19" rack mount, 16⅜" deep behind panel (134 x 483 x 416 mm).

Weight: net 34 lbs (15.3 kg); shipping 41 lbs (18.5 kg).

Accessories furnished: Model 10120A cable, 3 feet, BNC-to-BNC, 50 ohms ±0.5 ohm.

Accessories available: Model 10122A cable, 3 feet, BNC-to-Type N, 50 ohms ±0.5 ohm, $10; Model 908A, 50-ohm Coaxial Termination, $35; Model 10451A Multipulser generates pulse bursts to simulate 15 to 200 MHz rep rate, $150; Model 10240A Blocking Capacitor, 0.1 μF, isolates Model 215A from up to 200 V dc, $70.

Price: HP Model 215A, $1875.

PULSE GENERATOR
Fast-rise 100 MHz pulses
Model 216A

The Model 216A offers pulse repetition rates up to 100 MHz for testing fast circuits, yet retains a nearly ideal pulse shape with 2.5 ns rise time for accurate, dependable measurements. In addition, bursts of pulses may be produced internally to simulate pulse trains for logic circuit testing.

Pulse height is continuously variable, allowing exact pulse amplitudes to be selected for precise testing. The dc-coupled output eliminates baseline shift with changes in rep rate, and the 50-ohm output impedance prevents multiple reflections, insuring clean, easy-to-interpret waveforms.

216A

Specifications

Source impedance: 50 ohms, ±3%, shunted by approximately 10 pF at any output up to 15 V.

Leading edge only (at 10 V output into 50-ohm load).
- **Rise time:** <2.5 ns.
- **Overshoot and ringing:** ±4% p-p of pulse amplitude.
- **Corner rounding:** occurs no sooner than 96% of pulse amplitude.
- **Time to achieve flat top:** <20 ns.
- **Preshoot:** <2%.

Trailing edge only (at 10 V output into 50-ohm load).
- **Fall time:** <2.5 ns.
- **Overshoot:** <4%.
- **Corner rounding:** occurs no sooner than 96% of fall.
- **Time to settle within 2% of base line:** <20 ns.
- **Preshoot:** <5%.

Perturbations on flat top: <3% of pulse amplitude.

Peak voltage: 0.4 to 10 volts into 50 ohms to 100 MHz (15 volts maximum amplitude into open circuit).

Attenuator: 1, 2, 5, 10 volt steps.

Polarity: positive or negative.

Vernier: provides continuous adjustment from approximately 0.3 volts to 10 volts.

Pulse width: continuously variable in two ranges, from approximately 5 ns to 25 ns and from 25 ns to 100 ns; width jitter <100 psec +0.3% of pulse width with countdown ratio set for minimum jitter.

Maximum duty cycle: ≥45% up to 50 MHz decreasing to approximately 20% at 100 MHz.

Internal repetition rate: 1 MHz to 100 MHz in 3 ranges.

External triggering
- **Frequency:** sine waves from 1 MHz to 100 MHz, negative pulses from 0 to 100 MHz; pulse rise time <100 ns; pulse width >2 ns.
- **Sensitivity:** at least 0.5 volt peak minimum; maximum input, 10 volt peak.
- **Input impedance:** approximately 50 ohms, ac coupled.
- **External trigger delay:** approximately 140 ns between leading edge of input trigger pulse and leading edge of output pulse.

Trigger output pulse
- **Width:** 3.5 ns ±1 ns.
- **Amplitude:** >0.7 volts peak into 50 ohms.
- **Polarity:** negative.
- **Trigger timing:** approximately 130 ns advance with respect to leading edge of output pulse.

Countdown trigger output
- **Amplitude:** >0.5 volt peak into 50 ohms.
- **Polarity:** positive.
- **Countdown frequency:** variable from approximately 250 kHz to 450 kHz.

Gating of pulse bursts
- **Internal**
  - **Gate width:** variable from approx. 20 ns to 750 ns.
  - **Gate repetition rate:** variable from approximately 250 kHz to 450 kHz.
- **External:** gates on with +2 volt pulse having rise and fall times of <5 ns; maximum input, 10 volts.
- **Perturbations:** perturbations on gate envelope <5% into 50 ohms; above 50 MHz, width varies slightly from pulse to pulse.

General
- **Power:** 115 or 230 volts ±10%, 50 to 60 Hz, 120 W.
- **Dimensions:** 5½" high, 16¾" wide, 18⅜" deep (175 x 425 x 466 mm), hardware furnished for quick conversion to 5¼" x 19" rack mount, 16⅜" deep behind panel (134 x 483 x 416 mm).

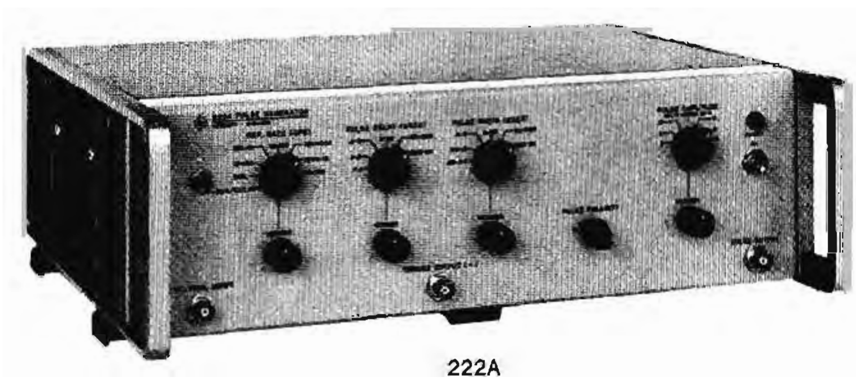
Weight: net 25 lbs (11 kg); shipping 31 lbs (14 kg).

Accessories available: Model 10120A Cable, 3 feet, BNC-to-BNC, 50 ohms ±0.5 ohm, $10; Model 10122A Cable, 3 feet, BNC-to-Type N, 50 ohms ±0.5 ohm, $10; Model 908A 50-ohm Coaxial Termination, $35; Model 10240A Blocking Capacitor, 0.1 μF, isolates Model 216A from up to 200 V dc, $100.

Price: HP Model 216A, $1775.

PULSE GENERATOR
Economical general-purpose testing
Model 222A

The Model 222A combines many features normally found only on more expensive instruments to provide an easy-to-use, yet versatile, general-purpose pulse generator. The 4 nsec rise time and full complement of controls permit a wide variety of pulse testing, including square wave testing. Oscilloscope-type triggering, variable pulse width, repetition rates to 10 MHz, closely specified pulse shape and many other features provide accurate, dependable measurements. The Model 222A, like other HP pulse generators, has a 50-ohm output impedance for eliminating error-producing reflections. The output pulse may be delayed from the trigger output by up to 5 ms for further measurement convenience.



222A

Specifications

Output pulse

Source impedance: 50 ohms shunted by approximately 15 pF at any output up to 12 V.

Amplitude

Peak voltage: 10 volts across 50 ohms; approximately 12 volts maximum.

Amplitude control: step attenuator provides 0.1, 0.2, 0.5, 1, 2, 5, 10 volts across 50 ohms; continuously variable between steps; minimum output less than 0.05 volts.

Polarity: positive or negative.

Pulse width

Range: 30 ns to 5 ms in 6 ranges, continuously variable between ranges.

Duty cycle: maximum duty cycle ≥50% from 100 Hz to 10 MHz; for maximum stability at high duty cycles, select width range which allows maximum clockwise rotation of width vernier; duty cycle from 10 to 100 Hz limited by 5 ms maximum pulse width.

Width jitter: <0.2% of maximum range width.

Pulse shape

Leading edge only (measured at 10 volts into 50 ohms)

Rise time: <4 ns.

Overshoot and ringing: <4% peak of pulse amplitude.

Corner rounding: occurs no sooner than 95% of pulse amplitude.

Time to settle within 3% of flat top: <20 ns.

Preshoot: <2%.

Trailing edge only (measured at 10 volts into 50 ohms)

Fall time: <4 ns.

Overshoot and ringing: <4% peak of pulse amplitude.

Corner rounding: occurs no sooner than 95% of pulse amplitude.

Time to settle within 2% of base line: <20 ns.

Preshoot: <4%.

Perturbations on flat top: <% of pulse amplitude.

Repetition rate and trigger

Internal

Repetition rate: 10 Hz to 10 MHz in 6 ranges, continuously variable between ranges.

Jitter: period jitter in any frequency range <0.2% of maximum period of that range.

Manual: pushbutton single pulse.

External

Triggering: ac coupled; sine wave from 10 Hz to 10 MHz, pulse from 0 to 10 MHz, either postive or negative slope.

Sensitivity: 1 volt p-p minimum; external pulses must be at least 10 ns wide: maximum input 20 volts peak; 0.25 watt maximum average power.

Input resistance: approximately 500 ohms.

External trigger delay: less than 20 ns between leading edge of external trigger input pulse and leading edge of trigger pulse.

Trigger output pulse:

Width: 22 (±8) nsec at 50% points.

Amplitude: >1 volt into 50 ohms.

Polarity: negative.

Pulse delay: pulse delayed from trigger output by <100 ns to 5 ms in 6 ranges, continuously variable between ranges.

Delay jitter: <0.2% of maximum delay of that range.

General

Power: 115 or 230 V ±10%, 50 to 60 Hz, 80 W.

Dimensions: 16¾" wide, 5½" high, 13¼" deep (425 x 140 x 336 mm); hardware furnished for quick conversion to 5¼" x 19" rack mount, 11¾" deep behind panel (133 x 483 x 298 mm).

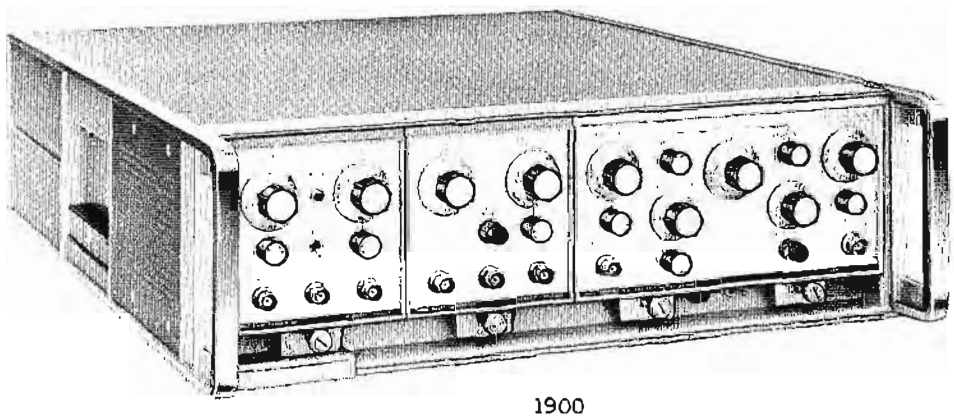
Weight: net 18 lbs (8 kg); shipping 23 lbs (10,4 kg).

Price: HP Model 222A, $690.

PULSE GENERATOR

Plug-in, variable risetime/falltime

Model 1900 system



1900

The new, all solid-state 1900 Pulse System from Hewlett-Packard is a major advancement in flexibility and versatility. Plug-in capability, programmability (optional), and freedom from radiated or conducted electromagnetic interference (RFI and EMI) are representative of the improved performance in this system.

Until the 1900, no pulse system could be so economically tailored to fit exact requirements, from general laboratory use to fully automated production test systems.

Plug-in flexibility

The 1900 system mainframe contains only power supplies, with optional programming wiring added if desired. The plug-in compartment accepts any combination of half-size or quarter-size plug-ins. Additional information, including specifications and accessories, is on page 358.

Model 1905A Rate Generator provides output triggers which are variable in frequency from 25 Hz to 25 MHz; it includes a push button for single pulse triggers. Additional information and specifications are on page 359.

Model 1908A Delay Generator delays or advances 25 MHz pulses over a range of 15 ns to 10 ms and includes a double pulse mode. Additional information and specifications are on page 359.

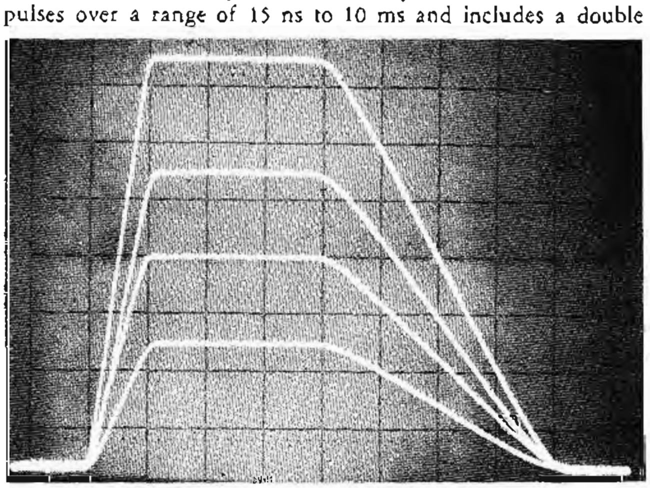


Figure 1. HP 1900 pulse system provides clean pulseshapes with variable risetimes and falltimes as well as variable output currents.

Model 1915A Variable Transition Time Output varies pulse risetimes and falltimes from 7 ns to 1 ms, and output currents from 40 mA to 1A (see Figure 1). Additional information and specifications are on page 360.

Updating the 1900 pulse system is easy and economical. Mainframe, rate plug-in, and delay plug-in will be compatible with newer output stages which will provide different pulse parameters such as faster rise- and falltimes.

In addition to simpler pulse generators, complex pulse systems may be formed by using several mainframes and appropriate plug-ins. For example, one rate generator can be used with several delay generators in turn driving several output stages. The resulting system provides several pulse sources whose shape and timing are independently variable, yet it uses a minimum of instruments. This pulse system is illustrated in Figure 2.

The rack-mount version of the 1900 system is only 5 inches high and a standard 19 inches wide. This saves valuable rack space, allowing additional instrumentation for increased versatility. The HP modular cabinet enclosure allows quick conversion to a bench instrument by removing two rack flanges and installing plastic feet.

Maintenance is fast and easy with the 1900 system. Entire plug-ins can be quickly replaced for minimum downtime. More complex plug-ins have replaceable plug-in circuit boards, also facilitating calibration and replacement. Multi-layer circuit boards are used in the 1900 system, minimizing point-to-point wiring and resulting in more consistent and reliable electrical performance.

Programming

All major functions of the 1900 system can be easily programmed. This capability may be ordered initially or easily added later for a nominal cost. Thus the same instrument bridges between a laboratory general purpose test instrument and a programmable unit for automated production testing.

Range switch programming is accomplished by grounding appropriate pins on a rear panel connector, using external switches, relays, or DTL logic. Verniers are programmed by

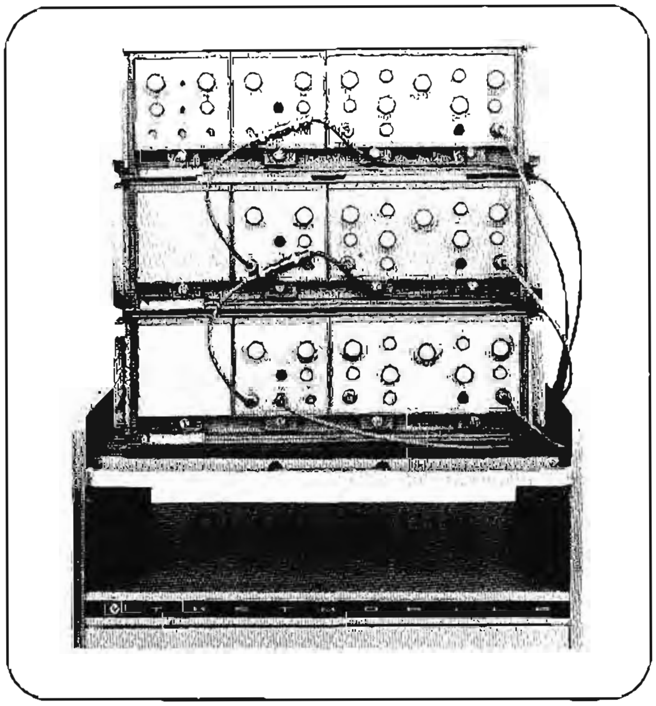


Figure 2. Pulse system versatility is demonstrated with one rate generator serving as clock for three delay generators, each delay generator in turn driving a variable transition time output plug-in. Same rate generator could provide clock signal to additional delay generators. Three output pulses have separately controlled delay, width, risetime, falltime, polarity, offset, and amplitude.

applying an external dc current (1 to 10 mA) to a connector pin. Any front panel manual setting can be duplicated by this programming technique. Program inputs can be overridden at any time by turning front panel function switch out of its PGM position.

Programming capability requires only addition of circuit boards and connectors. Some circuit boards are the plug-in type and others mount easily with a few screws. No solder connections are required for either type of circuit board.

Electromagnetic shielding

The 1900 pulse system is completely shielded against unwanted electromagnetic radiation and conduction (EMI and RFI). It meets EMI/RFI requirements of military specification MIL-I-6181D.

This shielding prevents outside interference from affecting 1900 operation and also prevents 1900 radiation and conduction from disturbing other circuitry.

Shielding precautions include special double covers, a line filter, sealing gaskets for plug-ins, and provision for screwdriver locking of plug-ins (in addition to normal knob locks).

External width input

A unique external width function of the Model 1915A output plug-in extends usability to many new applications such as pulse-code modulation (PCM) and digital circuits requiring non-return-to-zero (NRZ) logic.

Most pulse generators are triggered by a narrow pulse and generate a pulse with a width set by a panel control. Although the 1915A usually operates this way, it can be set to function as a pulse amplifier. In this operation, width and spacing of pulse trains are maintained.

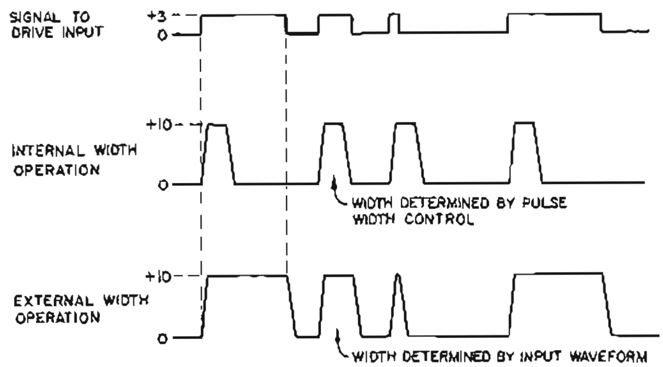


Figure 3. Middle waveform illustrates use of internal width control with pulses triggered by the top waveform. Lower waveform shows external width capability, using 1900 system as pulse amplifier with output pulse width determined by top waveform.

This feature allows application of variable width pulses to the drive input with these pulses reproduced at the output. However, risetime, falltime, amplitude, and baseline offset are controlled by the Model 1915A. Figure 3 illustrates internal and external width operation.

One of the most common uses for the external width capability is with word generators to obtain NRZ formats, essentially a variable width pulse train. These NRZ pulse trains may be amplified, risetimes varied, baseline offset, or polarity changed. Figure 4 demonstrates how the external width capability can be used as a regenerator to clean up noisy pulse trains.

The external width feature of the 1900 system will accept three of the most commonly used formats: RZ, NRZ, and biphase.

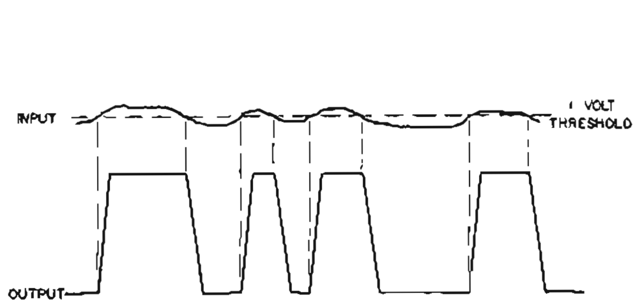


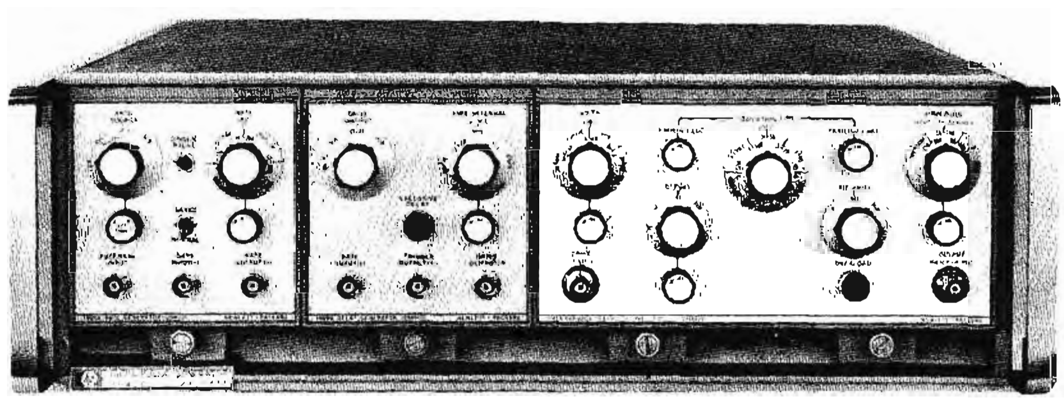
Figure 4. External width feature of 1900 system turns on output at 1 volt threshold. Output then remains on until input drops below threshold.

Complete plug-in versatility
Mainframe Model 1900A and accessories

Model 1900A Pulse Generator mainframe accepts all 1900-series plug-ins. The plug-in compartment holds any combination of quarter-size or half-size plug-ins. Plug-ins are completely interchangeable and may be interconnected by internal wiring and switches or by external cables.

Programming capability (connectors and cables) may be ordered initially as an option, or added later as a modification kit.

Shielding against electromagnetic conduction and radiation is standard on all instruments of the 1900 system.



1900A (shown with 1905A, 1908A, and 1915A plug-ins)

Specifications, 1900A

Plug-ins: mainframe accepts any 1900 series quarter-size or half-size plug-ins. Plug-ins may be interchanged in any manner within the mainframe.

Interconnection between plug-ins: either external (with BNC cables) or internally selectable with switches in the plug-ins.

RFI-EMI: mainframe with plug-ins installed will pass MIL-I-6181D specifications.

Dimensions: 16¾" wide, 5¼" high, 21⅜" deep over-all (425 x 133 x 543 mm); hardware furnished for quick conversion to 19" x 5¼" x 19⅜" behind panel rack mount (483 x 133 x 492 mm).

Weight: net, 35 lbs (16 kg); shipping, 46 lbs (21 kg).

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 300 watts max.

Options

Option 001: programming cables and four rear panel connectors, providing 36 pins to each quarter-size plug-in (or 72 pins for double-size). Price: Model 1900A Option 001, $175 (additional).

Option 002: factory-installed chassis slides, non-pivoting. Price: Model 1900A Option 002, on request (additional).

Accessories available

Chassis slides kit for field installation; non-pivoting. Order HP Part No. 01900-69501. Price: on request.

Programming kit for field installation. Price: on request.

Price: HP Model 1900A, $750.

Accessories

Blank plug-ins

Blank plug-ins are available for either filling of unused compartment space in a 1900 system, or for construction of special purpose plug-ins. Price: HP Model 10481A quarter-size unit, $20; HP Model 10482A half-size unit, $25.

Plug-in extender

The 1900 pulse generator system may be serviced and calibrated by simply removing the top covers. However, for greater convenience, a plug-in extender is available which accommodates both quarter-size and half-size units. The extender allows access to either quarter-size or half-size plug-ins outside the mainframe with the system still operating. Extender also includes wiring for programming options. Price: HP Model 10483A, $135.

Pulse adder

Model 15104A Adder is useful when outputs from two pulse sources must be combined to produce complex signals. It also serves as a signal splitter when one pulse source must drive two paths. Two or more adders may be used to combine outputs of three or more pulse sources.

Specifications, 15104A

Reflection: 10% in 150 ps pulse system (dc to over 2 GHz equivalent bandwidth).

Risetime: <150 ps.

Maximum input: 2 W into two inputs with third connector terminated in 50 ohms. Maximum average voltage not to exceed 5 V between two connectors.

Output voltage: algebraic sum of half the voltage from each input.

Input connectors: two BNC female, one BNC male.

Price: HP Model 15104A, $20.

Splitter Inverter

Model 15115A Splitter Inverter converts a single input pulse into two opposite polarity pulse outputs. This facilitates driving push-pull stages and flip-flops with one pulse source.

Specifications, 15115A

Reflection: 10% in a 50-ohm, 150 ps pulse system.

Risetime: 250 ps non-inverted output; 500 ps inverted output.

Droop at 500 ns pulse width: <2.5% non-inverted output; <4% inverted output.

Maximum average input: 6 dB non-inverted output; 6.2 dB inverted output.

Delay between inverted and non-inverted outputs: <1 ns.

Price: HP Model 15115A, $50.

Inverter

Model 15116A Inverter reverses polarity of input pulses. Extends possible variety of complex pulse waveforms when used with Model 15104A Adder and Model 15115A Splitter Inverter.

Specifications, 15116A

Reflection: 10% in a 50-ohm, 150 ps pulse system.

Risetime: 500 ps.

Droop at 500 ns pulse width: <5%.

Insertion loss: 0.3 dB.

Price: HP Model 15116A, $30.

Rate generator, delay generator

Models 1905A; 1908A

Model 1905A

The Model 1905A Rate Generator is a quarter-size plug-in which serves as a clock source for the 1900 system. The Model 1905A provides output triggers at repetition rates from 25 Hz to 25 MHz.

Either external triggering or internal rate generator operation may be used. Rate generator outputs are obtained using either sinusoidal or pulse waveforms as the external input. Outputs from Model 1905A may be synchronously gated externally by applying a suitable pulse waveform.

Rate source, rate range, and rate vernier may be externally programmed; see specifications.

Specifications, 1905A

Internal

Repetition rate: 25 Hz to 25 MHz in 6 decade ranges. 10:1 vernier allows continuous adjustment on any range.

Period jitter: <0.1% of selected period.

External input

Repetition rate: 0 to 25 MHz.

Input impedance: 50Ω, dc-coupled.

Sensitivity: 0.5 volts pk-pk.

Level: continuously variable over ±3 volt range.

Slope: + or −, selectable.

Delay: approximately 10 ns between trigger input and rate output.

Synchronous gating

Sensitivity: −2 volts or more required to gate pulse train on.

Input impedance: 50Ω, dc-coupled.

Delay: approx 27 ns between gate input and first rate output.

Manual operation: push button for single pulse.

Rate output

Amplitude: >+1 volt into 25Ω (drives two 1900 series plug-ins).

Risetime: <5 ns.

Width: <10 ns.

Connection: rate output may be connected internally or externally to other plug-ins, selected by internal switch.

Weight: net, 1½ lbs (0,7 kg); shipping, 3½ lbs (1,6 kg).

Option 001: programming connector and circuitry allowing Rate Source and Rate Range selection by contact closure to ground; Rate vernier programmed by analog current allowing continuous rate selection. Price: Model 1905A Option 001, $100 (additional).

Accessories available

Programming kit: field installation of same capability as Option 001. Price: on request.

Price: HP Model 1905A, $200.

Model 1908A

Pulses up to 25 MHz in frequency may be advanced or delayed with the Model 1908A Delay Generator, a quarter-size plug-in for the 1900 pulse system. Range for pulse advance or delay is from 15 ns to 10 ms.

A double pulse mode can be used to generate pulse pairs with variable separation of pulses.

The trigger output is useful for triggering other external equipment or it is sufficient to drive two variable transition time output plug-ins.

Drive output mode, time interval range, and time interval vernier can be externally programmed; see specifications.

Specifications, 1908A

Functions (drive output switch)

Delay: drive output delayed with respect to trigger output.

Advance: trigger output delayed with respect to drive output.

Double pulse: generated from drive output connector. Spacing determined by time interval setting.

Time interval

Range: 15 ns to 10 ms in 6 ranges. 10:1 vernier allows continuous adjustment on any range.

Jitter: <0.1% of selected time interval.

Excessive delay indicator: light comes on when selected time interval exceeds pulse period.

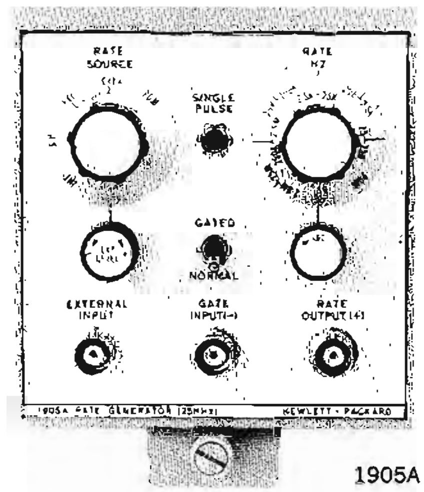
Rate input

Repetition rate: 0 to 25 MHz.

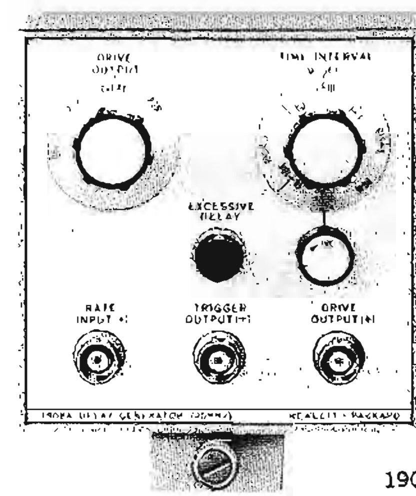
Input impedance: 50Ω, dc-coupled.

Sensitivity: >1 volt peak.

Width: portion of input trigger above 0.8 volts must be <7 ns.



1905A



1908A

Connection: rate input may be connected internally or externally from other plug-ins, selected by internal switch.

Trigger and drive outputs

Amplitude: >+1 volt into 25Ω drives two 1900 series plug-ins).

Width: <10 ns.

Risetime: <5 ns.

Minimum delay after rate input:

Trigger output: approx. 14 ns in drive output delay mode; approx. 29 ns in drive output advance mode.

Drive output: approx. 29 ns in drive output delay mode; approx. 14 ns in drive output advance mode.

Connection: drive output may be connected internally or externally to other plug-ins, selected by internal switch.

Weight: net, 1½ lbs (0,7 kg); shipping, 3½ lbs (1,6 kg).

Option 001: programming connector and circuitry allowing Drive Output mode and Time Interval range selection by contact closure to ground; Time Interval vernier programmed by analog current allowing continuous time interval selection. Price: Model 1908A Option 001, $100 (additional).

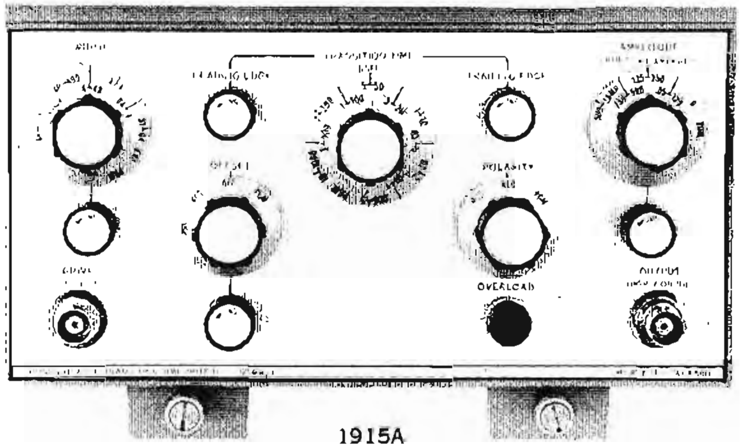
Accessories available

Programming kit: field installation of same capability as Option 001. Price: on request.

Price: HP Model 1908A, $200.

High power, variable rise and fall

Variable transition time output Model 1915A



1915A

Model 1915A Variable Transition Time Output, a half-size plug-in, provides high-power, variable risetime and falltime output pulses. These pulses, with reversible polarity and with risetime and falltime as fast as 7 ns, are useful in testing magnetic memory devices and in other applications requiring high currents and voltages. Maximum current available is 1 ampere (50 volts into 50 ohms).

Either 50-ohm or high impedance source is available. The 50-ohm source impedance preserves the clean pulse shape by absorbing reflections from an external load. The high impedance source provides maximum current and voltage.

Risetimes and falltimes are variable from 7 ns to 1 ms. A common control selects the range and verniers select risetime and falltime separately. Ratios between transition times up to 100:1 provide a wide degree of flexibility.

External width operation (described on pages 356 and 357) extends Model 1915A usefulness to applications such as pulse code modulation, variable pulse width logic, and other pulse-shaping requirements.

Offset capability of the Model 1915A allows the pulse baseline to be varied over a ±60 mA range. A zero position on the current offset switch allows setting the baseline quickly and accurately at ground.

All front panel control functions can be externally programmed. This capability is available initially as Option 001, or a kit may be ordered at a later date. Other options available (listed in specifications) are for amplitude calibration in volts, and either positive-only or negative-only offset and pulse output polarity (two Model 1915A's may be operated in one mainframe, provided the offset and pulse polarities are different).

Specifications, 1915A

Output pulse

Source impedance: 50Ω or high Z; self-contained 50Ω termination may be connected or disconnected.

High Z output: approximately 5 k ohms shunted by 45 pF.

50Ω output: approximately 50Ω shunted by 45 pF.

Amplitude (short circuit current): 50 milliamperes to 1 ampere in 4 ranges; 2.5:1 vernier allows continuous adjustment on any range. Voltage into external 50Ω is ±2.5 V to ±50 V with high Z source; ±1.25 V to ±25 V with 50Ω source. Maximum amplitude (including offset) is ±50 V.

Pulse top variations

With 50Ω source and 50Ω load: ±5% for transition times 7 ns to 10 ns; ±2% for transition times >10 ns.

With high Z source and 50Ω load: ±5% for all transition times.

Polarity: + or −, selectable.

Duty cycle: 0 to >90%, internal width mode; 0 to 100%, external width mode.

Baseline offset: ±60 milliamperes. Maximum offset into external 50Ω is ±1.5 volts with 50Ω source; ±3 volts with high Z source.

Overload: overload light comes on to indicate protection circuits are limiting output to prevent damage to output transistors. Two common combinations of overload conditions are: (a) 25-ohm combined load (source and external), <0.2% duty cycle, and width >2 μs; and (b) 50-ohm combined load, >2 μs transition time, and >35 volts amplitude.

Transition times: 7 ns (10 ns with high Z source) to 1 ms in 11 ranges (1,2,5 sequence); two 100:1 verniers allow independent control of rise- and falltimes.

Width

Internal

Ranges: 10 ns to 40 ms in 7 decade ranges (except for first range which is 10 to 40 ns); 10:1 vernier allows continuous adjustment on any range.

Width jitter: <0.5% of selected pulse width.

External: provides pulse amplifier operation; output pulse width determined by width of drive input.

Drive Input

Repetition rate: 0 to 25 MHz.

Input impedance: 50Ω, dc-coupled.

Sensitivity: >+1 volt peak.

Connection: drive input may be connected internally or externally from other plug-ins, selected by internal switch.

Weight: net, 5½ lbs (2,5 kg); shipping, 9 lbs (4,1 kg).

Options

Option 001: programming connector and circuitry allowing width range, Transition Time range, Amplitude range, Offset and Polarity selection by contact closure to ground; verniers for Width, Leading Edge, Trailing Edge, Offset, and Amplitude programmed by analog current allowing continuous control on any range. Price: Model 1915A Option 001, $275 (additional).

Option 002: provides positive-only pulse output and positive-only offset. Price: Model 1915A Option 002, on request.

Option 003: provides negative-only pulse output and negative-only offset. Price: Model 1915A Option 003, on request.

Option 004: calibration of pulse amplitude in voltage. Four ranges provide from ±2.5 V to ±50 V from high Z source into 50Ω external load or ±1.25 V to ±25 V from 50Ω source into 50Ω external load.

Accessories available

Programming kit: field installation of same capability as Option 001. Price: on request.

Price: HP Model 1915A, $1600.

Most systems, from simple servos to suspension bridges, are subject to random disturbances which must be accounted for in the design and—if possible—simulated at the prototype test stage. For the purpose of simulation it seems appropriate to use a randomly varying test signal—that is, low frequency noise—rather than the traditional sine wave. In environmental testing, too, the real-life 'shock environment' can often be reproduced accurately with a noise-stimulated transducer. The desirability of noise as a test signal has been appreciated for many years, but general acceptance of the technique has been slow—principally owing to the lack of satisfactory generators and related test gear for low frequency noise.

Conventional noise generators employ natural sources such as the gas discharge tube and temperature-limited diode. Generators of this type have the disadvantage that their total power output is subject to unpredictable long term variations: their power spectra, too, can often be unpredictable at low frequencies—in particular, below 50 Hz, where much of the interest in noise testing is focused.

Characterizing noise

The power spectrum describes only the frequency content of the noise signal, but does not characterize its waveshape: this is specified by the probability density function (p.d.f.), a statistical indication of the proportion of time spent by the signal at various amplitudes. The most commonly encountered p.d.f. is the classical bell-shaped, or Gaussian curve so familiar in statistics: this particular p.d.f. characterizes most random phenomena (for example, atmospheric changes) and for this reason, a noise signal designed to simulate such phenomena must have a p.d.f. which closely approximates the Gaussian curve. The question of p.d.f. is another problem area with conventional noise generators. How can 'Gaussianness' be specified? And, more difficult, over what period of time must the signal be evaluated to be certain that its amplitude characteristics tend to be Gaussian? Are the signal properties observed in a given period representative of the next similar period? This suggests that a series of identical experiments involving truly random noise will yield different results each time. This 'statistical variance' can often be reduced to acceptable limits by increasing the observation (that is, averaging) time—but it can never be entirely eliminated.

Pseudo-random noise

The need exists, then, for a test signal having the desirable properties of random noise—that is, broad spectrum and Gaussian probability density function—yet not having the bad property . . . randomness. In other words, the signal should be one which introduces no statistical variance into test results, even though the measurements are made in a finite time.

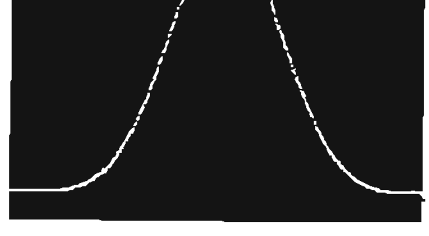
Such a signal exists . . . *pseudo-random* noise is a signal which looks and acts like random noise, but is in fact periodic. This kind of noise is the main product of the Hewlett-Packard Model 3722A Noise Generator.

Pseudo-random waveforms from the 3722A consist of completely defined patterns of selectable length, repeated over and over without interruption. They have power spectra and p.d.f.'s similar to those of random noise but, because the waveforms are synthesized, their statistical properties are precisely known. Perhaps the most important feature of pseudo-random noise testing is the fact that, if the measurement time is made exactly equal to the length of one pseudo-random pattern, the results of the experiment will be identical at every repetition, provided nothing else has changed.

This repeatability of pseudo-random noise is especially valuable when parameters of the system under test are varied—for example, in an analog computer model of a complex system. In such tests, it is reassuring to know that changes in test results arise from parameter manipulation and not from statistical variance in the test signal. The basic output from the Model 3722A is two-level, binary noise (random telegraph signal), available as a pseudo-random signal in a variety of pattern lengths, and also as a truly random, non-repeating signal. Binary noise is commonly used in testing systems controlled by two-state elements such as switches, relays, fluid control valves, and so on. Recently, however, binary noise has assumed greater importance in connection with actual identification of systems . . . that is, obtaining the impulse response of a system by injecting low-level binary noise into the system and then cross-correlating the input and output signals. This technique can be demonstrated very simply using the Model H01-3722A Generator, a standard Model 3722A instrument with two separate binary outputs, one of which can be variably delayed with respect to the other.

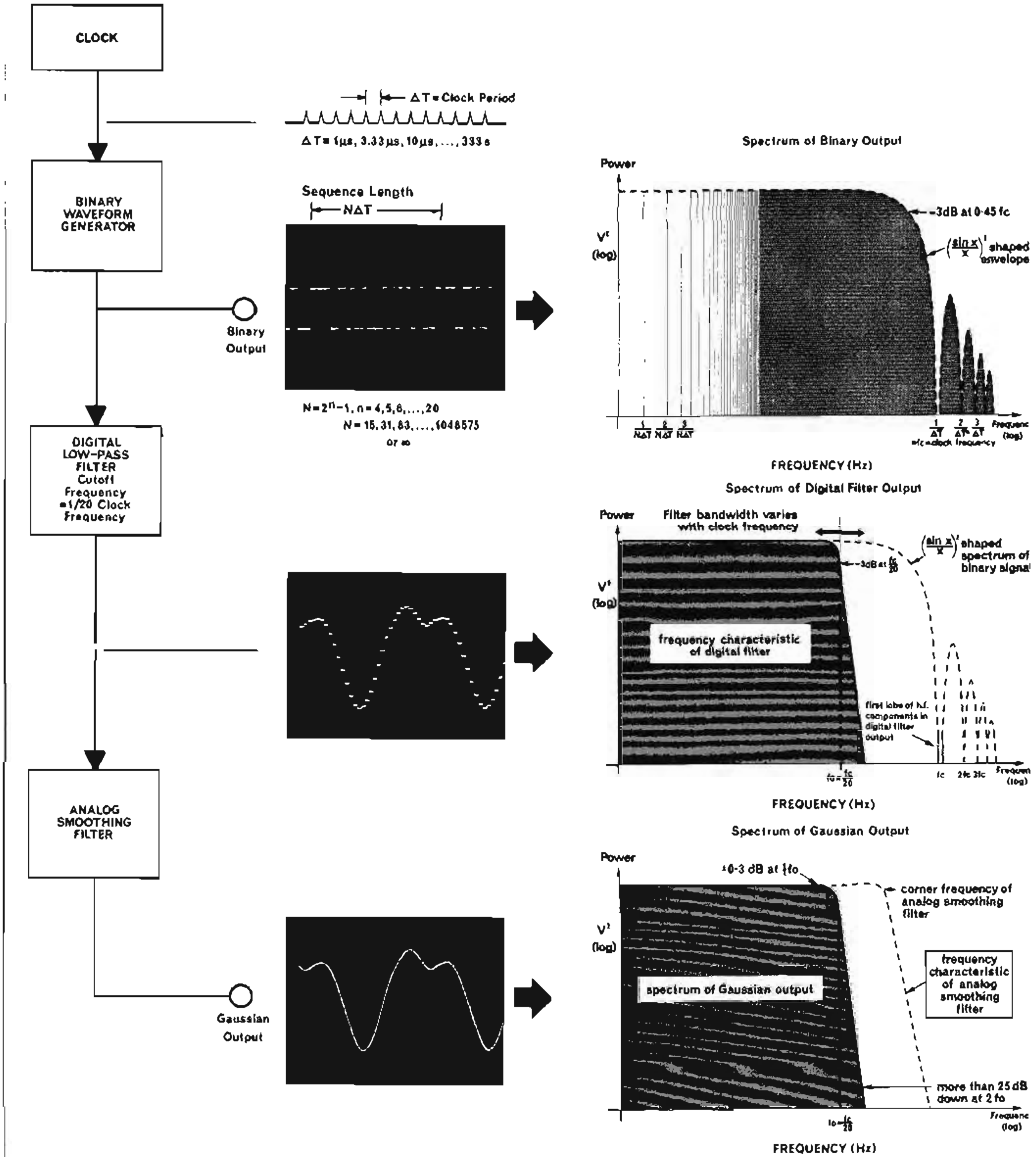
The principal output from the Model 3722A is Gaussian noise, which is derived from the binary signal by low-pass filtering. A unique method of digital filtering is employed to give an almost rectangular power spectrum with very little power beyond a selectable cut-off frequency. The particular advantage of this digital filter, as opposed to the conventional analog filter, is that it yields a signal of constant power regardless of cut-off frequency (in any event, analog filtering is not practicable at the very low frequencies useful in noise testing—the lowest cut-off frequency of the digital filter in the Model 3722A is about 1 cycle in 100 minutes!).

Part of a pseudo-random Gaussian noise sequence generated in Model 3722A from 524,287-bit binary pattern. Clock period is 1 μs, giving noise bandwidth of 50 kHz.



Probability density function of pseudo-random Gaussian noise (same sequence as at left) displayed on Model 5400A Multi-channel Analyzer.

3722A Noise Generator



Model 3722A Noise Generator synthesizes pseudo-random or random binary signal in a digital waveform generator which is timed by a crystal-controlled clock. Clock rate and length of pseudo-random sequences are variable. Gaussian signal is derived from binary output by digital low-pass filtering. Discrete steps in digital filter output are removed by analog filter. Pseudo-random binary output of noise generator has line power spectrum having a flat envelope from dc to an upper 3 dB frequency which is selectable from 0.00135 Hz to 450 kHz. Spectrum of pseudo-random Gaussian output has flat envelope from dc to an upper 3 dB frequency which is selectable from 0.00015 Hz to 50 kHz. Random outputs have continuous power density spectra having same shapes as envelopes of spectra of pseudo-random outputs.

NOISE GENERATOR

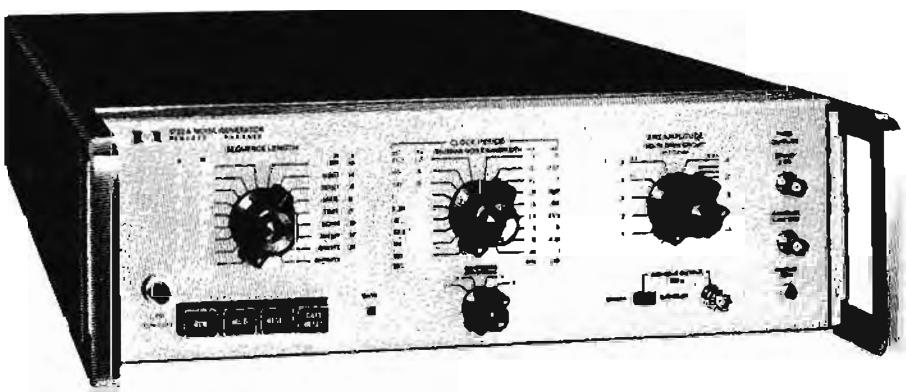
Produces calibrated noise patterns

Model 3722A

The Model 3722A Noise Generator uses digital techniques to synthesize binary and Gaussian noise patterns. These pseudo-random' patterns, which are of known content and duration, are repeated over and over without interruption. Since one pattern is identical with the next, each pattern has the same effect on the system under test: for this reason, pseudo-random noise signals cause no statistical variance in test results. The Model 3722A also generates truly random binary and Gaussian noise.

Basis of the Model 3722A is a binary waveform generator—a shift register which operates under the control of either a feedback mechanism (pseudo-random mode) or a random noise source (random mode). The shift register is clock triggered, with the result that transitions between output levels of the binary waveform can occur only in time with beats of the clock—although whether or not a transition occurs on a given beat is determined by the feedback mechanism or random noise source. The binary output has a $(\sin x/x)^2$ shaped spectrum and the Gaussian output, which is derived from the binary signal by precision low-pass filtering, has an almost rectangular spectrum. Both binary and Gaussian outputs are controllable in bandwidth, but the output power remains constant regardless of selected bandwidth—a particularly useful feature, of importance in applications where usable noise power must be made available in a very restricted frequency band. Frequency of the first null in the binary spectrum is selectable from 0.003 Hz to 1 MHz, and the bandwidth (at −3 dB point) of the Gaussian noise is selectable from 0.00015 Hz to 50 kHz.

Outputs from the Model 3722A are available at fixed amplitudes of ±10 V (binary) and 3.16 V rms (Gaussian), and a precision amplitude control provides a variable output of either signal ranging from 0.1 V rms up to the level of the fixed outputs.



3722A

Specifications

Binary output (fixed amplitude)

Amplitude: ±10 V.

Output impedance: <10Ω.

Load impedance: 1 kΩ minimum.

Rise time: <100 ns.

Power density: approximately equal to (clock period x 200) V^2/Hz, at low frequency end of spectrum.

Power spectrum: $(\sin x/x)^2$ form: first null occurs at clock frequency and −3 dB point occurs at 0.45 x clock frequency.

Gaussian output (fixed amplitude)

Amplitude: 3.16 V rms.

Output impedance: <1Ω.

Load impedance: 600Ω minimum.

Zero drift: <5 mV change in zero level in any 10°C range from 0° to +55°C.

Power density: approximately equal to (clock period x 200) V^2/Hz at low frequency end of spectrum.

Power spectrum: rectangular, low pass: nominal upper frequency f_0 (−3 dB point) equal to 1/20th of clock frequency. Spectrum is flat within ±0.3 dB up to $\frac{1}{2}f_0$, and more than 25 dB down at $2f_0$.

Crest factor: up to 3.75, dependent on sequence length.

Variable output (Binary or Gaussian)

Amplitude (open circuit)

Binary: 4 ranges: ±1 V, ±3 V, ±3.16 V and ±10 V, with ten steps in each range, from x 0.1 to x 1.0.

Gaussian: 3 ranges: 1 V rms, 3 V rms, and 3.16 V rms, with ten steps in each range, from x 0.1 to x 1.0.

Output impedance: 600Ω ±1%.

Main controls

Sequence length switch: first 17 positions select different pseudo-random sequence lengths: final position selects random mode of operation (INFINITE sequence length). Sequence length (N) is number of clock periods in sequence: possible values of N are 15, 31, 63, 127, 255, 511, 1023, 2047, 4095, 8191, 16383, 32767, 65535, 131071, 262143, 524287, 1048575. $N = 2^n - 1$, where n is in the range 4 to 20 inclusive.

Clock period switch: selects 18 frequencies from internal clock:

Clock period	Clock frequency	Gaussian noise bandwidth
333 s	0.003 Hz	0.0015 Hz
100 s	0.01 Hz	0.0005 Hz
33.3 s	0.03 Hz	0.0015 Hz
10 s ↓ 3.33 μs	0.1 Hz ↓ 300 kHz	0.005 Hz ↓ 15 kHz
1 μs	1 MHz	50 kHz

Internal clock

Crystal frequency: 3 MHz nominal.

Frequency stability: $< \pm 25$ ppm over ambient temperature range 0° to +55°C.

Output: +12.5 V rectangular wave, period as selected by CLOCK PERIOD switch.

External clock

Input frequency: usable BINARY output (pseudo-random only) with external clock frequencies up to 1.5 MHz.

Input level: negative-going signal from +5 V to +3 V initiates clock pulse.

Maximum input: ±20 V.

Secondary outputs

Sync: negative-going pulse (+12 V to +1.5 V) occurring once per pseudo-random sequence; duration of pulse equal to selected clock period.

Gate: gate signal indicates start and completion of selected number of pseudo-random sequences (1, 2, 4 or 8, selected by front panel control). Two outputs are provided:—

1. Logic signal: output normally +12.5 V, falls to +1 V at start of gate interval and returns to +12.5 V at end of interval.
2. Relay changeover contacts: gate relay switching is synchronous with logic signal.

Binary relay: relay changeover contacts operate in sync with binary output signal.

Remote control

Control inputs: remote control inputs for RUN, HOLD, RESET and GATE RESET functions are connected to 36-way receptacle on rear panel.

Sequence length indication: 18 pins plus one common pin on the 36-way receptacle are used for remote signalling of selected sequence length (contact closure between common pin and any one of the 18 pins).

General

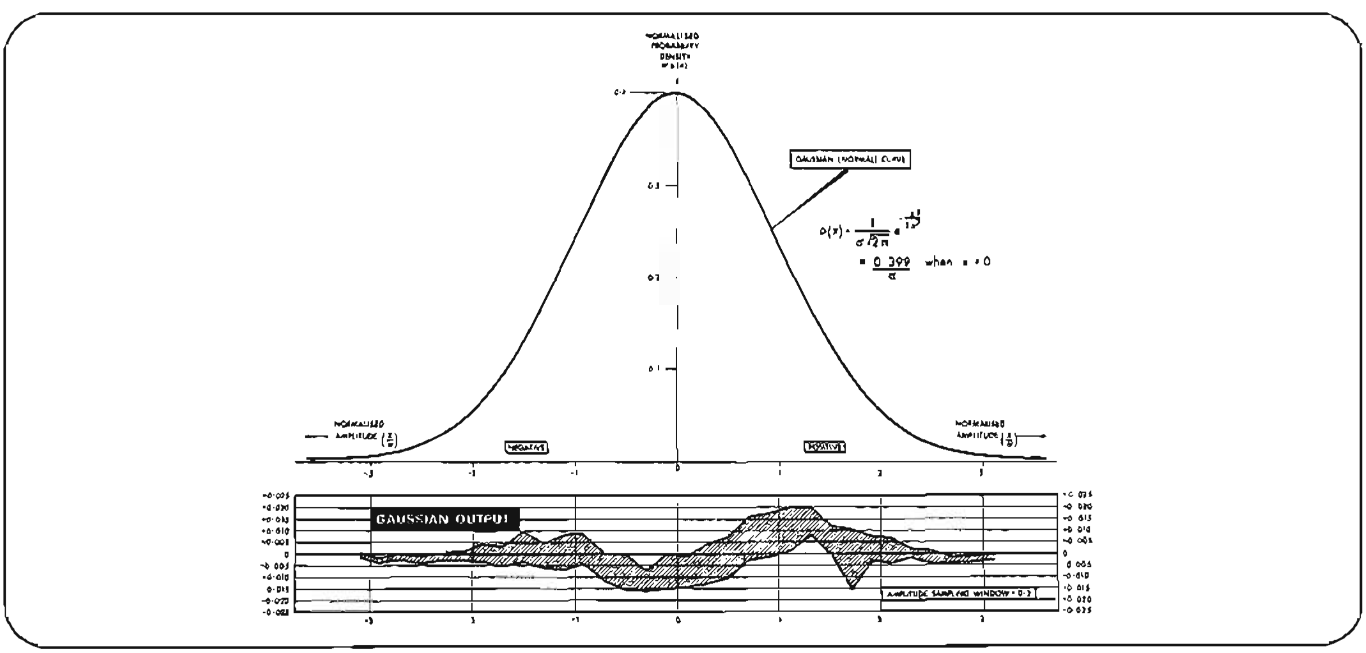
Dimensions: 16¾" wide, 5-7/32" high, 16⅜" deep (425 x 132.6 x 416 mm).

Weight: net 23 lbs (10,5 kg); shipping 30 lbs (13,5 kg).

Price: Model 3722A, $2,650 ($2,400 at factory in Scotland).

Option 01

Zero moment option: shifts relative position of sync pulse and pseudo-random binary sequence such that first time moment of sequence, taken with respect to sync pulse, is zero (sequence shift mechanism is operative only when selected sequence length is ≤1023): option 01 also provides facility for inverting binary output signal. ADD $50 ($45 at factory in Scotland).

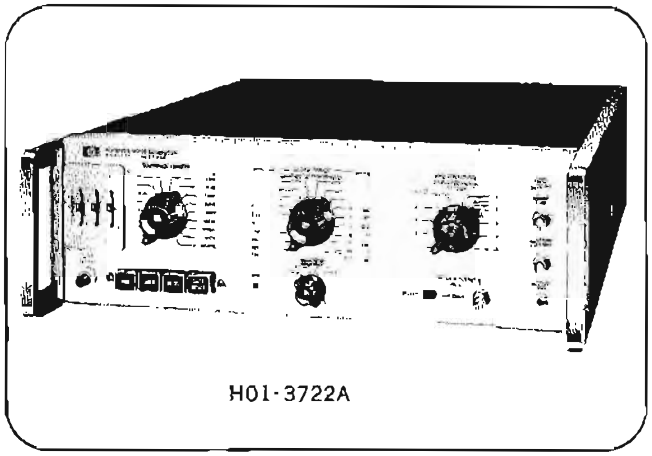


Envelope (shaded area) shows measured departures from the normal curve of 3722A Gaussian output p.d.f.'s for sequence lengths of 8,191 and greater.

NOISE GENERATOR
For cross-correlation experiments
Model H01-3722A

Hewlett-Packard Model H01-3722A, with only an integrator as additional equipment, provides all the facilities required for measurements of point-by-point correlation. Specification H01-3722A is a standard Model 3722A Noise Generator modified to provide a second binary output which can be delayed by a selectable number of clock periods with respect to the main binary output. The delayed binary output is available only when the instrument is in the pseudo-random mode, that is, generating repeated noise patterns.

The delay introduced between the two binary outputs is selected by three decade switches on the front panel. These switches, which are set according to a conversion table supplied with the instrument, provide almost all possible delays ranging from zero to the number of bits (N) in the sequence in use.



H01-3722A

Delayed binary output

Typical performance figures for the delayed output are:—

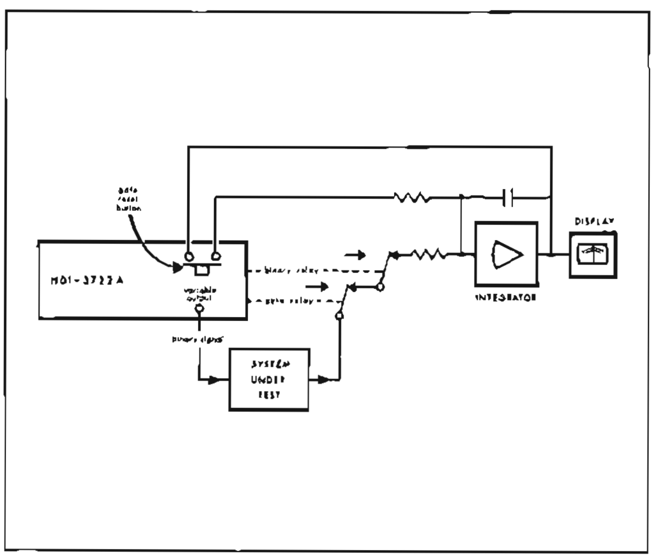
Amplitude: switches between +1.5 V and +12 V.

Maximum sink current at 1.5 V level: 10 mA.

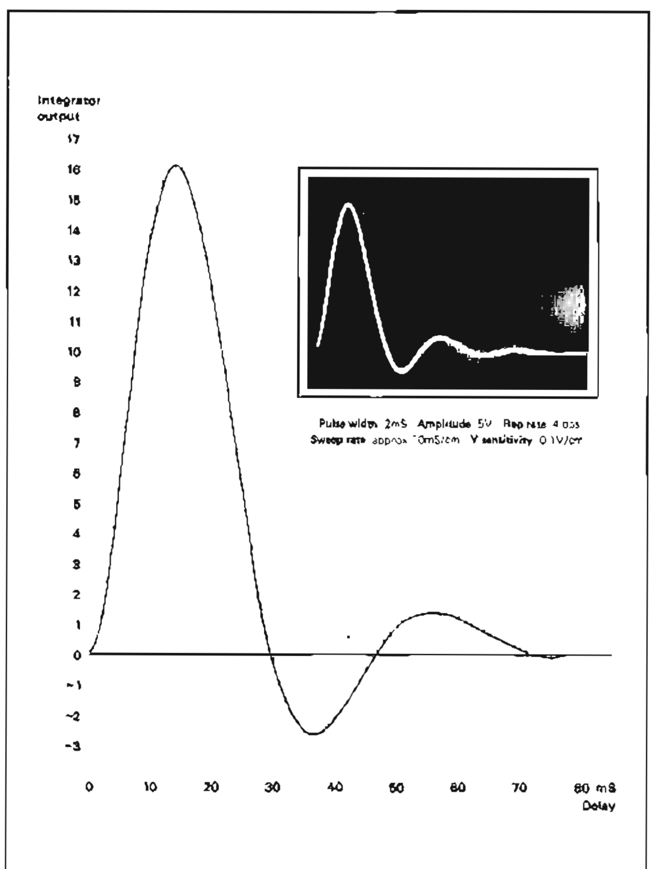
Rise time: <200 ns.

Fall time: <100 ns.

Price: Model H01-3722A, $2,950. ($2,620 at factory in Scotland).



Typical set-up for cross-correlation with the H01-3722A. Here, the main binary output is applied to the system under test, and the output from the system is multiplied by the delayed binary signal (the binary relay is controlled by the delayed signal: relay contact closed is equivalent to multiplication by 1, and contact open is equivalent to multiplication by zero). Integration time is controlled by the gate relay, which closes for a pre-selected number of noise patterns. This set-up is suitable only for systems having long time constants (greater than 1 second). For systems with short time constants, electronic switches must be substituted for the relays.



Impulse response of LC filter measured using H01-3722A. Photo inset shows filter's response to a 2 mS pulse.

This section contains technical information for function generators and oscillators, covering frequencies from 0.00005 Hz to 32 MHz. Table 1 illustrates the frequency range and power output of Hewlett-Packard oscillators and function generators. The following explanations are divided into two parts. First will be the lower frequency multi-output function generators and the next the higher frequency sine-wave oscillators.

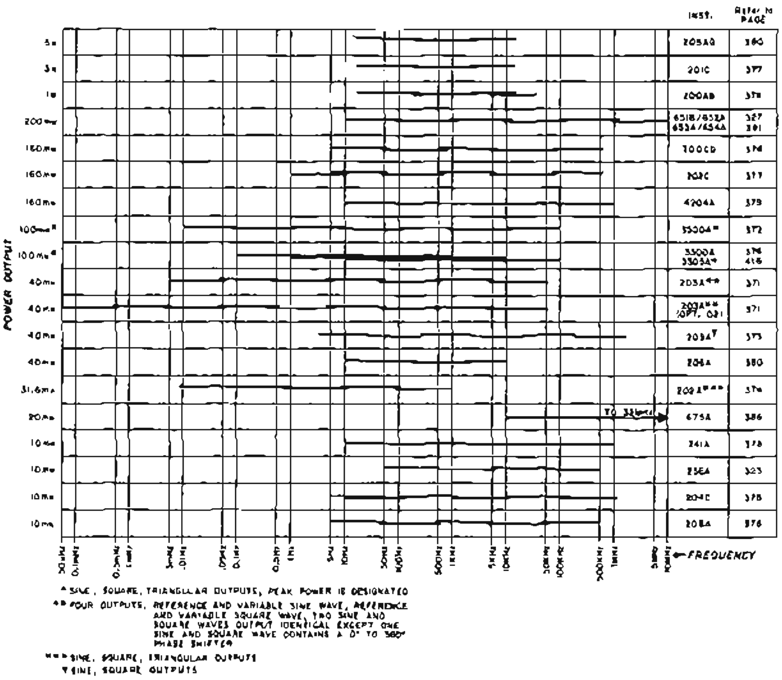


Table 1. Frequency range and power output of HP oscillators. Line segments show span of each range.

FUNCTION GENERATORS

A function generator is a signal generator that delivers a choice of different waveforms with frequencies adjustable over a wide range. The keynote of the modern function generator is versatility. The function generators now produce sine, triangle, square-wave, sawtooth waves and variable aspect ratio pulses with a provision to sweep or analog program frequency up to four decades. This is useful for automatic testing systems and sweeping audio amplifiers, filters and servo systems.

HP's function generators extend from a low frequency of 0.00005 Hz (HP 203A Option 02) up to a high frequency in the MHz range.

A modern innovation is the plug-in function generator. One may use a single main frame and several plug-ins to achieve maximum versatility at a minimum cost. Function generators now have several outputs available at the same time, each having a choice of wave shapes. By providing a square wave and a triangle wave at the same time, linearity measurements and gating may be achieved simultaneously.

Function generators that provide single or multiple-cycle outputs have simplified many measurements. A theoretically infinite on-off ratio can now be attained in pulse burst operation. To vary the starting phase of a single cycle or pulse burst and end at the same phase is also valuable for underwater research and other applications.

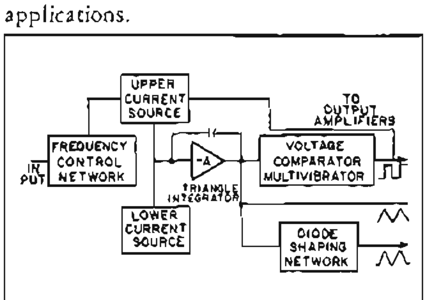


Figure 1. 3300A Function Generator.

The capability of the function generator to phase lock to an external source opens new possibilities for making audio measurements. By using two function generators, an adjustable phase sine output or a square or triangle wave output with adjustable delay may be obtained. In addition, one function generator may be phase locked to a harmonic of the sine wave of another; and almost any waveform desired may be obtained by summing the harmonics and fundamental, and adjusting the phase and amplitude of the harmonics. One can also phase lock the function generator to a frequency standard and generate all wave shapes with the frequency, accuracy and stability of the stable source.

Besides the many uses mentioned, the function generator is being used extensively in medical research projects for nerve stimulation and electroanesthesia. As medical electronic research continues to grow, the function generator will find more and more applications in this field.

HP 3300A

Since the low frequency of an RC oscillator is limited, an entirely different approach is used in the 3300A Function Generator.

The main frame of this instrument delivers sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz. The circuit outlined in Figure 1 uses a frequency control network governed internally by the frequency dial or externally through the rear-panel, frequency-control terminal.

The frequency-control voltage regulates the current sources driving the triangle generator. An increase or decrease in current increases or decreases the slope of the triangular wave. Frequency will increase if the + and − slopes are increased. The voltage comparator multivibrator changes state at predetermined limits on the positive and negative slopes of the triangular integrator's output. This change of state reverses the current into the triangular integrator, reversing the slope of the triangular output.

The circuit produces low-frequency square and triangular waves. The triangular wave is synthesized into a sine wave by a diode resistive network. The synthesizing circuitry alters the slope of the triangular wave as its amplitude changes, resulting in a sine wave with less than 1% distortion.

The entire oscillator circuitry is floating. The ground may be established at any desired voltage level. A special feature of this oscillator is that waveform amplitude is controlled by the reference voltages, rather than by a long-time-constant AGC circuit. As a result, there are no transients when switching between ranges or tuning to other frequencies. Another feature of the HP 3300A is two output amplifiers that provide simultaneous, individually selected outputs of any of the waveform functions.

3300A Plug-ins

The 3300A is made more versatile by the use of plug-ins (the 3300A must have a plug-in to operate). The HP Model 3301A Auxiliary Plug-in, 3302A Trigger/Phase Lock Plug-in, the 3304A Sweep/Offset Plug-in and the 3305A Sweep Plug-in are now available. The HP 3301A Auxiliary Plug-in provides internal connections for the basic operation of the unit, as described in the specifications for the 3300A Function Generator.

The HP Model 3302A Trigger/Phase Lock Plug-in enables the Model 3300A Function Generator to produce either a single cycle or a burst of cycles of any of the output waveforms in response to an input trigger. The waveform bursts may also be frequency modulated.

The plug-in employs two basic operating principles. In the "Trigger" mode, it suppresses waveform generation in the main frame circuits, thus restricting the generator output to a single waveform cycle or burst of cycles. In the "Phase-Lock" mode, it contributes a correction voltage to the Function Generator frequency-control circuits, phase-locking the output frequency to an external frequency source.

A front-panel meter indicates when phase lock is achieved. The phase relationship between the input and output signals can be adjusted by the front panel PHASE control over a range of 0° to 180° (180° to 360° by using the inverted output or by reversing the input polarity switch). The phase multivibrator acts as a detector (see Figure 2) which is set by the input signal and reset by the main frame square wave. These pulses are filtered to derive a dc control voltage.

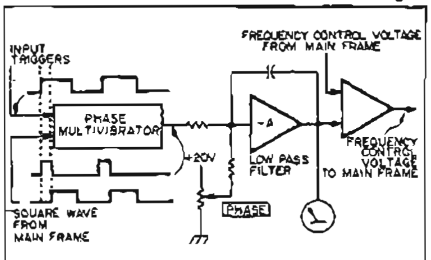


Figure 2. Block diagram of 3302A plug-in phase lock mode.

Thus, the 3300A frequency is continuously locked to the input. The 3300A may be locked to a harmonic of the input signal.

When the MODE switch is set to "Free Run", the plug-in circuits are disabled and the function generator operates in its basic manner. With the MODE switch set to either "Single" or "Multiple", the plug-in circuits stop the generation of waveforms by clamping the output of the triangle integrator to its input at a selected phase (see Figure 3). The waveform generating circuits are released by pressing the MANUAL TRIGGER button on the plug-in or by applying a trigger pulse or gate to the plug-in input. The point in the waveform at which waveform generation starts and stops is determined by the START/STOP-PHASE control, which can be adjusted over a range of −90° to +90° of the waveform.

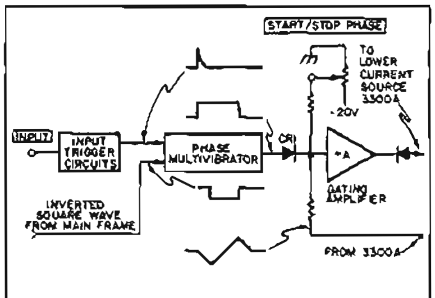


Figure 3. Block diagram of 3302A plug-in shown in single and multiple modes.

The HP 3304A Sweep/Offset Plug-in provides internal sweeping up to a decade of frequency. It generates a sawtooth waveform and delivers it to either of the 3300A output terminals, and it also provides an offset square wave and a dc offset for all of the signals generated by the 3300A and 3304A.

For the sawtooth mode of operation, the 3304A uses a sawtooth generator, a RANGE switch, a FREQUENCY control and a ± SAWTOOTH selector switch (see photo page 373).

For the internal sweeping of the 3300A output functions, the 3304A uses the negative sawtooth output. The start frequency is set by the 3300A FREQUENCY dial and RANGE selector (it may be by remote control). The circuitry of the 3304A adds the start frequency control voltage and the negative sawtooth ramp. The negative voltage swing of the ramp is controlled by the 3304A SWEEP WIDTH control. The rate of the sweep is controlled by the 3304A sawtooth frequency.

For the dc offset which is applied to all output functions of the 3300A, the 3304A applies a dc voltage between output ground and circuit ground. This dc offset voltage is controlled by a front-panel + and − switch and by a fine and coarse adjustment.

The 3305A is a Sweep Plug-in for the 3300A main frame which sweeps frequencies from 0.1 Hz to 100 kHz in three overlapping ranges (each range covers four-decades of frequency: 0.1 Hz to 1 kHz, 1 Hz to 10 kHz and 10 Hz to 100 kHz). Here, a low-frequency logarithmic sweeper can be obtained merely by purchasing another plug-in for the 3300A Function Generator.

The 3305A Sweep Plug-in is basically a controlled-current generator for the 3300A main frame. It provides automatic sweep, manual sweep, triggered sweep and it may be programmed by an external analog voltage.

The start and stop frequencies can be independently adjusted to any point on any range. The sweep of the preset frequencies allows logarithmic frequency plots to be made and a good approximation to a linear sweep can be obtained when the sweep width is small. A linear sawtooth output is available for the X-axis of oscilloscopes or X-Y recorders. After the X-axis of the recorder is set up, the sweep width, the start position, the range and the sweep time can be changed without necessitating re-adjustment of the horizontal sweep. This Sweep Plug-in also includes signal blanking and pen lift during retrace.

Any of the 3300A outputs: sine, square or triangular, can be swept logarithmically over four decades at either channel A or channel B of the 3300A main frame.

For additional information on this 3305A Sweep Plug-in, refer to the Sweep Generator technical information, page 411, and the product pages 374 and 416.

Because of its versatility, the HP 3300A with its various plug-ins may be used for all of the applications listed in the first few paragraphs of this section.

HP 203A

Another HP function generator is the 203A Variable Phase Function Generator. This instrument has a sine wave and square wave output with a second channel that can be phase-shifted continuously through a full 360° range.

Although this function generator is intended primarily for low-frequency work, it has a frequency range extending from 60 kHz down to 0.005 Hz or, with options, down to as low as 0.00005 Hz (5 hours for 1 cycle). All four output signals are supplied simultaneously and all have individual 40 dB attenuators.

For a stable, low-distortion sine wave source, the 203A is ideal, for it has less than 0.06% combined harmonic distortion, hum and noise at full output.

HP 209A

A modification to the Wien bridge oscillator is the 209A Sine-Square Wave Oscillator. Stable, accurate signals which can be synchronized with an external source are instantly available over a frequency range of 4 Hz to 2 MHz. The amplitude of the sine and square wave outputs are separately adjustable and are available simultaneously. Distortion and flatness can be improved at low frequencies by a low distortion mode switch.

The block diagram in Figure 4 shows the basic construction of the sine-square oscillator. The Wien bridge oscillator requires a loop gain of unity in order to oscillate. This requirement is met by positive and negative feedback circuits. The amplitude of the output is held constant by a peak comparator and an automatic gain control (AGC), as explained in the 204C operation page 369.

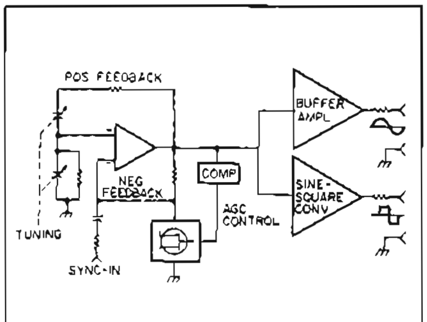


Figure 4. Block diagram of 209A Sine and Square Wave Oscillator.

The sine wave output from the oscillator circuit is amplified by the buffer amplifier and fed to the output terminals. The amplifier has a high open loop gain that is controlled by the negative feedback to provide a gain of 2. This enables the circuit to have very low distortion characteristics. The output is fed through a complementary symmetry transistor pair similar to the oscillator amplifier output.

The sine wave output from the oscillator circuit is also applied to the sine-square converter. The sine wave is fed to a tunnel diode which produces a small square wave output with fast rise and fall times. This small square wave signal is then shaped and amplified. It appears at the output as a 20 volt peak-to-peak square wave.

OSCILLATORS

Signal sources have been described by various names—oscillators, test oscillators, audio signal generators, etc. Different names are applied, depending on the design and intended use of the source. The oscillator is basic to all the sources and generates sine-wave signals of known frequency and amplitude. In the recently developed transistorized sources, the name "test oscillator" has been used to describe an oscillator having a calibrated attenuator and output monitor. The term "signal generator" is reserved for an oscillator with modulation capability.

Basic oscillator requirements

In selecting an oscillator, the user will be most interested in its frequency coverage. The question to be answered here is, "Will the instrument supply both the lowest and highest frequencies of interest for anticipated tests?" As shown in Table 1, page 366, Hewlett-Packard manufactures a broad range of oscillators and function generators covering the frequency spectrum from 0.00005 Hz to 32 MHz.

The user's next concern will be with the available output power or voltage. Some tests require large amounts of power, while others merely require sufficient voltage output. For almost any application, there is a Hewlett-Packard oscillator capable of delivering the desired voltage output into a high-impedance load or of supplying the desired power into lower-impedance loads.

Some Hewlett-Packard oscillators have a low internal impedance. This low impedance can easily be converted to a desired output impedance with a resistive network. This assures a constant impedance over a wide frequency range. In most HP oscillators, transformer coupling is used to provide a balanced and isolated output. Some instruments have transformer taps for supplying the wide variety of impedances encountered in normal test work. Since many audio-range oscillators are used with 600-ohm systems, several include 600-ohm adjustable attenuators on the output.

Besides frequency range and power output, the user will be interested in the oscillator's stability, its dial resolution and the amount of harmonic distortion, hum and noise in the output signal.

Dial resolution and accuracy

In the ideal case, the user should be able to set the tuning dial of his oscillator to a particular frequency with assurance that the oscillator will deliver that frequency at all times. Most Hewlett-Packard oscillators have dial accuracies of ±2%. The dials may be precisely set by a vernier control, and the calibration marks are easily read. The accuracy with which the frequency tracks the tuning dial enters into the overall accuracy figure.

Frequency stability

The frequency stability of the oscillator determines the ability of the instrument to maintain a selected frequency over a period of time. Component aging, power-supply variations and temperature changes all affect stability. The Hewlett-Packard designed RC oscillator circuits, described later, assure stability by using large amounts of negative feedback. Carefully chosen components, such as precision resistors and variable capacitors in the frequency-determining networks, contribute to long-term stability. Oscillator stability is included in the overall 2% dial accuracy figure.

Amplitude stability

Amplitude stability is important in certain oscillator applications. Amplitude stability is inherent in the Hewlett-Packard RC oscillator circuit because of the large negative feedback factor and the amplitude stabilizing techniques. The "frequency response," or amplitude variation as the frequency is changed, is of special interest when the oscillator is used for response measurements throughout a wide range of frequencies.

Distortion

Distortion in the oscillator's output signal is an inverse measure of the purity of the oscillator's waveform. Distortion is undesirable in that a harmonic of the test signal may feed through the circuits under test, generating a false indication at the output. If the oscillator is used for distortion measurements, the amount of distortion that it contributes to the measurements should be far less than that contributed by the circuits under test.

The Hewlett-Packard Wien bridge RC oscillator is a low-distortion, sine-wave generator; all Hewlett-Packard Wien bridge oscillators have less than 1% distortion (typically 0.25%). Where 0.25% distortion may be too large, a selective amplifier following the oscillator will reduce this to less than 0.1%. A tuned, selective amplifier is used in the HP 206A Low-Distortion, Audio-Signal Generator for this purpose. The 203A Function Generator, 204C and 209A Oscillators are ideal sources with low distortion and wide frequency coverage. See pages 371 and 375.

Hum and noise

Hum and noise can be introduced at a variety of points in oscillator circuits; but when the circuit operates at a relatively high level, the amount of hum and noise introduced into the device under test is usually negligible. Hum and noise introduced by a power amplifier usually remain constant as the output signal amplitude is diminished. Hence, even though the hum and noise power may be quite small compared to the rated output, these spurious signals sometimes become a significant portion of low-level output signals. To overcome such a limitation, many Hewlett-Packard oscillators have their amplitude control on the output side of the power amplifier so that hum and noise are reduced proportionally with the signal when low-level signals are desired for test purposes.

Synchronization

Recent Hewlett - Packard oscillators have incorporated capabilities to synchronize the oscillator with an external signal (refer to Figures 4 and 7).

At the frequency setting of the Wien bridge oscillator, the closed loop gain is theoretically infinite. An applied sync voltage will be amplified and sent to the AGC circuit. This increase in AGC voltage will disable the oscillator. Now the oscillator becomes a highly selective amplifier at the tuned frequency of the oscillator. The AGC circuit maintains a constant voltage to the output attenuator, and because of the high selectivity of the amplifier, the output will be a clean sine wave at the sync frequency. This synchronization of the sine wave oscillator output to an external signal is possible even with a square wave sync signal input.

Theory of operation

The Wien bridge RC oscillator has become the standard oscillator circuit for adjustable frequency test signals. These oscillators are far less cumbersome than the LC types and far more stable than the beat-frequency types formerly used for the below-rf range.

The basic Hewlett-Packard Wien bridge oscillator circuit, shown in Figure 5, is a two-stage amplifier with both negative and positive feedback loops. Positive feedback for sustaining oscillations is applied through the frequency selective network, R_1C_1-R_2C_2, of the Wien bridge.

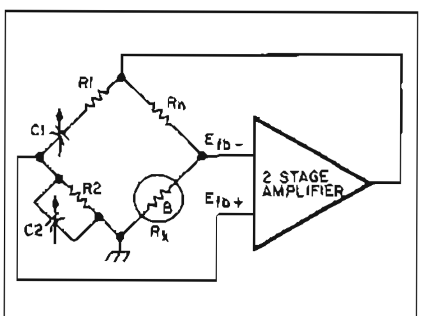


Figure 5. Basic HP Wien bridge RC oscillator circuit.

The amplitude and phase characteristics of the network, with respect to its driving voltage, are shown in Figure 6. These curves show the amplitude response is maximum at the same frequency at which the phase shift through the network is zero. Oscillations are therefore sustained at this frequency. The resonant frequency, f_0, is expressed by the equation:

$$f_0 = \frac{1}{2\pi RC}, \text{ when } R_1 = R_2 \text{ and } C_1 = C_2.$$

Unlike LC circuits, where the frequency varies inversely with the square root of C, the frequency of the Wien bridge oscillator varies inversely with C. Thus,

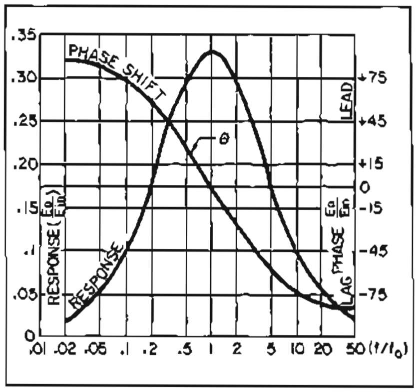


Figure 6. Characteristics of frequency-determining network.

frequency variation greater than 10-to-1 is possible with a single sweep of an air-dielectric tuning capacitor. Range switching usually is accomplished by switching the resistors.

The negative feedback loop involves the other pair of bridge arms, R_n and R_k. In a Wien bridge RC oscillator, R_k is often a temperature-sensitive resistor with a positive temperature coefficient. It is an incandescent lamp operated at a temperature level lower than its illumination level. This lamp, being sensitive to the amplitude of the driving signals, adjusts the voltage division ratio of the branch accordingly. Thus, as the amplitude of oscillations increases, the resistance of R_k increases. The negative feedback also increases, reducing the gain of the amplifier and restoring the amplitude to normal.

The amplitude of oscillations in any oscillator increases because of the positive feedback until some form of limiting occurs. The Hewlett-Packard Wien bridge RC oscillator depends on the temperature-sensitive resistor for amplitude control. Thus the amplifier may be operated entirely within the linear portion of its transfer characteristic, resulting in a low-distortion, sinusoidal output.

A different type of amplitude stabilization is used in the solid-state Hewlett-Packard RC oscillators, such as the 208A, 651B and the 652A. Because the current drawn by a lamp would be incompatible for use with transistors and battery power sources, these instruments use a peak-detector circuit which provides a bias voltage proportional to the oscillator output voltage.

Another variation of the solid state Wien bridge RC oscillator is used in the 204C shown in Figure 7. The oscillator with this type of amplitude stabilization will hold the amplitude constant (±1%) up to a frequency of 1.2 MHz.

As the amplitude of the amplifier changes, a peak comparator sends an error signal to the automatic gain control (AGC) which contains a field effect transistor. The purpose of the AGC is to continuously control the oscillator gain to maintain unity loop gain. The resistance of the AGC circuit can be varied slightly to change the divider ratio of the negative feedback network An error in output voltage is detected by the peak comparator and sent to the AGC field effect transistor. This changes the resistance ratio in the negative feedback loop, thus bringing the output back to a constant level. The Wien bridge RC oscillator is capable of stable oscillations with low distortion output. The 204C has less than 0.01% hum and noise with distortion of 0.1% from 30 Hz to 100 kHz.

With the addition of a power amplifier to isolate the oscillator from the load, this circuit is capable of providing useful test signals for a broad variety of purposes. The low-cost HP Model 200AB Oscillator uses such an arrangement.

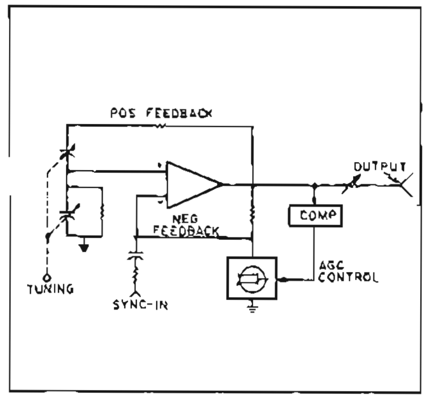


Figure 7. Block diagram of the 204C Oscillator.

Pushbutton tuning

Pushbutton oscillator tuning is possible with a modified Wien bridge. Here, the resistive branches of the frequency-selective network are made up of parallel combinations of resistors. The 241A Pushbutton Oscillator has three pushbutton, decade-switch selectors for changing the resistors in the frequency selective network. Each decade selects resistive value for one pair of resistors in the frequency-determining network.

Ranges are switched by changing capacitors with a five-position pushbutton switch. Total frequency range of the 241A Oscillator is from 10 Hz to 1 MHz in 4500 discrete steps. An overlapping vernier control permits setting to intermediate frequencies.

Pushbutton tuning enables the frequency to be changed by precise increments. Frequency selection to three-digit resolution with 1% accuracy and resettability to within 0.02% are possible.

Digital Oscillator

Another HP oscillator is the 4204A Digital Oscillator. This instrument has five switches enabling ±0.2% selection from any of 36,900 discrete frequencies between 10 Hz and 999.9 kHz. An overlapping vernier control permits setting of intermediate frequencies and extension of the top range to over 1 MHz. An output monitor allows accurate determination of output levels. This instrument provides the functions of an audio oscillator, ac voltmeter, and an electronic counter, in applications requiring an accurate frequency source of known amplitude. Refer to page 378 for complete specifications.

Balanced RC oscillator

A more refined circuit is the balanced vacuum tube Wien bridge RC oscillator used in the HP200CD and 202C. This circuit provides several advantages over the basic single-ended oscillator circuit.

The circuit has zero-output impedance because of the positive feedback from the plate of each output tube to the control and screen grids of the opposite output tube. Zero output impedance means that the circuit is insensitive to load changes. Positive feedback effectively increases the amplifier gain, A, to infinity. From the equation, $Z_o = Z_o/(1 + A\beta)$, where Z_o is the output impedance without feedback and β is the stabilizing negative feedback factor, it can be seen that the output impedance Z_o becomes zero if A is infinite. Series resistors are inserted in the output leads to present a 600-ohm impedance load and also to prevent short circuiting of the power tubes' cathodes.

In the balanced circuit, no dc passes through the lamp circuit; the lamp current is pure ac. This means that lamp heating occurs at twice the oscillating frequency, enabling the circuit to be operated down to half of the low-frequency limit of the single-ended oscillator. In addition, the capacitor-tuning rotors are near ground potential, reducing leakage effects in these capacitors and permitting larger resistors to be used in the RC circuits for low-frequency operation.

Broadband balanced Wien bridge oscillator

A more recent balanced, solid state test oscillator covering the frequency range of 10 Hz to 10 MHz is shown in Figure 8. The RC oscillator uses a different approach for level accuracy. The output of the RC capacitor tuned bridge oscillator is sent through a variable attenuation pad to a balanced differential amplifier. The output of this amplifier is +10 dBm at 0 on the meter. Level control over this wide frequency range is accomplished by controlling the intensity of a light shining on a photo cell. This controls the attenuation of the pad

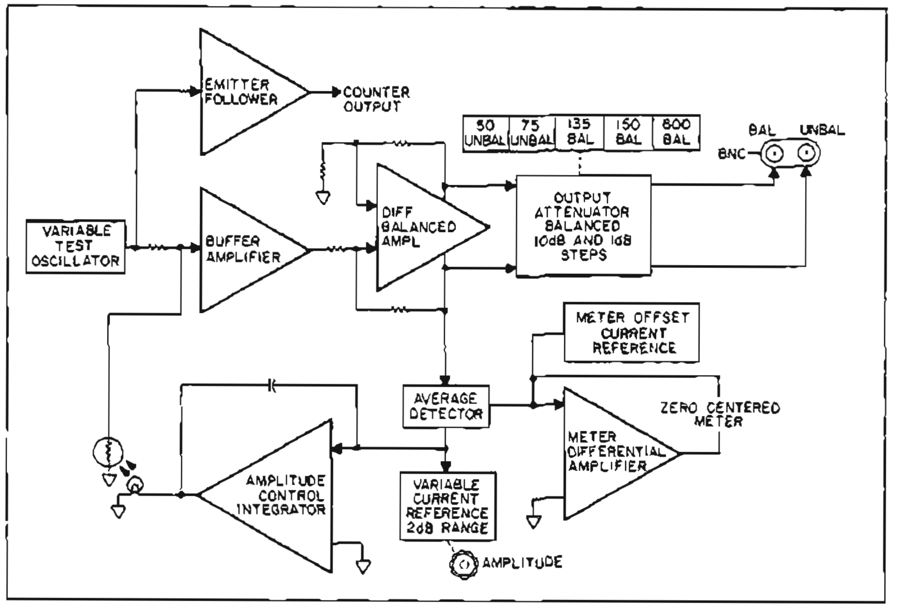


Figure 8. Block diagram of the balanced 654A Oscillator.

at the input of the balanced amplifier. The output of the differential balanced amplifier is average detected and compared against a reference current (set by front panel control) in the amplitude control integrator. This integrator controls the intensity of the lamp, hence the resistance of the photo cell. The input to the balanced attenuator is kept constant as the frequency is changed. A special common mode feedback loop assures excellent balance in the output over the full frequency range. The output attenuator is balanced in 10 dB and 1 dB steps. The impedance switch connects different resistors to the output connectors for 50 and 75 ohms unbalanced and 135, 150 and 600 ohms balanced outputs.

The meter is 0 centered and reads in dBm for the various impedances. An offset current source and a meter differential amplifier set the meter pointer at center deflection for a +10 dBm input to the attenuator. A change of ±1 dB gives full meter deflection with a resolution of 0.02 dB. The maximum output of +11 dBm at each of the output impedances can be attenuated in 10 dB and 1 dB steps. Refer to page 327 for the communications version of this oscillator.

High-frequency oscillators

The high-frequency limit of the RC oscillator is imposed by the amplitude and phase characteristics of the oscillator-amplifier. An amplifier phase shift of just a fraction of a degree causes 1% error in calibration. A modified Wien bridge oscillator is used on all the ranges of the HP 650 series oscillators, instead of phase-shift oscillators which are commonly used above 100 kHz. This is made possible through the use of a wideband, transistorized oscillator-amplifier with the phase shift controlled several octaves past the oscillator's upper 10-MHz limit. An impedance converter provides a high impedance in series with the input of a differential amplifier on the first four frequency ranges (X10 to X10 k). The added high impedance prevents the RC bridge circuit from being loaded by the low input impedance of the differential amplifier on lower frequency ranges. A complementary symmetry circuit is used to provide power gain and to increase the dynamic voltage range of the oscillator. A typical output circuit of a Hewlett-Packard solid-state 10 Hz to 10 MHz oscillator is shown in Figure 9.

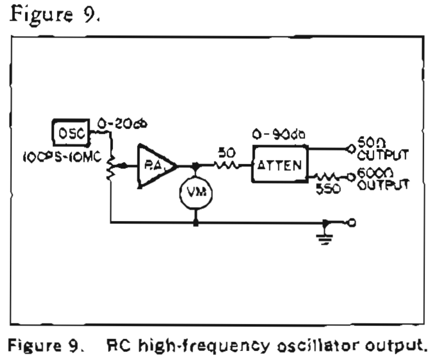


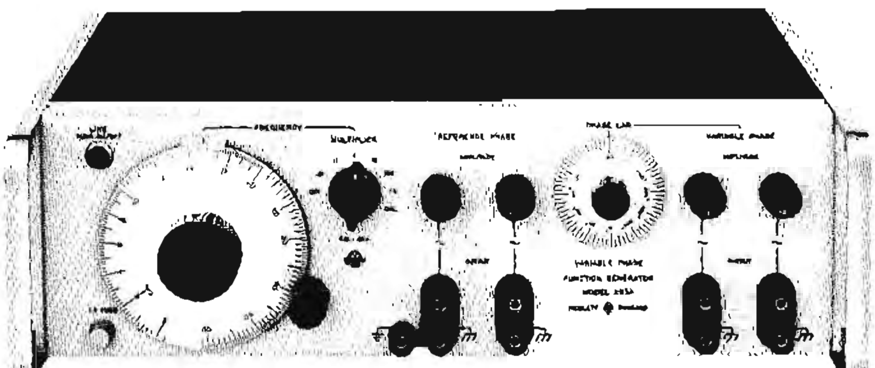
Figure 9. RC high-frequency oscillator output.

The oscillator circuits described here are used in Hewlett-Packard's broad line of signal sources. These signal sources span a frequency range of 0.00005 Hz to 32 MHz, encompassing the subsonic, audio, ultrasonic, video and rf ranges. All of the Hewlett-Packard oscillators and test oscillators described in this catalog have been designed with the requirements of a maximum number of applications in mind. The various techniques were chosen in order to maximize the performance offered while minimizing the cost so that a Hewlett-Packard oscillator is available to meet your application.

VARIABLE-PHASE GENERATOR

Sine- and square-waves 0.00005 Hz to 60 kHz

Model 203A



203A

The solid-state HP Model 203A Low-Frequency Function Generator provides two transient-free low-distortion square and sinusoidal test signals particularly useful for a wide variety of low-frequency applications. Field and laboratory testing of servo, geophysical, medical and high-quality audio equipment become practical when using the 203A.

The 203A frequency range of 0.005 Hz to 60 kHz is covered in 7 overlapping bands (2 additional ranges available on special order, offering frequency range to 0.00005 Hz). Accurate ±1% frequency setting is provided by 180 dial divisions. A vernier drive allows precise adjustment.

30 volt output

The 203A provides a maximum output voltage of 30 V peak-to-peak for all waveforms. The sinusoidal signals have a distortion that is less than 0.06% and provide virtually transient-free outputs when frequency and operating conditions are varied rapidly. The four output circuits of the 203A have individual 40 dB continuously variable attenuators.

Outputs consist of a reference sine and square wave, and a variable-phase sine and square wave. The two sine- and square-wave outputs are electrically identical except that one sine- and square-wave output contains a 0-to-360 degree phase-shifter. These four signals (two reference phase and two variable phase) are available simultaneously from the 203A. The output system is floating with respect to ground and may be used to supply an output voltage that is terminal grounded, or may be floated up to 500 volts dc above chassis ground. The output impedance is 600 ohms for all outputs.

Special features

A front-panel calibration provision permits the user to easily calibrate the oscillator frequency to the environment in which the instrument is used. The HP 203A features a unique method of mixing, filtering and dividing the frequency to maintain an exact decade relationship. Interchangeable decade modules provide greater reliability and ease of servicing.

Specifications, 203A

Frequency range: 0.005 Hz to 60 kHz in seven decade ranges.*

Dial accuracy: ±1% of reading.

Frequence stability: within ±1% including warmup drift and line voltage variations of ±10%.

Output waveforms: sine and square waves are available simultaneously; all outputs have common chassis terminal.

Reference phase: sine wave, 0 to 30 V peak-to-peak; square wave, 0 to 30 V peak-to-peak (open circuit).

Variable phase: sine wave, 0 to 30 V peak-to-peak; square wave, 0 to 30 V peak-to-peak; continuously variable, 0 to 360°; phase dial accuracy, ±5° sine wave, ±10° square wave (open circuit).

Output impedance: 600 ohms.

Output power: 5 volts into 600 ohms (40 mW); 40 dB continuously variable attenuation on all outputs.

Distortion: total harmonic distortion hum and noise >64 dB below fundamental (<0.06%) at full output.

Output system: direct-coupled output is isolated from ground and may be operated floating up to 500 V dc.

Frequency response: ±1% referenced to 1 kHz.

Square wave response: rise and fall time, <200 ns; overshoot, <5% at full output.

Power: 115 or 230 volts ±10%, 50 to 1000 Hz, approximately 25 W.

Dimensions: cabinet: 5¼" high, 16¾" wide, 11½" deep (133 x 425 x 286 mm); rack mount kit(00203-84401) furnished with instrument.

Weight: net 20 lbs (9,17 kg); shipping 28 lbs (12,6 kg).

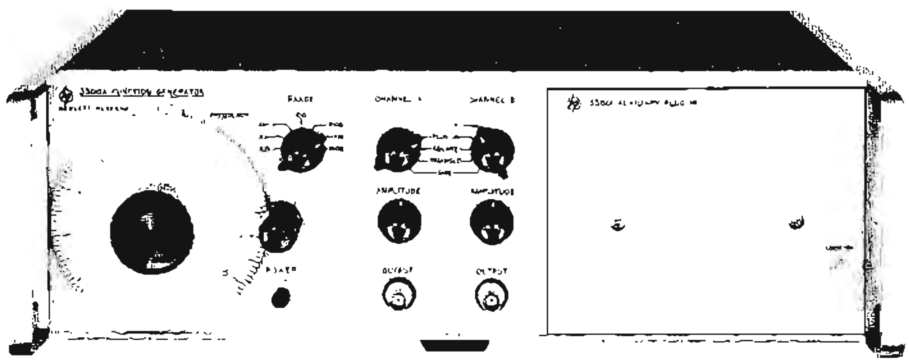
Price: HP 203A, $1250; Option 01 (0.0005 Hz range), add $50; Option 02 (0.00005 Hz range), add $150.

*Two lower ranges of 0.0005 Hz (Option 01) and 0.00005 Hz (Option 02) are available on special order.
Manufactured by Yokogawa-Hewlett-Packard Ltd., Tokyo.

FUNCTION GENERATOR

Plug-ins, multiple outputs, versatility

Model 3300A & 3301A plug-in



3300A/3301A

Description

Plug-ins and multiple outputs set the HP 3300A Function Generator apart from other function generators. Any two of three waveforms—sine, square or triangular—may be selected by a front-panel switch over the frequency range from 0.01 Hz to 100 kHz, continuously adjustable in seven decade ranges. This solid-state, multi-purpose source provides simultaneous signals of any two waveforms over the entire frequency range with independent variable amplitudes.

Plug-ins, which insert directly into the front panel, include the HP 3301A Auxiliary Plug-in to provide internal connections for basic unit operation. The 3302A plug-in provides single and multiple-cycle operation with adjustable start-stop phase. A phase-lock loop in the 3302A permits synchronizing the 3300A with an external signal and gives adjustable phase control. The HP 3304A Sweep/Offset Plug-in provides internal sweeping, dc offset, sawtooth waves and offset square waves. The 3305A Sweeper Plug-in supplies internal log sweep and manual sweep over four decades with calibrated variable start-stop frequency control within four decades. Sweep width is continuously-adjustable. It has manual or external triggering. Sweep can be analog-programmed, with horizontal sweep available for driving scopes or recorders.

The frequency of the HP 3300A can be controlled by either the front-panel frequency dial or an external voltage applied to a rear-terminal connector. This feature is useful for sweeping filters, amplifiers and other frequency-dependent devices and for externally programming frequencies for production testing.

The output system of the HP 3300A is dc coupled and fully floating with respect to power-line ground. An internal shield reduces radiated interference and provides common-mode rejection with floating output. It can be used to supply a balanced output, using both output amplifiers. Each output amplifier will deliver 35 V p-p into an open circuit.

Specifications

Output waveforms: sinusoidal, square and triangular selected by panel switch (any two outputs available simultaneously).

Frequency range: 0.01 Hz to 100 kHz in 7 decade ranges.

Frequency response: ±1%, 0.01 Hz to 10 kHz; ±3%, 10 kHz to 100 kHz on the X10 k range.

Dial accuracy: ±1% of maximum dial setting (1 minor division), 0.01 Hz to 10 kHz at +25°C; ±2% of maximum dial setting, (2 minor divisions), 10 kHz to 100 kHz on the X10 k range.

Maximum output per channel: >35 V p-p open circuit; >15 V p-p into 600Ω; >2 V p-p into 50Ω.

Output attenuators (both channels): 40 dB range.

Sine-wave distortion: <1%, 0.01 Hz to 10 kHz; <3%, 10 kHz to 100 kHz on the X10 k range.

Square-wave response: <250 ns rise and fall time on all ranges; <1% sag, <5% overshoot at full output; <1% symmetry error.

Triangle-linearity error: <1%, 0.01 Hz to 10 kHz; <2%, 10 kHz to 100 kHz at full output; <1% symmetry error.

Sync-pulse output: >10 V p-p open circuit. <5 μs duration.

Output impedance (both channels): 600Ω ±20%.

DC stability: drift; <±0.25% of p-p amplitude over a period of 24 hours (after 30-min. warmup).

Remote frequency control: 0 to −10 V will linearly change frequency >1 decade within a single range. Frequency resettability with respect to voltage ±1% of maximum frequency on range selected.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 60 W max.

Dimensions: standard HP full module 16¾" wide, 5" high (without removable feet), 11" deep (425 x 127 x 279 mm).

Weight: net 20 lbs (9 kg); shipping 24 lbs (10,8 kg).

Accessories furnished: rack mount kit for 19" rack.

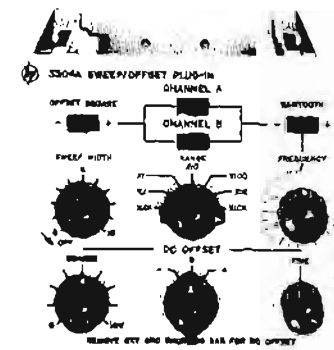
Plug-ins available

HP 3301A Auxiliary Plug-in, $30.
HP 3302A Trigger Plug-in (see page 373).
HP 3304A Sweep/Offset Plug-in (see page 373).
HP 3305A Sweeper Plug-in (see page 374).

Price: HP 3300A Function Generator, $650.

FUNCTION GENERATOR PLUG-INS
Variable phase, phase lock, sweeper, dc offset
Models 3302A, 3304A

3302A



3304A

The HP **3302A Trigger/Phase Lock Plug-in** provides single-cycle, multiple-cycle and phase-lock operation. The instrument can be triggered over the entire frequency range, either manually or by applying an external voltage.

In single-cycle operation, one cycle of any function can be obtained by pushing the manual trigger or applying a voltage to the external trigger input.

In the multiple-cycle mode of operation, any number of complete cycles of any function can be obtained by holding the manual trigger depressed, or by applying an external gate voltage.

The 3300A may be phase-locked to any periodic signal with a frequency from 10 Hz to 100 kHz to obtain sine, triangle and square wave outputs with frequency characteristics of the externally-applied signal.

The HP **3304A Sweep/Offset Plug-In** provides internal sweeping, dc offset, sawtooth waves and offset square waves. Up to ±16 V of dc offset is available for all signals generated in the main frame and plug-in. In addition, the independently frequency-controlled sawtooth wave may be switched internally to the frequency control circuit of the HP 3300A Function Generator to permit sweeping over a decade of frequency within a single range.

Specifications, 3302A

Trigger requirements

Single cycle: manual or external, dc coupled. Requires at least 0.5 V to trigger externally. May be triggered with positive or negative input voltage which starts at or goes through zero volts (±20 V peak max.)

Multiple cycle: manual or external start/stop, dc coupled. Requires at least 0.5 V to start, 0 V to stop. May be triggered with either positive or negative input voltage (±20 V peak max.).

Phase lock: 10 Hz to 100 kHz (upper 4 ranges only), dc coupled. Requires + and — 0.5 Vp to lock, 10 V p-p for specified accuracy with sine-wave input. The 3302A will lock on a fundamental or harmonic of the input signal.

Phase dial accuracy: ±10° from 10 Hz to 10 kHz; ±20° from 10 kHz to 100 kHz on X10 k range (fundamental only).

Introduced distortion: <1%, 10 Hz to 10 kHz; <3%, 10 kHz to 100 kHz on X10 k range (fundamental only).

Dimensions: 6-1/16" wide, 4¾" high, 10¼" deep (154 x 121 x 260 mm).

Weight: net 3 lbs (1,4 kg); shipping 5 lbs (2,5 kg).

Price: HP 3302A Trigger/Phase Lock Plug-in, $225.

Specifications, 3304A

DC offset

Voltage range: adjustable 0 to ±16 V open circuit and a ±1 V vernier control.

DC stability: ±50 mV over a 24-hr. period (after 30-min. warm-up).

Offset square wave

Output polarity: positive or negative, from dc offset voltage or ground potential.

Amplitude: >15 V p-p open circuit; continuously adjustable with 3300A amplitude control.

Rise time: <400 ns.

Overshoot: <5% at full output.

Sag: <1%.

Sawtooth waveform

Frequency range: 0.01 Hz to 100 kHz, continuously adjustable over 7 decade ranges.

Dial accuracy: <±10% full scale, 0.01 Hz to 1 Hz; <±5% full scale, 1 Hz to 100 kHz.

Amplitude: >15 V p-p open circuit; continuously adjustable over a 40 dB range with 3300A amplitude control.

Frequency response: <2%, 0.01 Hz to 10 kHz; <5%, 10 kHz to 100 kHz.

Output polarity: positive or negative, from dc offset voltage or ground potential.

Linearity: <1%, 0.01 Hz to 10 kHz; overshoot, <5%.
<2%, 10 kHz to 100 kHz; overshoot, <5%.

Flyback time: <5% + 250 ns.

Internal sweep

Controls: start frequency set by 3300A frequency dial; sweep range set by sweep width control on plug-in.

Sweep rate: determined by sawtooth frequency setting

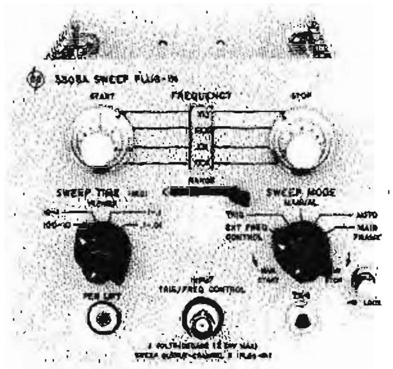
Sweep width: adjustable from 0 to at least 1 decade on any one range.

Dimensions: 6-1/16" wide, 4¾" high, 10¼" deep (154 x 121 x 260 mm).

Weight: net 4 lbs (1,8 kg); shipping 6 lbs (2,7 kg).

Price: HP 3304A Sweep/Offset Plug-in, $265.

SWEEP PLUG-IN FOR 3300A
Four-decade logarithmic sweep
Model 3305A



3305A

The 3300A/3305A will sweep logarithmically, repetitively between any two frequencies within one of the three (4-decade) ranges: 0.1 Hz to 1 kHz, 1 Hz to 10 kHz, and 10 Hz to 100 kHz. Calibrated independent START-STOP controls greatly simplify setting desired sweep end points. Adjustable sweep time from 0.01 to 100 seconds provides sweep times slow enough for accurate response testing of low-frequency high-Q systems and fast enough for good visual displays of higher frequency responses.

The manual sweep, vernier adjustment of frequency between the start-stop limits, allows close observation of a small portion of a response curve. This manual control also permits measurement of a critical frequency with counter accuracy and simpler set-ups for oscilloscopes or X-Y recorders.

Programming

For automated testing, the 3300A/3305A frequency can be analog-programmed over any one of the three (4-decade) ranges. Up and down sweeping, up to two decades, can be obtained by a triangular input. Also individual or multiple sweeps can be externally triggered.

Sweep output

X-axis readjustment is eliminated since the sweep output amplitude is independent of start-stop, sweep time and sweep width.

Specifications, 3305A

Frequency range: 0.1 Hz to 100 kHz in three ranges.
- **Sweep width:** limits adjustable 0 to 4 decades in any of three (4-decade) bands: 0.1 Hz to 1 kHz, 1 Hz to 10 kHz, 10 Hz to 100 kHz. Start-stop dial accuracy: ±10% of setting.

Sweep modes
- **Automatic:** repetitive logarithmic sweep between start and stop frequency settings.
- **Manual:** vernier adjustment of frequency between start and stop frequency settings.
- **Trigger:** sweep between start and stop frequency settings and retrace with application of external trigger voltage or by depressing front-panel trigger button.
- **Trigger requirements:** ac coupled, positive going at least 1 V peak with >2 V per ms rise rate. Max. input, ±90 Vp.

Sweep time: 0.01 s to 100 s in 4 decade steps, continuously adjustable vernier.

Retrace time: <0.003 s for 0.1 to 0.01 s sweep times; <0.03 s for 1 to 0.1 s sweep times; <4 s for 100 to 1 s sweep times.

Blanking: oscillator disabled during retrace.

Pen lift: terminals shorted during sweep; open during retrace in auto and trigger modes for 100 to 1 s sweep times.

Sweep output: linear ramp at CHANNEL B OUTPUT (PLUG-IN); amplitude adjustable independently of sweep width: max. output >15 V p-p into open circuit, >7 V p-p into 600Ω.

External frequency control
- **Sensitivity:** 6V/decade (refer: START setting), ±24 V max.
- **V-to-F conversion accuracy:** for each 6 V change in programming voltage, frequency changes 1 decade ±5% of end F.
- **Input impedance:** 400 kΩ ±5%. Maximum rate: 100 Hz.

General
- **Dimensions:** 6-1/16" wide, 4¾" high, 10¼" deep (154 x 121 x 260 mm).
- **Weight:** net 4 lbs 6 oz (2 kg); shipping 6 lbs 6 oz (3 kg).
- **Price:** HP 3305A, $975.

LOW FREQUENCY FUNCTION GENERATOR
Model 202A

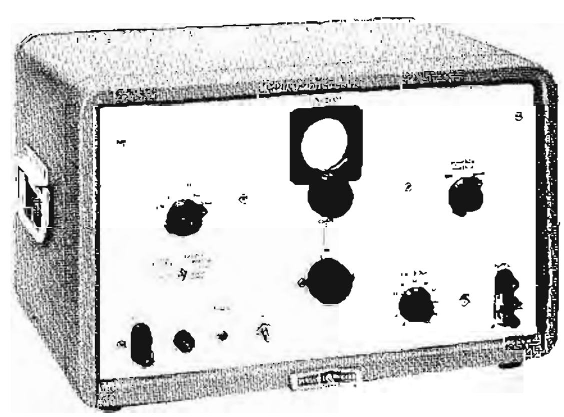
Description

The HP Model 202A Low Frequency Function Generator has a continuously variable output frequency from 0.008 Hz to 1200 Hz. Any of the three desired waveforms—sine, square or triangular—can be selected from a front panel switch. Frequency stability is within 1% with less than 1% sine wave distortion. The output system is fully floating with respect to ground and it can be used to supply a balanced voltage or an output voltage with either terminal grounded. Maximum output is 30 volts peak-to-peak across a rated load of 4000 ohms (10.6 volts rms for a sine wave). Refer to data sheet for complete specifications.

Power: 115 V or (230 V must be specified) ±10% 50 to 400 Hz, 150 W.

Weight: net 42 lbs (18,9 kg); shipping 52 lbs (23,4 kg) (cabinet).

Price: HP 202A, $665. (cabinet).
HP 202AR, $650. (rack mount).

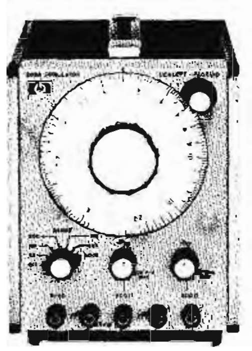


202A

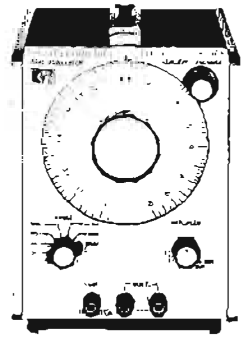
SINE, SQUARE OSCILLATORS

Low distortion; wide range; balanced output

Models 209A, 204C



209A



204C

The HP 209A is a small, lightweight, sine/square oscillator. Stable, accurate signals which can be synchronized with an external source are instantly available over a frequency range from 4 Hz to 2 MHz. Separately adjustable sine/square outputs are located on the front panel. Distortion and flatness can be minimized at low frequencies by a rear panel LOW DISTORTION MODE switch.

Specifications (209A)

Frequency: 4 Hz to 2 MHz in 6 ranges.
Dial accuracy: ±3% of frequency setting.
Flatness: at maximum output into 600Ω load. 1 kHz reference.

	4–100	100–300k	300k–1M	1M–2M (Hz)
Low distortion mode	±1%	±0.5%	±1%	±5%
Normal mode	+5%, −1%	±0.5%	±1%	±5%

Distortion: 200 Hz to 200 kHz, 0.1% (−60 dB); 4 Hz to 200 Hz, <0.2% (−54 dB); 200 kHz-2 MHz, <1% (−40 dB).
Hum and noise: <0.01% of input.

Output characteristics sine wave

Output voltage: 5 V rms (40 mW) into 600Ω; 10 V open circuit.
Output impedance: 600Ω.
Output control: 20 dB range continuously adjustable.
Output balance: >40 dB below 20 kHz. Output can be floated up to ±500 V peak between output and chassis ground.

Output characteristics square wave

Output voltage: 20 V p-p open circuit symmetrical about 0 V. Output can be floated up to ±500 V peak.
Rise and fall time: 50 ns. Symmetry: ±5%.
Output impedance: 600 to 900Ω depending upon output control setting.

Synchronization

Sync output: sine wave in phase with output; 1.7 V rms open circuit; impedance 10 kΩ.
Sync input: same as 204C.

General

Operating temperature: instrument will operate within specifications from 0°C to 55°C.
Power: AC-line 115 V or 230 V ±10%, 50 Hz to 400 Hz, <7 W.
Dimensions: 5⅛" wide, 6¼" high (without removable feet), 8" deep (130 x 159 x 203 mm).
Weight: net 6 lbs (2,7 kg); shipping 8 lbs (3,6).
Accessories available: HP 11075A Instrument Case, $45.
Price: HP 209A, $320.

The HP 204C is a small, lightweight capacitive-tuned oscillator. Interchangeable power packs, line, rechargeable batteries or mercury batteries make this instrument ideal for both field and laboratory use. Internal heat generation and temperature coefficient is small, resulting in unusually low drift. Stable, accurate signals which can be synchronized with an external source are instantly available over a frequency range from 5 Hz to 1.2 MHz. Distortion can be minimized at low frequencies by a rear panel Low Distortion Mode switch; however, settling time with a rapid frequency change is increased.

Specifications (204C)

Frequency: 5 Hz to 1.2 MHz in 6 overlapping ranges.
Dial accuracy: ±3% of frequency setting.
Flatness: at maximum output into 600Ω load. 1 kHz reference.

	5–100	100–300k	300k–1.2M (Hz)
Low distortion mode	±1%	±0.5%	±1%
Normal mode	+5%, −1%	±0.5%	±1%

Distortion: 30 Hz to 100 kHz, 0.1% (−60 dB); 5 Hz to 30 Hz, <0.6% (−44 dB); 100 kHz-1.2 MHz, linearly derated to <1%.
Hum and noise: <0.01% of output.

Output characteristics

Output voltage: 2.5 V rms (10 mW) into 600Ω; 5 V rms open circuit.
Output impedance: 600Ω.
Output control: >40 dB range; continuously adjustable.
Output balance: >40 dB below 20 kHz. Can be floated up to ±500 V peak between output and chassis ground.

Synchronization

Sync output: sine wave in phase with output; 1.7 V rms open circuit; impedance 10 kΩ.
Sync input: oscillator can be synchronized to external signal. Sync range, the difference between sync frequency and set frequency, is a linear function of sync voltage. ±1%/V rms for sine wave with a maximum input of ±7 volts peak.

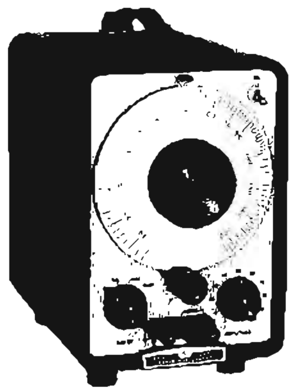
General

Operating temperature: specifications are met from 0°C to 55°C.
Power: standard: ac-line 115 V or 230 V ±10%, 50 Hz to 400 Hz, <4 W. Opt. 01: mercury batteries 300 hours operation. Opt. 02: line/rechargeable batteries 115 V or 230 V ±10%, 50 Hz to 400 Hz, <4 W. 40 hours operation per recharge.
Dimensions: 5⅛" wide, 6¼" high (without removeable feet), 8" deep (130 x 159 x 203 mm).
Weight: net 6 lbs (2,7 kg); shipping 8 lbs (3,6 kg).
Accessories available: HP 11107A AC Power Pack for 204C, $60. HP 11108A Mercury Power Pack for 204C, $75. HP 11109A Rechargeable Battery/AC Power Pack for 204C, $95. HP 11075A Instrument Case, $45.
Price: HP 204C, (ac line) $240. HP 204C Option 001 (mercury batteries) add $15. HP 204C Option 002 (rechargeable batteries, ac-line) add $35.

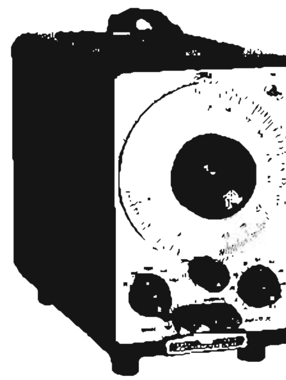
AUDIO OSCILLATORS

Exceptional value, highest quality

Models 200AB, 200CD



200AB



200CD

Features:

- No zero setting, high stability
- Constant output, low distortion
- Wide frequency range, log scale
- No frequency change with load variation

Hewlett-Packard RC oscillators have long been basic tools for making electrical and electronic measurements of precise accuracy. These world-famous test instruments give you the most compact, dependable, accurate and easy-to-use commercial oscillators available.

The HP 200 Series Oscillators have high stability and accurate, easily resettable tuning circuits. Low-impedance operating levels, together with superior insulation, guarantee peak performance throughout years of trouble-free service. The instruments have wide frequency range and long dial lengths and feature an improved vernier frequency control. Operation is simplified — just three controls are required. Instruments are compact, light in weight and enclosed in a convenient, aluminum case with carrying handle. They occupy minimum bench space and are easily portable. Rack mounting is available on order.

200AB Audio Oscillator, Low Cost, 20 Hz to 40 kHz

The 200AB sinewave oscillator frequency range of 20 Hz to 40 kHz is covered in four overlapping decade bands. Accurate frequency setting is provided by a dial, 90divisions,and an effective scale length of 63 inches. The oscillator provides one watt or 24.5 volts into 600 ohm load. The output circuit is balanced and floating over the entire frequency range so that the instrument may be used to drive off-ground loads. The cabinet form is convenient for bench operation and the rack mount permits combining the 200AB with other instruments in a standard rack. The panel arrangement aids in swift and straightforward operation. HP 200AB, $215 (cabinet); HP 200ABR, $220 (rack mount).

200CD Wide-Range Oscillator, Multi-Purpose, 5 Hz to 600 kHz

One of the most popular of all HP oscillators, Model 200CD covers the range of 5 Hz to 600 kHz in five overlapping decade bands. Accurate frequency setting is provided by 112 dial divisions and an effective scale length of 78 inches. A vernier drive allows precise adjustment.

The 200CD gives a maximum sinewave output of at least 10 volts across its rated load of 600 ohms and at least 20 volts open circuit. Its distortion rating is very low, less than 0.2% from 20 Hz to 200 kHz. A special feature of the 200CD is that its waveform purity does not depend on load. The output impedance is nominally 600 ohms. The output transformers are balanced within 0.1% at the lower frequencies and within approximately 1% at the higher frequencies. The 200CD is particularly useful for testing servo and vibration systems, medical and geophysical equipment, audio amplifiers, sonar and ultrasonic apparatus, carrier telephone systems, video frequency circuits, etc. Waveform purity is maintained with extremely low loads Frequency is covered in 5 decade ranges, and accuracy is ±2% including warm-up, aging, tube changes, etc. Frequency response is ±1 dB full range. A convenient panel grounding terminal is provided to ground one of the output terminals when single-ended operation is desired. A simple bridged T Attenuator is provided to control output power. Where a well-balanced adjustable output source is desired, the HP 11004A Line Matching Transformer can be used. HP 200CD, $250 (cabinet); HP 200CDR, $255 (rack mount).

The H20-200CD is a standard 200CD modified to have an extremely low distortion output. Refer to the Table of Specifications, page 377. HP H20-200CD, $305.

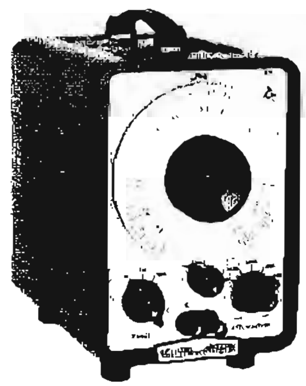
201C Audio Oscillator, High Power, 20 Hz to 20 kHz

Particularly designed for amplifier testing, transmission line measurements, loudspeaker testing, frequency comparison and other high fidelity tests, this audio oscillator meets every requirement for speed, simplicity and pure waveform. The frequency range, 20 Hz to 20 kHz, is covered in 3 bands; response is ±1 dB full range. Output is 3 watts or 42.5 volts into 600 ohms; an attenuator adjusts output 0

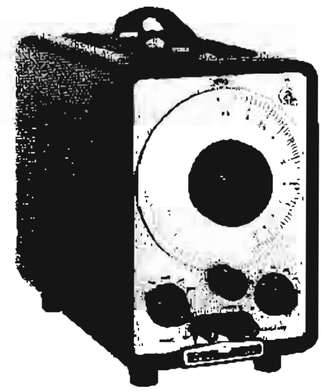
AUDIO OSCILLATORS

Exceptional value, highest quality

Models 201C, 202C



201C



202C

to 40 dB in 10 dB steps and provides either low impedance or constant 600-ohm impedance. Distortion at 1 watt output and above 50 Hz is less than 0.5%. HP 201C, $275 (cabinet); HP 201CR, $280 (rack mount).

202C Low-Frequency Oscillator, Excellent Waveform 1 Hz to 100 kHz

Model 202C brings to the low-frequency spectrum the accuracy and stability you associate with audio measurements. It provides excellent waveforms in the subsonic, audio and ultrasonic frequency ranges, and has broad applicability for industrial, field or laboratory use. Specifically, it may be used for these important tests: vibration or stability characteristics of mechanical systems; electrical simulation of mechanical phenomena; determining electro-cardiograph and electro-encephalograph performance; seismograph response; making vibration checks of structural components; obtaining performance characteristics of geophysical prospecting equipment; making operational checks of servo-mechanism systems and general audio measurements.

The transformer-coupled, balanced output of the Model 202C enables it to meet the signal source requirements for tests of a wide variety of systems. The instrument provides an output of at least 10 volts across its rated load of 600 ohms and at least 20 volts open circuit. A special feature is that waveform purity does not depend upon load. Distortion is less than 0.5%; hum voltage is less than 0.1%, and recovery time is extremely short—5 seconds at 1 Hz. HP 202C, $325 (cabinet); HP 202CR, $330 (rack mount).

Specifications

HP Model	Frequency range	Calibration accuracy	Output to 600 ohms	Output impedance	Maximum distortion	Maximum hum and noise¶	Input power (watts)	Weight—lb (kg) net	Weight—lb (kg) ship	Size—Inches (mm) W H D	Price
200AB	20 Hz to 40 kHz (4 bands)	±2%	1 W (24.5 V)	75 ohms (mid-freq)	1% 20 Hz to 20 kHz; 2% 20 kHz to 40 kHz	0.05%	80	15 (6,7)	16 (7,2)	7½ x 11½ x 12 (191 x 292 x 305)	$215
200CD	5 Hz to 600 kHz (5 bands)	±2%	>160 mW >(10 V)	600 ohms	0.2% 20 Hz to 200 kHz; 0.5% 5 Hz to 20 Hz and 200 kHz to 600 kHz	>60dB below (<0.1% of) rated output	90	22 (9,9)	24 (10,8)	7⅜ x 11½ x 14⅜ (187 x 292 x 365)	$250
H20-200CD			(7.5 V)		**						$305
201C	20 Hz to 20 kHz (3 bands)	±1%†	3 W (42.5 V)	600* ohms	0.5% ‡	0.03%	85	16 (7,2)	19 (8,6)	7½ x 11½ x 12½ (191 x 292 x 318)	$275
202C	1 Hz to 100 kHz (5 bands)	±2%	160 mW (10 V)	600 ohms	0.5% §	0.1%	85	25 (11,3)	27 (12,2)	7½ x 11½ x 14¼ (191 x 292 x 368)	$325

*Output impedance: 600Ω ±10%, 20 dB, 30 dB and 40 dB settings; <600Ω, 0 dB and 10 dB settings. †Internal controls permit precise calibration of each band. ‡0.5% 50 Hz to 20 kHz at 1 watt output; 1% over full range at 3 watts output. §Above 5 Hz.

**Same as 200CD except: distortion; 0.05% 60 Hz to 50 kHz, 0.1% 20 Hz to 50 Hz and 50 kHz to 400 kHz, 0.5% 5 Hz to 20 Hz and 400 kHz to 600 kHz. Output: 7.5 V into 600 ohm load.

¶Measured with respect to full rated output.

General:

Frequency response: flat ±1 dB over instrument range; reference level at 1 kHz.

Size and weight: maximum overall size and weights are given for cabinet models; 19" rack models also available.

Power: 115 or (230 volts must be specified) ±10% at 50 to 400 Hz.

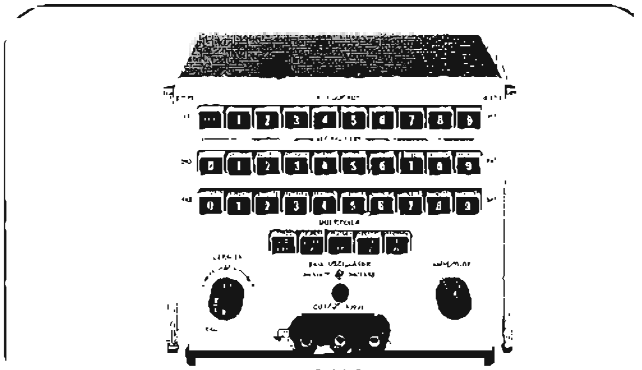
Accessories available: 11000A Cable Assembly, $5; 11001A Cable Assembly, $6; 11004A, 11005A Line Matching Transformers, see pages 383. Cables are on page 226.

TEST OSCILLATORS

Pushbutton or rechargeable battery operation

Models 241A, 208A

Pushbutton oscillator (241A)



241A

Any frequency between 10 Hz and 999 kHz can be selected to three significant figures by simply pushing the three appropriate frequency pushbuttons and one of five decade multipliers. These pushbuttons control 900 base frequencies in increments of 0.1 Hz from 10.0 to 99.9 Hz, providing 4500 discrete frequency settings. Infinite resolution is provided by a vernier control, extending the upper frequency to 1 MHz.

Since each discrete frequency setting is a digital function effectively isolated from every other setting, a high degree of calibration dependability is achieved—a major advantage for user convenience. Accuracy is within ±1% of selected value on any range.

Frequency response is flat ±2% over the entire range at any attenuator setting. This is obtained by using special, fixed-precision resistors and large amounts of negative feedback in a unique biased-diode control circuit. A front-panel control adjusts the bridged-tee attenuator for output levels of −30 dBm to +10 dBm presenting a constant output impedance of 600 ohms.

Specifications 241A

Frequency range: 10 Hz to 1 MHz, 5 ranges, 4500 frequency increments with vernier overlap.
Calibration accuracy: ±1%.
Frequency response: ±2% into rated load.
Output impedance: 600 ohms.
Distortion: 1% maximum.
Hum and noise: .05% of output.
Output: +10 to −30 dBm into 600 ohms (2.5 volts maximum).
Power: 115 or 230 volts, 50 to 400 Hz, 1 watt.
Dimensions: standard ½ module 7¾" wide, 6¼" high (without removable feet), 8" deep (197 x 159 x 203 mm).
Weight: net 7¾ lbs (3.5 kg); shipping 10 lbs (4,5 kg).
Accessory furnished: detachable power cord, NEMA plug.
Accessories available: HP 11000A Cable, 44" long, dual banana plugs, $5.00. HP 11002A Test Leads, 60" long, dual banana plug to alligator clips, $8.00. HP 11004A, Line Matching Transformer, (5 kHz to 600 kHz) balanced output for 135 or 600 ohms, $60.00. HP 11005A Line Matching Transformer (20 Hz to 45 kHz), balanced output for 600 ohms, $80.00.
Price: HP 241A, $490.

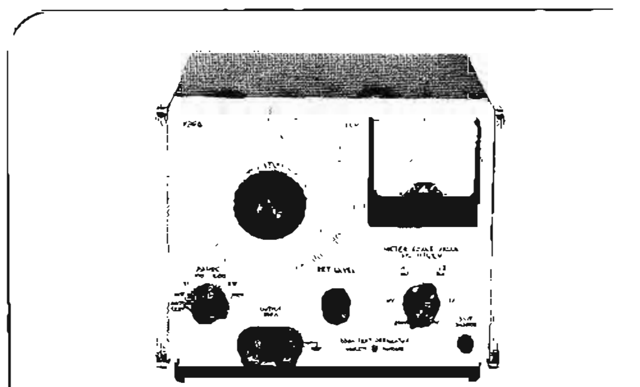
Test oscillator (208A)

Rechargeable battery operation

The solid-state design, light weight, modular construction, and battery operation of this oscillator contributes to its portability. Rapid attenuation selection and monitored oscillator levels ideally suit the 208A Oscillator to transmission line work, production line tests and similar situations where output levels must be known.

Specifications 208A

Frequency range: 5 Hz to 560 kHz in 5 ranges. 5% overlap between ranges, vernier control.
Dial accuracy: ±3%.
Frequency response: ±3% into rated load.
Output: 10 milliwatts, nominal 2.5 V rms (+10 dBm) into 600 ohms.
Output impedance: 600 ohms.
Output attenuator
  Meter scale value: 0.01 mV to 1 V full scale (6 steps).
  Multiplier: 2.5 multiplier, concentric with Meter Scale Value switch, to obtain 0.025 mV to 2.5 volts.
Output attenuator accuracy: 5 Hz to 100 kHz, error is less than ±3% at any step. From 100 kHz to 560 kHz, error is less than 5% at any step. Specifications include multiplier accuracy.
Output monitor: Transistor voltmeter monitors level at input to attenuator and after set level. Accuracy ±2% of full scale into 600 ohms.
Set level: continuously variable bridged "T" attenuator with 10:1 voltage range.
Distortion: less than 1%.
Hum and noise: less than 0.05% at maximum output.
Operating temperature range: 0°C to +50°C.
Power source: 4 rechargeable batteries (furnished). Thirty-hour operation per recharge. Oscillator may be operated during recharge from ac line. (115 V or 230 V ±10%, 50 to 400 Hz, 3 watts).
Dimensions: 7$^{25}/_{32}$" wide, 6$^{3}/_{32}$" high (without removable feet), 8" deep (155 x 197 x 203 mm).
Weight: net 8¼ lbs (3.5 kg); shipping 11 lbs (5 kg).
Price: HP 208A, $540.



208A

208A optional

(same as 208A except)

Output attenuator: 0 to 110 dB in 1 dB steps.

Accuracy, 10 dB section: from 5 Hz to 100 kHz, error is $<\pm 0.125$ dB at any step; from 100 kHz to 560 kHz, error is $<\pm 0.25$ dB at any step.

Accuracy, 100 dB section: from 5 Hz to 100 kHz error is $<\pm 0.25$ dB at any step; from 100 kHz to 560 kHz error is $<\pm 0.5$ dB at any step.

Output monitor: solid-state voltmeter monitors level at input to attenuator, and after set level; scale calibrated −10 dBm to +11 dBm: accuracy ±0.25 dB at +10 dBm into 600 ohms.

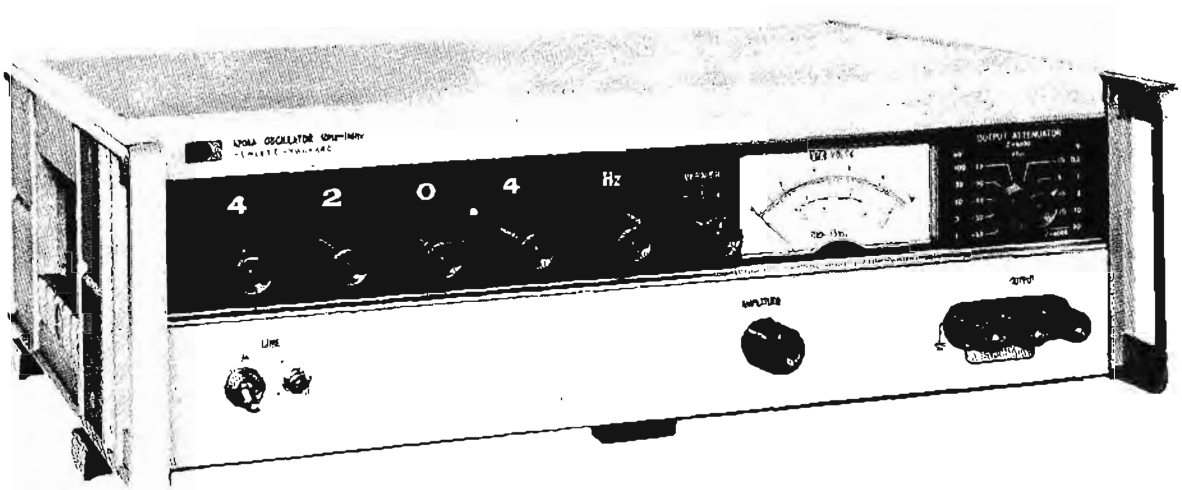
Set level: continuously variable bridged "T" attenuator with 20 dB minimum range.

Price: HP 208A, Option 01, add $10.

DIGITAL OSCILLATOR

Four digit frequency resolution, 10 Hz to 1 MHz

Model 4204A



4204A

Advantages:

- Simple, rapid 0.2% frequency selection
- Flat frequency response, 10 Hz to 1 MHz
- 0.01% frequency repeatability
- Excellent stability

Uses:

- Production line and repetitive testing
- Standard source for calibrating ac to dc converters
- Response testing of wide or narrow band devices
- Filter checkout

The HP 4204A Digital Oscillator provides accurate, stable test signals for both laboratory and production work. This one instrument does the jobs of an audio oscillator, and ac voltmeter, and an electronic counter, in applications requiring an accurate frequency source of known amplitude.

Any frequency between 10.00 Hz and 999.9 kHz can be digitally selected with an in-line rotary switch, to four significant figures. As many as 36,900 discrete frequencies are available. Infinite resolution is provided by one vernier control, which also extends the upper frequency limit to 1 MHz. Frequency accuracy is better than ±0.2% and repeatability is typically better than ±0.01%.

A built-in high impedance voltmeter measures the output. The meter is calibrated to read volts or dBm into a matched 600 ohm load. (0 dBm = 1 mW into 600 ohms.) The output attenuator has an 80 dB range, adjustable in 10 dB steps with a 20 dB vernier. Maximum output power can be increased to 10 volts (22 dBm) into 600 ohms.

Specifications

Frequency range: 10 Hz to 1 MHz, 4 ranges.

Frequency accuracy: ±0.2% or ±0.1 Hz (at 25°C).

Frequency stability:

±10% line voltage variation: Less than ±0.01%.

Change of frequency with temperature: <±100 ppm/°C.

Frequency response: flat within ±3%.

Output: 10 V (22 dBm) into 600 ohms, (160 mW). 20 V Open Circuit.

Output attenuators: 80 dB in 10 dB steps; <±0.5 db error.

Distortion: less than 0.3%, 30 Hz to 100 kHz. Less than 1%, 10 Hz to 1 MHz.

Hum and noise: less than 0.05% of output.

Dimensions: cabinet; 5¼" high, 16¾" wide, 11¼" deep. (134 x 426 x 286 mm).

Power: 115 V/230 V switch, ±10%, 10 watts, 50 to 60 Hz.

Weight: net, 19 lbs (8,5 kg); shipping, 28 lbs (11 kg).

Price: $695.

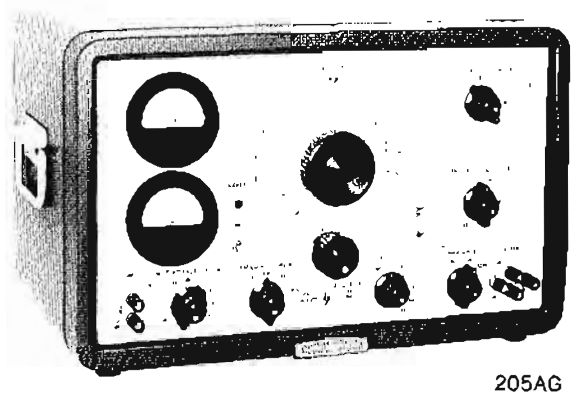
Option 01: Output monitor top scale calibrated in dBm/600Ω; bottom scale calibrated in volts; add $10.

Manufactured by Yokogawa-Hewlett-Packard Ltd., Tokyo.

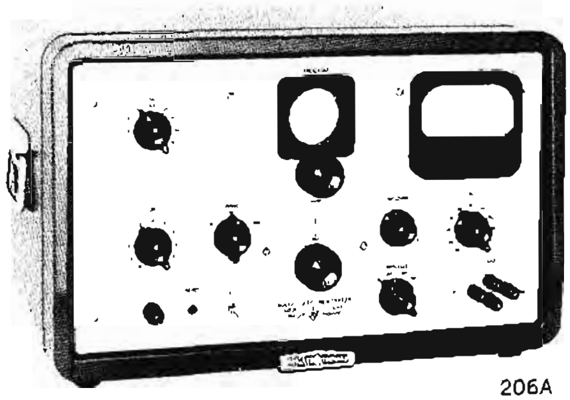
AUDIO SIGNAL GENERATORS

Versatile instruments, 20 Hz to 20 kHz

Models 205AG, 206A



205AG



206A

The 205AG Audio Signal Generator materially speeds and simplifies a variety of audio testing jobs where sizable amounts of power are required.

Two voltmeters measure input and output of the device under test. The output level is adjusted by means of the step attenuators, and output impedance can be instantly changed by means of a selector switch to commonly used impedances.

Specifications, 205AG

Frequency range: 20 Hz to 20 kHz in three decade ranges.

Dial accuracy: ±2% under normal temperature conditions. (Including warm up and changes due to aging of tubes and components.)

Output: five Watts maximum into resistive loads of 50, 200, 600 and 5000 ohms; output circuit is balanced and center-tapped; any terminal may be grounded.

Frequency response: ±1 dB, 20 Hz to 20 kHz at output levels up to +30 dBm with output meter reading held constant at +37 dB; ±1.5 dB, 20 Hz to 20 kHz at output levels above +30 dBm with output meter reading held constant at +37 dB (reference 1 kHz).

Output impedances: 1/6 load impedance with zero attenuator setting; approaches the load impedance with attenuator settings of 20 dB or more.

Distortion: less than 1% at frequencies above 30 Hz.

Hum level: more than 60 dB below the output voltage or 90 dB below 0 level, whichever is the larger.

Output meter: calibrated directly in Volts at 600 ohms and dBm (0 dBm = 1 mW in 600 ohms); voltage scale 0 to 65 V, dB scale +20 to +37 dBm.

Input meter: calibrated in dBm from −5 to +8 dBm and in Volts from 0 to 2 V rms; voltage accuracy is ±5% of full scale.

Input attenuator: extends meter range to +48 dBm and to 200 V rms in 5 dB steps; accuracy ±0.1 dB.

Output attenuator: 110 dB in 1 dB steps.

Power: 115 or (230 Volts must be specified) ±10%, 50 to 400 Hz, 158 W max.

Dimensions: cabinet: 20¾" wide, 12¾" high, 15½" deep (527 x 324 x 394 mm); rack mount: 19" wide, 10½" high, 14" deep behind panel (483 x 267 x 356 mm).

Weight: net 56 lbs (25,2 kg), shipping 67 lbs (30 kg) (cabinet); net 49 lbs (22,1 kg), shipping 63 lbs (28,3 kg) (rack mount).

Price: HP 205AG, $700 (cabinet); HP 205AGR, $685 (rack mount).

The HP 206A Audio Signal Generator provides a source of continuously variable audio-frequency voltage at a total distortion level of less than 0.1%. This unusually low distortion, coupled with simple, straightforward circuitry, rugged construction and typical HP ease of operation, makes this signal generator ideal for use in the maintenance of FM broadcasting units and high fidelity audio systems.

The 206A Generator includes an output-matching transformer which allows it to be matched to resistive loads of 50, 150, and 600 ohms. This output system is balanced to ground, and each winding is center-tapped. The internal impedance matches the load impedance. A single-ended 600-ohm output is provided which bypasses the line-matching transformer.

Specifications, 206A

Frequency range: 20 Hz to 20 kHz in three decade ranges.

Dial accuracy: ±2% including warmup drift.

Output: +15 dBm into impedances of 50, 150 and 600 ohms; 10 volts are available into an open circuit.

Output impedances: the generator has a matched internal impedance, and the selection of output impedances includes 50, 150 and 600 ohms center-tapped and balanced, and 600 ohms single-ended.

Frequency response: better than ±0.2 dB at all levels, 30 Hz to 15 kHz, when the output meter reading is held constant.

Distortion: less than 0.1% at frequencies above 100 Hz and less than 0.25% from 20 Hz to 100 Hz.

Hum level: at least 75 dB below the output signal or more than −100 dBm, whichever is larger.

Output meter: calibrated in dBm and also in volts at 600 ohm level, (0 dBm equals 1 mW into 600 ohms).

Output attenuators: 111 dB in 0.1 dB steps.

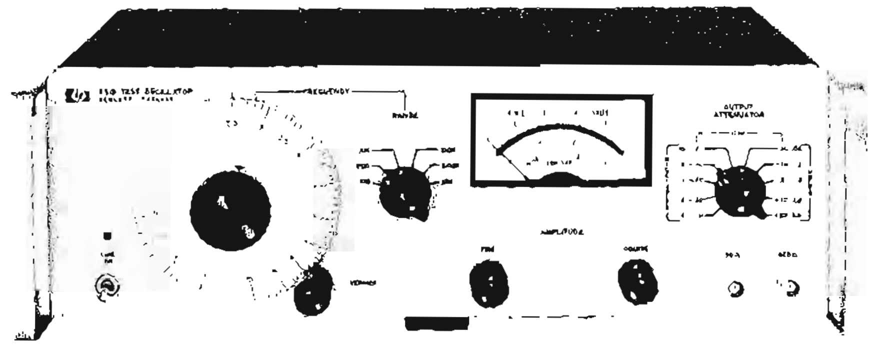
Power: 115 or (230 Volts must be specified) ±10%, 50 to 400 Hz, 146 W max.

Dimensions: cabinet: 20¾" wide, 12¾" high, 15" deep (527 x 324 x 381 mm); rack mount: 19" wide, 10½" high, 14" deep behind panel (483 x 267 x 356 mm).

Weight: net 57 lbs (25,6 kg), shipping 66 lbs (29,7 kg) (cabinet); net 50 lbs (22.5 kg), shipping 62 lbs (27,9 kg) (rack mount).

Price: HP 206A, $975 (cabinet); HP 206AR, $960 (rack mount).

TEST OSCILLATORS
10 Hz to 10 MHz; 0.75% attenuator accuracy
Models 651B, 652A



651B

HP 651B Description

Amplitude and frequency stability of this solid-state capacitance tuned Hewlett-Packard Test Oscillator provides test quality signals for laboratory or production measurements from 10 Hz to 10 MHz. Two output impedances are available from the front panel providing 200 mW into 50Ω or 16 mW into 600Ω.

HP 651B Specifications

Frequency range: 10 Hz to 10 MHz, 6 bands, dial calibration: 1 to 10.

Amplitude stability: ±2% per mo., 20°C-30°C.

Dial accuracy (indicating warm-up and ±10% line voltage variation): ±2%, 100 Hz to 1 MHz; ±3%, 10 Hz to 100 Hz and 1 MHz to 10 MHz.

Output (max): 3.16 V into 50Ω or 600Ω; 6.32 V open circuit.

Ranges: 0.1 mV to 3.16 V full scale, 10 steps in 1, 3, sequence: −70 dBm to +23 dBm (50Ω output) full scale, 10 dBm per step; coarse and fine adjustable.

Flatness: (Amplitude not readjusted to a reference on the output monitor) ±2% 100 Hz to 1 MHz; ±3% 10 Hz to 100 Hz; ±4% 1 MHz to 10 MHz*.

(Amplitude readjusted to a reference on the output monitor.)

Range	Frequency 10 Hz – 20 Hz	20 Hz – 4 MHz	4 MHz – 10 MHz
3 V and 1 V	2%	1%	2%
.3 V to .3 mV	2.5%	1.5%	2.5%
.1 mV	3%	2%	3%

Distortion: <1%, 10 Hz to 2 MHz; <2%, 2 MHz to 5 MHz; <4%, 5 MHz to 10 MHz.

Hum and noise: less than 0.05% of maximum rated output.

Output monitor: voltmeter monitors level at input of attenuator in volts or dB.

Accuracy: ±2% of full scale.

Attenuator

Range: 90 dB in 10 dB steps.

Accuracy: ±0.075 dB, −60 dBm to +20 dBm; ±0.2 dB, −70 dBm to −60 dBm.

Amplitude control: 20 dB range, coarse and fine.

Temperature range: 0°C to +50°C.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 30 W.

Dimensions: 16¾" wide, 5" high (without removable feet), 13¼" deep (425 x 127 x 337 mm).

Weight: net 16 lbs (7,3 kg); shipping 21 lbs (9,6 kg).

Accessories furnished: rack mount kit for 19" rack.

Price: HP 651B, $590.

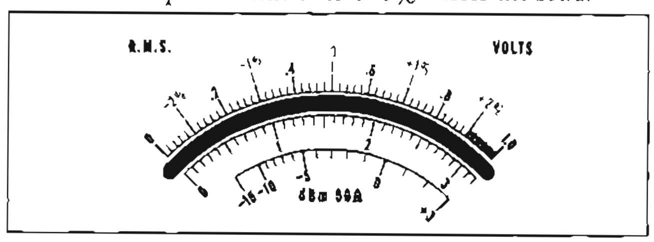
Option 01: output monitor calibrated to read dBm for 600Ω add $25.

Option 02: outputs, 75Ω and 600Ω; calibrated in dBm/75Ω, add $25.

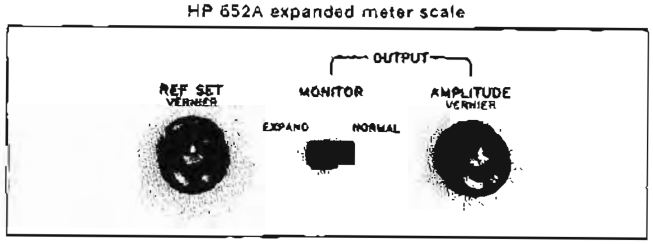
Note: other output impedances above 50Ω are available.

Description

The HP Model 652A also incorporates an expandable output monitor for amplitude control to 0.25% across the band.



HP 652A expanded meter scale



HP 652A output controls

HP 652A Specifications

(Same as Model 651B except as indicated below)

Expand scale: expands reference voltage of the Normal Scale from 0.9 to 1.0 or 2.8 to 3.2.

Flatness (Amplitude readjusted using expanded scale on output monitor): ±0.25% 3 V and 1 V range; ±0.75% 0.3 V to 0.3 mV range; ±1.75% 0.1 mV range.

Accessories furnished: HP 11048B 50Ω feed-thru termination; rack mounting kit.

Price: HP 652A, $725.

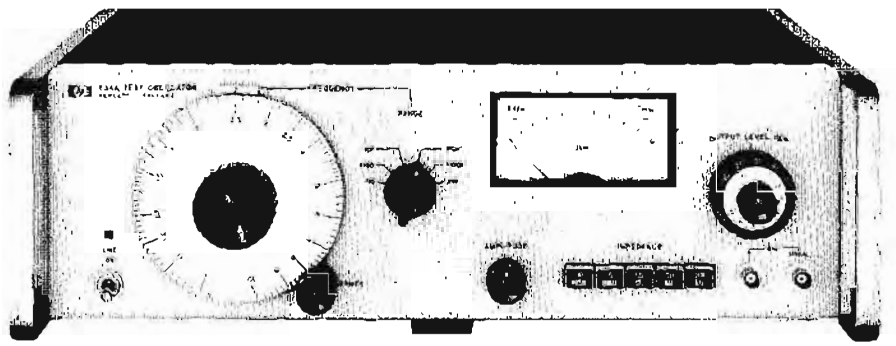
(refer to page 198 for calibration system)

*The response above 1 MHz at 600Ω output is affected by capacitive loads.

TEST OSCILLATOR

Balanced, unbalanced outputs of 50Ω to 600Ω

Model 654A



654A

Features:

Flatness of ±0.5% from 10 Hz to 10 MHz.
Output levels from +11 dBm to −90 dBm.
Selectable balanced outputs.

Uses:

Research laboratories
Communications industries
Production testing

Description

The 654A Test Oscillator is a lightweight, portable solid-state signal source. Its 10 Hz to 10 MHz frequency band, amplitude stability, accuracy and level flatness make it an ideal general purpose test oscillator. The selective outputs of 50Ω, 75Ω unbalanced and 135Ω, 150Ω, 600Ω balanced make it useful in electronic research laboratories, in production testing, and as a commercial test instrument.

Other balanced outputs can be obtained by special order to replace the ones in the standard instrument. These balanced outputs have many uses in the communications industry. With the balanced outputs within the 654A itself, the use of external balance transformers is eliminated.

The meter is zero centered and reads in dBm. The expanded meter scale from −1 dBm to +1 dBm gives good resolution on all ranges from −80 dBm to +10 dBm.

Tentative Specifications

Frequency range: 10 Hz to 10 MHz in 6 bands.

Frequency accuracy: 100 Hz to 5 MHz, ±2%; 10 Hz to 5 MHz, ±3%; 10 Hz to 10 MHz, ±4%.

Level flatness (+10 dBm and 0 dBm): ±0.5% from 10 Hz to 10 MHz; (10 Hz to 1 MHz for balanced outputs).

Output impedance: 50Ω unbalanced, 75Ω unbalanced; 135Ω balanced, 150Ω balanced and 600Ω balanced.

Output level: +11 dBm to −90 dBm, 10 dB and 1 dB steps with adjustable ±1 dB meter range; calibrated for each impedance.

Amplitude control: >2 dB.

Overall attenuator accuracy: ±1.5% (0.15 dB) except ±10% (1 dB) at output levels below −60 dBm at frequencies greater than 300 kHz.

Meter range: ±1 dBm full scale.

Meter resolution: 0.02 dB.

Meter tracking: ±0.05 dB.

Balance (on balanced impedances): >50 dB for frequencies from 10 Hz to 1 MHz.

Distortion (THD):
10 Hz to 1 MHz, >40 dB below fundamental.
1 MHz to 10 MHz, >34 dB below fundamental.

Hum and noise: >70 dB down at full output.

Output connectors: BNC. Maximum voltage which can be applied to the output: <±3 V peak.

Counter output: >0.1 V rms into 50Ω; BNC connector.

Operating temperature: 0°C to +55°C (32°F to 130°F).

Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, 30 W nominal, 35 W max.

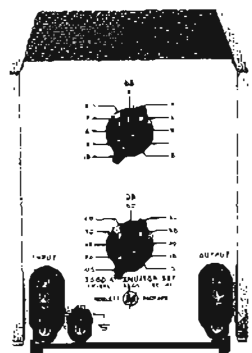
Dimensions: 16¾" wide, 5" high (without removable feet), 11¼" deep (425 x 127 x 286 mm).

Weight: net 21 lb (9,5 kg); shipping 26 lb (11,8 kg).

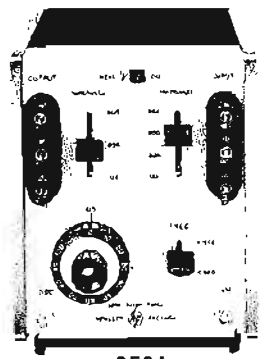
Accessories furnished: rack mounting kit for 19" rack.

Price: HP 654A, $875.

ATTENUATORS, ACCESSORIES
Match 900, 600, 500 or 135-ohm lines
Models 350C,D, 353A, 11004A, 11005A



350D



353A

HP 353A Patch Panel

This Patch Panel contains a precision attenuator variable in 1 dB steps to 110 dB and two sets of impedance matching transformers. One set of transformers matches 900 ohm, 600 ohm or 135 ohm lines. The other set of transformers terminates the line in 900 ohms, 600 ohms, 135 ohms or in 10 k ohms for bridging measurements. Refer to page 321 for specifications.

HP 350C, 350D Attenuators

When a high order of accuracy, wide frequency response, large power-handling capacity or special features are required, HP 350 Series Attenuators are of great value and convenience. They are particularly useful in attenuating output of audio and ultrasonic oscillators, measuring gain and frequency response of amplifiers, measuring transmission loss and increasing the scope and usefulness of other laboratory equipment.

350C/D Specifications

Attenuation: 110 dB in 1 dB steps.

Accuracy: 10 dB section:

	0 dB — 10 dB
dc to 100 kHz	$<\pm0.125$ dB/step
100 kHz to 1 MHz	$<\pm0.25$ dB/step

Accuracy: 100 dB section:

	0 dB — 70 dB	70 dB — 100 dB
dc to 100 kHz	$<\pm0.25$ dB	$<\pm0.5$ dB/step
100 kHz to 1 MHz	$<\pm0.5$ dB	$<\pm0.75$ dB/step

Power capacity: 350C, 500 ohms; 5 W (50 Vdc or rms) maximum, continuous duty. 350D, 600 ohms; 5 W (55 Vdc or rms) maximum, continuous duty.

DC Isolation: signal ground may be ±500 Vdc from external chassis.

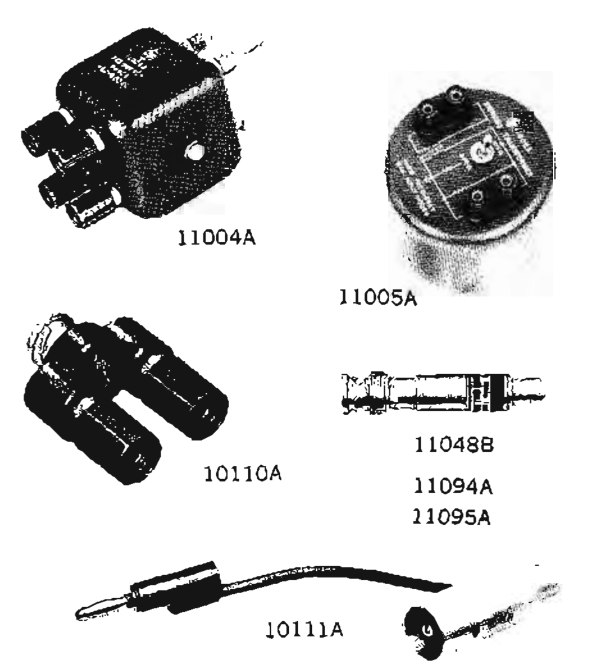
Dimensions: 5⅛" wide, 6¼" high (without removable feet), 8" deep (130 x 159 x 203 mm).

Weight: net 4 lbs (1,8 kg); shipping 5 lbs (2,3 kg).

Accessories available: HP 11000A Cable Assembly, 44" of RG-58C/U 50Ω coaxial cable terminated by dual banana plugs, $5. HP 11001A Cable Assembly, as above but with one BNC male connector, $6. 11075A Carrying Case (refer to pages 227 and 228), $45.

Price: HP 350C; 500Ω attenuator, $140. HP 350D; 600Ω attenuator, $140.

Oscillator Accessories



11004A

11005A

10110A

11048B

11094A

11095A

10111A

11004A Line-Matching Transformer

The 11004A Transformer, with a frequency response between 5 kHz and 600 kHz, provides fully balanced 135 or 600Ω output from single-ended input. Maximum level +22 dBm. HP 11004A, $60.

11005A Line-Matching Transformer

The 11005A Transformer, with a frequency response between 20 Hz and 45 kHz, provides a fully balanced 600Ω output from single-ended input. Maximum level is +15 dBm. HP 11005A, $80.

10110A, 10111A BNC-to-Binding-Post Adapters

These adapters mate with a BNC or binding post receptacle, respectively, and provide either binding post or BNC output connectors. The 10110A is a BNC male-to-binding-post adapter; the 10111A is a BNC female-to-banana-plug adapter. Spacing between binding posts is ¾". HP 10110A, $5; HP 10111A, $7.

11048B 50-ohm Feed Thru **11094A 75-ohm Feed Thru**
11095A 600-ohm Feed Thru

Precision feed-thru termination with male and female connectors. HP 11048B, $10; HP 11094A, $10; HP 11095A, $10.

SIGNAL GENERATORS TO 40 GHz

Signal generators

Hewlett-Packard offers a complete line of easy-to-use HF, VHF, UHF, and SHF signal generators, precision instruments covering frequencies between 50 kHz and 40 GHz. Each Hewlett-Packard generator incorporates the following:

(1) accurate, direct-reading, frequency calibration

(2) variable output, accurately calibrated and direct reading

(3) constant output impedance, well matched

(4) varied modulation capabilities

(5) low RF leakage

(6) low harmonic content

(7) freedom from spurious or incidental modulation.

This ensures the utmost convenience and accuracy for all kinds of measurements, including receiver sensitivity, selectivity or rejection, signal-to-noise ratio, gain bandwidth characteristics, conversion gain, antenna gain, transmission line characteristics, as well as power to drive bridges, slotted lines, filter networks, etc.

Sweeping signal generators

A result of Hewlett-Packard thin film and hybrid microcircuit technology, the 8601A Generator/Sweeper is one of a new breed of signal generators that also sweep. Signal generator characteristics are summarized in Table 1. Intended to be a general purpose instrument, the 8601A also satisfies many specialized test and design applications. Some examples are: component test, attenuation and insertion loss; use with VSWR bridges and hybrid detectors; measurement of adjacent channel interference and spurious responses. From 10 kHz to 32 MHz, the 675A Sweep Signal Generator also offers many convenient features, as described on Page 386.

HF to UHF signal generators

These signal generators, including HP 606B, 608E, 608F, and 612A, collectively cover frequencies from 50 kHz to 1.23 GHz and are characterized by extremely low drift and incidental frequency modulation. All may be amplitude (sine, square, pulse) modulated. A feedback loop in the 606B keeps its output and

Table 1

Model	Frequency range	Characteristics	Page
606B Signal Generator	50 kHz to 65 MHz	output 3 V to 0.1 μV, mod. BW dc to 20 kHz, low drift and noise, low incidental FM, low distortion, auxiliary RF output, stabilized phase lock capability	388
8601A Generator Sweeper	100 kHz to 110 MHz	$\pm$1% of frequency dial accuracy, cal output +20 to −110 dBm into 50 ohms, leveled to $\pm$0.25 dB full range, very low drift, residual FM and RFI leakage, 30% AM, 75 kHz dev FM, aux output, crystal cal	387
608E Signal Generator	10 to 480 MHz	output 1 V to 0.1 μV, into 50-ohm load; AM, pulse modulation, direct calibration, leveled power output, aux RF output	392
608F Signal Generator	10 to 455 MHz	output 0.5 V to 0.1μV into 50 ohms, amplitude, pulse modulation, direct calibration, low incidental FM and drift, leveled output, aux RF output, stabilized phase lock capability	392
8708A Synchronizer	50 kHz to 455 MHz	Companion for 606B or 608F permitting 2/10^7 continuous settability & stability, FM and phase modulation	394
612A Signal Generator	450 to 1230 MHz	output 0.5 V to 0.1 μV into 50-ohm load; AM, pulse or square-wave modulation, direct calibration	397
614A Signal Generator	0.8 to 2.1 GHz	output at least 0.5 mW to −127 dBm (0.1 μV) into 50 ohms, pulse or frequency modulation, direct calibration	400
8614A Signal Generator	0.8 to 2.4 GHz	output +10 to −127 dBm into 50 ohms, leveled below 0 dBm; internal square-wave; external pulse, AM and FM; auxiliary RF output	398
8614B Signal Source	0.8 to 2.4 GHz	output 15 mW; precision attenuator 130 dB range; internal square-wave, external pulse and FM; auxiliary RF output	398
616B Signal Generator	1.8 to 4.2 GHz	output 1 mW to −127 dBm (0.1 μV) into 50-ohm load, pulse or frequency modulation, direct calibration	400
8616A Signal Generator	1.8 to 4.5 GHz	output +3 to −127 dBm into 50 ohms, leveled below 0 dBm; internal square-wave, external pulse, AM and FM; auxiliary RF output	398
8616B Signal Source	1.8 to 4.5 GHz	output 3 mW; precision attenuator 130 dB range; internal square-wave, external pulse and FM; auxiliary RF output	398
618C Signal Generator	3.8 to 7.6 GHz	output 1 mW to −127 dBm (0.1 μV) into 50 ohms, pulse, frequency or square-wave modulation, direct calibration, ext FM and pulse modulation, auxiliary RF output	402
620B Signal Generator	7 to 11 GHz	output 1 mW to −127 dBm (0.1 μV) into 50 ohms, pulse, frequency or square-wave modulation, direct calibration, ext FM and pulse modulation, auxiliary RF output	402
626A Signal Generator	10 to 15.5 GHz	output +10 dBm to −90 dBm; pulse, frequency or square-wave modulation, direct calibration	404
628A Signal Generator	15 to 21 GHz	output +10 dBm to −90 dBm; pulse, frequency or square-wave modulation, direct calibration	404
938A Frequency Doubler	18 to 26.5 GHz	driven by 9 to 13.25 GHz source, HP 626A, 8690B or klystrons; 100 dB precision attenuator	406
940A Frequency Doubler	26.5 to 40 GHz	driven by 13.25 to 20 GHz source, HP 628A, 8690B or klystrons; 100 dB precision attenuator	406

percent modulation constant as frequency is varied. The 608E and 608F also offer level power output resulting in significant time saving as well as operator convenience when the generator is being used to conduct tests at several frequencies. The 606B, 608E, and 608F offer an auxiliary RF output. This fixed-level CW signal can be applied to an HP 5245L Counter for very accurate indication of carrier frequency.

Stabilized RF signal generation

The HP 606B and 608F contain voltage variable capacitors in their oscillator tank circuit enabling phase-locked operation with the HP Model 8708A RF Synchronizer obtaining $2/10^{7}$ settability and stability. Phase-locked operation of the HP 606B and 608F Signal Generators can be obtained without compromise of the instruments' modulation or attenuation characteristics while phase-locked. The HP 8708A Synchronizer enables continuous tuning between lock points, permitting continuous frequency response examination of devices such as highly-selective, steep-skirt, narrow-band filters. The HP 8708A Synchronizer provides the additional benefit of phase and frequency modulation capability with the 606B and 608F signal generators.

Signal sources above 10 MHz

Signal generators available from Hewlett-Packard include general-purpose oscillators and amplifiers, FM signal generators, and specialized signal generators for aircraft navigation systems.

The 3200B VHF Oscillator is a compact, versatile source in the 10 to 500 MHz range suitable for driving bridges and slotted lines, and for general-purpose laboratory work. The 230A Signal Generator Power Amplifier provides a convenient means of obtaining power levels up to 4.5 watts in the 10 to 500 MHz range when operated in conjunction with a signal generator.

HP's FM signal generators offer unusual modulation linearity and stability. The 202H FM-AM Signal Generator operates in the 54 to 216 MHz range and is designed to serve the broadcast FM, VHF-TV, and mobile communications markets. The 202J Telemetering Signal Generator is specifically designed for VHF telemetry and covers the 195 to 270 MHz frequency range. An accessory 207H Univerter provides additional RF and IF coverage when used with either the 202H or 202J Signal Generators.

The 211A Signal Generator is specifically designed for the testing and calibration of aircraft VOR omni-range and ILS localizer receivers; an external modulator, such as the Collins 479-F3, is required to provide simulated course and bearing. The 232A Glide Slope Signal Generator is specifically designed for the testing and calibration of ILS glide slope receivers. The 8925A DME/ATC Test Set is designed to provide complete facilities for the testing and calibration of aircraft DME radios and ATC transponders; suitable external modulators are required, such as the Collins 578D-1 and 578X-1, to simulate ground station operation.

Special purpose signal sources

Application	Frequency range	Modulation	Output	Model	Page
Down converter for 202H	100 kHz to 55 MHz	See specifications		207H	391
Test, calibrate FM receivers	54 to 216 MHz	FM, AM	0.2 V	202H	390
Telemetry tests	1430 to 1540 MHz 2150 to 2310 MHz	FM	−10 to −127 dBm	3205A	407
VOR/ILS tests	88 to 140 MHz	AM	0.2 V	211A	409
ILS tests	329.3 to 335 MHz	AM	0.2 V	232A	
DME/ATC tests	962 to 1213 MHz	Pulse	−10 dBm	8925A	408
Receiver, Transmitter Tests	5280 to 7780 MHz[1]	FM, AM	1 mW	623B	401
	7100 to 8500 MHz	FM, AM	31.6 mW	5636	
	8500 to 10,000 MHz	FM, AM	1 mW	624C	

[1] Not continuous coverage, see specifications.

UHF to SHF signal generators and sources

This group of instruments, covering 800 MHz to 21 GHz, features extremely simple operation. The 614A, 616B, 618C, 620B, 626A and 628A Signal Generators provide large, direct-reading frequency and attenuator dials. They may be pulse, square-wave, and frequency modulated. Their versatility makes them useful for measuring signal-to-noise ratio, receiver sensitivity, SWR and transmission line characteristics.

The HP 8614A and 8616A Signal Generators are particularly easy to use. Frequency and attenuation are set on direct-reading digital dials, and push-buttons permit fast, easy selection of function (CW, square-wave modulation or external amplitude, pulse or frequency modulation). Leveled output enables frequency response testing without time-consuming readjustment of the generator at each new frequency. Each unit contains a unique PIN diode modulator which permits such a wide range of amplitude modulation that remote control of output level or precise leveling with external equipment is possible.

The 8614B and 8616B Signal Sources can be used in many applications previously requiring signal generators. The sources have precision attenuators for relative measurements such as insertion loss, and they have pulse and square-wave capability.

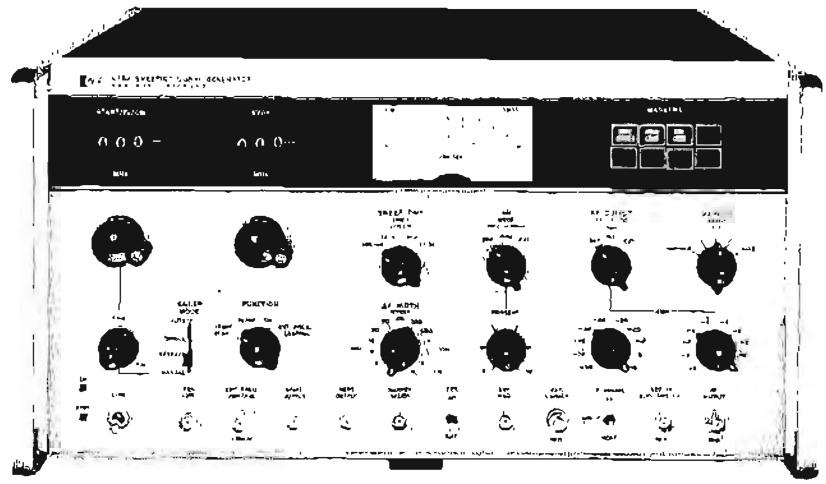
Frequency doublers

Broadband frequency doublers, HP 938A and 940A, provide low-cost signal generator capability in the 18 to 40 GHz range. Designed to be driven by signal sources in the 9 to 20 GHz range, the frequency doublers preserve the versatility and stability of the driving source. Thus, the signals may be CW, pulsed or swept. An output monitor and precision attenuator provide a metered output, even though the input signal is uncalibrated.

SWEEP SIGNAL GENERATOR

Programmable; Freq. range: 10 kHz to 32 MHz

Model 675A



675A

Signal Generator (CW)

The CW dial accuracy, low residual and spurious FM, low distortion at all voltage levels, and excellent frequency settability make it ideal for signal generator applications. The CW signal can be internally amplitude modulated by a 1 kHz ±15 Hz sine wave with percentage modulation adjustable up to 50%. External amplitude modulation and frequency modulation (ext. freq. control) provide added versatility for communications receiver and transmitter testing. Refer to pages 417 and 418 for sweeper specifications. Refer to page 466 for network analyzer specifications.

Specifications

Frequency range: 10 kHz to 32 MHz in one range.

Output: maximum +13 dBm (1 V rms into 50Ω, 2 V rms open circuit); continuously adjustable; impedance, 50Ω.

RF Flatness	10 kHz	50 kHz	200 kHz	1MHz	10 MHz	32 MHz
Unleveled:	±1 dB					
Internally leveled:		±1 dB	±0.15 dB			
Externally leveled:	±0.15dB					

System Flatness

Using internal RF Detector, internally leveled:	10 kHz	50 kHz	200 kHz	10 MHz	32 MHz
	± 1 dB	±0.4 dB	±0.25 dB		

Using External RF †Detector, Externally leveled: ††	10 kHz	100 kHz	1 MHz	10 MHz	32 MHz
	±0.25 dB*				

Internal Detector Output (Vertical): at least 1.2 V dc for 1 V rms.

Signal Generator Functions

CW dial accuracy: ±0.5% of full scale (+20°C to +40°C). ±1% of full scale (0 to +20°C, +40°C to +50°C).

CW settability: 1 kHz.

CW resolution: 20 kHz.

Internal AM: 0 to 50% sinusoidal, 985 to 1015 Hz continuously adjustable.

External AM: 0 to 50%, dc to 1 kHz leveled; 0 to 50%, 50 Hz to 600 kHz unleveled.

Sensitivity: at least 50% for 2 V to 5 V rms input.

†, †† refer to accessories

*0 dB reference is point midway between max. p-p deviation.

External frequency control and external FM

Sensitivity: 1 MHz/V.

Input impedance: 1 MΩ.

Rate: dc to 4 kHz. Above 4 kHz the range and sensitivity decreases 20 dB/decade.

Attenuator

Range: 99 dB in 10 and 1 dB steps.

Accuracy: ±0.3 dB, +10 dB to −12 dB; ±0.4 dB, −13 dB to −89 dB; +6 μV constant error.

Output monitor

Range: −3 to +3 dB (0.5 V to 1 V).

Accuracy: ±0.3 dB, 200 kHz to 32 MHz.

Counter output: >300 mV rms.

Distortion

Harmonic: >30 dB down from fundamental.

Spurious: >50 dB down from fundamental.

Residual (line related) FM: <70 Hz peak.

Spurious FM: <60 Hz rms.

Auxiliary output (rear panel): 100 MHz to 132 MHz unleveled.

General

Temperature range: 0° to +50°C.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 80 W max.

Dimensions: 16¾″ wide, 8¼″ high (without removable feet), 18⅜″ deep (425 x 210 x 467 mm).

Weight: net 46 lbs (20,8 kg); shipping 51 lbs (23,2 kg).

Accessories furnished: HP 11048A 50Ω Feed-Thru Termination; rack mount kit for 19″ rack.

Accessories available

HP 11300A Single-Frequency Marker (frequency must be specified), $75 (additional $25 for those factory installed).

†HP 11097A RF Detector, $30.

††HP 11098A Leveling Detector, $30.

HP 676A Phase/Amplitude Detector (see page 419).

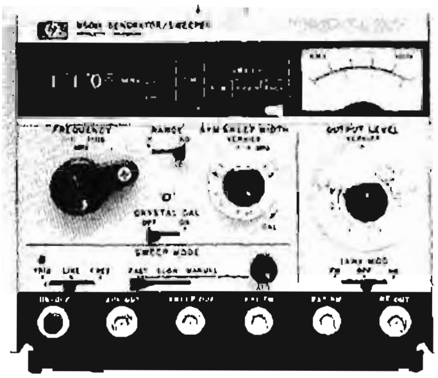
Price: HP 675A, $2250.

Option 01: 1 MHz harmonic comb marker, add $75.

Option 02: 100 kHz harmonic marker, add $75.

Option 03: 100 kHz and 1 MHz harmonic markers, add $125.

GENERATOR/SWEEPER
A general-purpose production and lab tool
Model 8601A



8601A

Signal generator performance

The 8601A offers excellent CW characteristics with ±1% of frequency dial accuracy and a wide range of continuously adjustable output power levels accurate to ±1 dB from +13 dBm to −110 dBm. A power output meter is calibrated in both dBm and rms volts into 50 ohms. These features and low RFI leakage mean that receiver sensitivity can be measured at 1 microvolt with ease. In addition, flatness (power output versus frequency) is better than ±0.25 dB over the entire band and ±0.1 dB over any 10-MHz portion from 1 to 110 MHz. Many other signal generator applications can also be satisfied by the 8601A because of its low noise output—more than 70 dB down in a 1-kHz bandwidth.

A unique AM marker system built into the automatic leveling circuit provides 0.01% frequency identification at 5-MHz intervals. The frequency vernier with ±0.1% of frequency variation and the AUX output signal that's always between 100 kHz - 11 MHz regardless of band allow 2-kHz settability on high band (200-Hz on low band) when used with the H01-5321A low-frequency counter.

A small amount of modulation is available at the flick of a switch to provide a convenient test situation. For example, discriminator sensitivities to AM and FM can be checked without the use of a an external oscillator. 30% AM and 75 kHz deviation FM (7.5 kHz on low band) are provided by an internal 1-kHz oscillator. External AM and full band external FM allow the 8601A to be programmed in both frequency and amplitude.

Design

Superior frequency-lock circuits keep residual FM very low (less than 500 Hz peak on high band, 50 Hz peak on low band), enabling CW-mode stability comparable to many nonsweeping signal generators on the market today. Voltage-tuned oscillator nonlinearities are avoided by a feedback loop that contains a very linear pulse count discriminator. The discriminator output voltage is compared to a command voltage in a differential amplifier whose output controls the frequency of the VTO to obtain an ultra-linear voltage-to-frequency characteristic. Furthermore, the bandwidth of the frequency control loop is reduced for CW and manual operation on the high band to improve spectral quality. A calibrated precision potentiometer across an extremely stable power supply provides a low-noise tuning voltage.

Major Specifications
8601A utilized as a generator

(Refer to *complete* specifications on pages 420-421)

Frequency characteristics

Coverage: low range, 0.1-11 MHz; high range, 1-110 MHz.

Accuracy: (In CW).

Low range, ±1% of frequency or ±10 kHz, whichever is greater.

High range, ±1% of frequency or ±100 kHz, whichever is greater.

Settability: vernier settability, ±0.01%; vernier range, ±0.1%; coarse settability using 10-turn pot is 5 kHz, low range; 50 kHz, high range.

Drift in CW:

(0.01% +500 Hz)/10 min, high range, after 1 hr warmup.

(0.01% +50 Hz)/10 min, low range, after 1 hr warmup.

0.025%/°C temperature change.

0.001%/V line voltage change.

Less than 5 min to stabilize for any frequency change on each band.

Harmonics and spurious signals (CW above 250 kHz, +10 dBm on the +10 dBm attenuator step or below): harmonics at least 35 dB below carrier. Spurious signals at least 40 dB below carrier.

Residual FM in CW:

Line related components:

Less than 50 Hz peak, low range.

Less than 500 Hz peak, high range.

Incidental FM with 30% AM:

Less than 100 Hz peak, low range.

Less than 1 kHz peak, high range.

Incidental FM in CW is negligible.

Residual AM: AM noise modulation index (rms, 10 kHz bandwidth) is <−50 dB. (Typically −60 dB at 25°C.)

Incidental AM: incidental AM modulation index is <−55 dB with 75 kHz deviation.

Output characteristics

Level: +20 to −110 dBm. 10-dB steps and 13-dB vernier provide continuous settings over entire range. Meter monitors output in dBm and rms volts into 50Ω.

Accuracy: ±1 dB accuracy for any output level from +13 dBm to −110 dBm.

Flatness: ±0.25 dB over full range, ±0.1 dB over any 10-MHz portion.

Amplitude modulation

Internal AM: 30% ±5% at 1 kHz, less than 3% distortion. Typically <1% distortion for output readings on upper half of meter scale.

External AM: 0 to 50%, up to 400 Hz. 0 to 30%, up to 1 kHz. Applied through external AM input on front panel. Sensitivity typically 2 V peak/10% modulation index at 400 Hz (10-50% AM).

Frequency modulation

Internal FM: high range: 75 kHz ±20% peak deviation, 1-kHz rate; low range: 7.5 kHz ±20% peak deviation, 1-kHz rate; less than 3% distortion. Typically <1%.

External FM: sensitivity: 5 MHz per volt ±5%, high range; 0.5 MHz per volt ±5%, low range; negative polarity.

Deviations to the band edges are possible for rates to 100 Hz; voltage-to-frequency linearity is ±0.5%, allowing remote frequency programming. FM rates to 10 kHz are obtainable with less linearity and accuracy.

Crystal calibrator

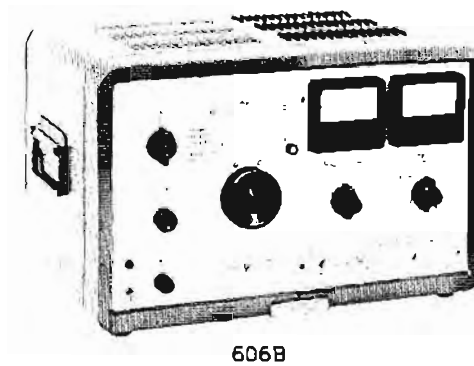
Internal 5-MHz crystal allows frequency calibration to ±0.01% at any multiple of 5 MHz.

Price: Model 8601A, $1,975.00.

HF SIGNAL GENERATORS

New convenience and performance 50 kHz-65 MHz

Models 606B, 606A



606B

Description

The Hewlett-Packard 606B Signal Generator provides you with high quality, versatile performance with distinctive ease of operation in the important and widely used 50 kHz to 65 MHz frequency range. Output signals are stable and accurately known, output amplitude can be precisely established over a very wide dynamic range, and versatile modulation capabilities are incorporated to satisfy virtually all measurement requirements. Convenient size and shape, together with a simple, straightforward control panel layout, make the 606B well suited for production line use as well as laboratory or field applications.

Design

The 606B is a master oscillator-power amplifier (MOPA) design with a broadband buffer amplifier stage between the oscillator and power amplifier circuits for isolation. The MOPA design permits optimization of the oscillator circuit for highest stability including low drift, minimum residual FM, low harmonics, etc., without restricting the modulation characteristics. Modulation is applied to the power amplifier circuit with negligible effect on the oscillator frequency (because of the buffer stage). Very fine frequency settability is achieved through incorporation of a ΔF control which provides better than 10 ppm resolution.

Highest frequency stability

While the basic frequency stability of the 606B is excellent (less than 0.005% drift over a 10-minute period after warm-up), the inclusion of frequency control circuitry in the 606B makes it possible to achieve 250 times greater stability by phase-locking the 606B with the HP 8708A Synchronizer. The 8708A, which is fully compatible with the 606B in every respect, can stabilize the 606B at any frequency (not just at discrete points) with a resultant stability of 2×10^{-7}/10 minutes and a very high degree of spectral purity. The combination of the 606B and 8708A also permits you to perform narrow band frequency- or phase-modulation of the 606B carrier with very low modulation distortion. The 8708A is described on page 395.

Simplified operation

An outstanding feature of the 606B is the employment of feedback in the RF power amplifier section which results in superior performance characteristics and true ease of operation. The feedback circuit maintains both the output level and the percentage of modulation essentially constant over the entire frequency range, thus making it unnecessary to readjust controls when changing the operating frequency. The use of feedback also enables you to change the output level without affecting the degree of modulation. The constant output, constant modulation feature results in significant time saving as well as operator convenience, making the 606B an ideal choice for production line operations where semi-skilled personnel can make meaningful measurements.

Versatile amplitude modulation

The use of feedback in the power amplifier section also yields excellent amplitude modulation characteristics. Up to 95% modulation can be achieved with modulating frequencies ranging from dc to 20 kHz. Envelope distortion is very low, less than 1% at 30% AM and less than 3% at 70% AM; this allows you to make more accurate measurements of the distortion characteristics on receivers or detectors. Internal modulation oscillators of 400 Hz and 1000 Hz are provided, and the modulation percentage can be set and read directly on the accurate front panel modulation meter. The wide modulation bandwidth (dc to 20 kHz) means the 606B may be modulated with square waves or other complex signals including tone-burst modulation, or you can remotely program the output amplitude. The buffer stage between the master oscillator and power amplifier holds incidental FM with AM to a minimum, ensuring accurate measurements.

Accurate output level

The output level from the 606B is continuously adjustable from 3 volts to 0.1 microvolts rms into a 50 ohm load. Direct calibration is provided in both volts and dBm (+23 to −120 dBm) and the output calibration is accurate to within 1 dB at any frequency or level setting. The output system of the 606B is a well matched 50 ohm circuit which minimizes mismatch ambiguities as a factor in overall measurement accuracy. The extremely wide range of output amplitude control makes the 606B very useful for driving bridges and filters as well as complete receiver measurements including sensitivity, selectivity, and image rejection.

The 606B provides an auxiliary RF output; this fixed level (100 millivolts rms minimum) CW signal is for use with the 8708A Synchronizer and can also be applied to an HP 5245L Counter for very accurate indication of carrier frequency. Using the auxiliary RF output does not place any restriction on the modulation capabilities nor on the main RF output level. The 606B also contains a crystal calibrator to provide accurate frequency checkpoints at every 100 kHz or 1 MHz throughout the frequency range of the instrument.

Specifications, 606B

Frequency characteristics

Range: 50 kHz to 65 MHz in 6 bands (50-170 kHz, 165-560 kHz, 0.53-1.8 MHz, 1.76-6 MHz, 5.8-19.2 MHz, 19-65 MHz); total scale length approximately 95 in.

Accuracy: ±1%.

Drift: (attenuator on 1 volt range and below) less than 50 parts in 10^6 (or 5 hertz, whichever is greater) per 10 minute period after 2-hour warmup; less than 10 minutes to restabilize after changing frequency.

Stability when used with 8708A Synchronizer: 5 x 10^{-8}/minute, 2 x 10^{-7}/10 minutes, 2 x 10^{-6}/day; 2 x 10^{-7}/°C, 0° to 55°C; 2 x 10^{-7}/10% line voltage change.

Resettability: vernier control resettability better than 0.15% after initial warmup.

ΔF control: ultra-fine frequency vernier provides better than 10 parts in 10^6 settability; total range of ΔF control approximately 0.1%.

Crystal calibrator: provides frequency checkpoints every 100 kHz and 1 MHz; headphone jack provided for audio frequency output (headphone not included); crystal frequency accuracy better than 0.01% from 0° to 50°C; cursor on frequency dial adjustable over small range to aid in interpolation adjustment; calibrator may be turned off when not in use.

Residual FM: less than ±1 part in 10^6 or ±20 hertz, whichever is greater.

Frequency control input: BNC female connector for "frequency control output" from 8708A Synchronizer; can also be used for external frequency control: voltage change from —2 to —32 volts changes frequency approximately 0.2% at low end of each band and approximately 6% at high end; nominally 4 kΩ input impedance, direct-coupled; voltage limits: 0 volt ≤applied voltage ≤50 volts negative.

Output level: continuously adjustable from 0.1 microvolt to 3 volts into 50-ohm resistive load; output attenuator calibrated in 10-dB steps from 3 volt full scale to 1.0 microvolt full scale (into 50 ohms), also calibrated in dBm (0 dBm=1 milliwatt in 50 ohms); vernier control provides continuous adjustment of voltage between full scale ranges; output level indicated on RF output meter calibrated in volts (0 to 1 and 0 to 3 volts) and dBm (—10 to +3 dBm).

Frequency response and output accuracy (attenuator range 1 volt and below; 50-ohm resistive load): at any output voltage setting, output level variation with frequency change is less than 2 dB, total, across entire frequency range; output accuracy better than ±1 dB at any frequency.

Impedance: 50 ohms, SWR less than 1.2 on 0.3 volt attenuator range and below.

RFI: meets all conditions specified in MIL-I-6181D; permits receiver sensitivity measurements down to at least 1.0 microvolt.

Harmonic output: at least 30 dB below the carrier.

Spurious AM: hum and noise sidebands are 70 dB below carrier down to thermal level of 50 ohm output system.

Auxiliary RF output: fixed level CW signal from RF oscillator provided at front panel BNC female connector for use with HP 8708A Synchronizer or other external equipment (e.g., frequency counter). Minimum output: 100 mV rms into 50 ohms from 50 kHz to 19.2 MHz, 200 mV rms from 19 to 65 MHz.

Modulation characteristics

Internal AM:

Frequency: 400 and 1000 Hz, ±5%; modulation signal available at front panel BNC female connector for synchronization of external equipment.

Modulation level: 0 to 95% on 1 volt range and below; 0 to at least 30% on 3 volt range.

Carrier envelope distortion: less than 1% at 30% AM; less than 3% at 70% AM (attenuator on 1 volt range and below).

Incidental frequency modulation (attenuator on 1 volt range and below, 30% modulation): less than 5 x 10^{-8} + 100 Hz peak.

External AM:

Frequency: dc to 20 kHz maximum, dependent on carrier frequency (f_c) and percent modulation as tablulated:

Maximum modulation frequency:

30% Mod:
0.06 f_c;
70% Mod:
0.02 f_c;
Squarewave Mod:
0.003 f_c (3 kHz max).

Modulation level: 0 to 95% on 1 volt attenuator range and below, 0 to at least 30% on 3 volt range.

Input required: 4.5 volts peak produces 95% modulation (maximum input 50 volts peak); input impedance 1000 ohms.

Carrier envelope distortion: less than 1% at 30% AM, less than 3% at 70% AM (attenuator on 1 volt range and below).

Modulation meter accuracy: ±5% of full scale, 0 to 90%, for modulation frequencies to 10 kHz, ±10% of full scale for frequencies from 10 kHz to 20 kHz.

Modulation level constancy (internal or external AM; attenuator on 1 volt range and below): modulation level stays constant within ±½ dB regardless of carrier frequency and output level changes.

General

Power: 115 or 230 V ±10%, 50 to 400 Hz, 135 W.

Dimensions: cabinet mount, 20¾" wide, 12½" high, 14¾" deep. (527 x 318 x 370 mm).

Weight: cabinet mount, net, 55 lb (24,8 kg); shipping, 65 lb (29,3 kg); rack mount, net, 50 lb (22,5 kg); shipping, 63 lb (28,4 kg).

Accessories available:

11507A Output Termination, provides 3 positions: 50 ohms (for use into high impedance); 5 ohms (10:1 voltage division); IEEE Standard Dummy Antenna (driven from 10:1 divider); price, $70.

11509A Fuse Holder, provides protection for output attenuator when 606B is used for transceiver tests; price, $25.

10514A Mixer, for use as nanosecond pulse modulator; price, $95.

Price: Model 606B (cabinet mount), $1550; Model 606BR (rack mount), $1535.

Model 606A

The Model 606A covers the same frequency ranges as the 606B, but does not include the frequency control input feature that allows frequency stabilization by the Model 8708A Synchronizer. Model 606B specifications apply to the 606A with the following exceptions: an auxiliary uncalibrated RF output is not included; harmonic output is less than 3%; the crystal calibrator provides check points at 100 kHz (useful to 6 MHz) and 1 MHz intervals; output power level frequency response is ±1 dB over the entire frequency range.

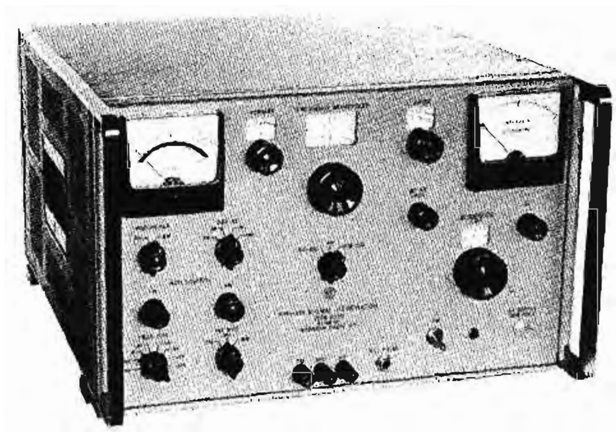
Price: HP 606A (cabinet), $1450; HP 606AR (rack mount) $1435.

FM-AM SIGNAL GENERATOR

FM, AM, CW and pulse coverage 54 to 216 MHz

Model 202H

The HP 202H FM-AM Signal Generator covers the frequency range from 54 to 216 MHz and is designed for the testing and calibration of FM receiving systems in the areas of broadcast FM, VHF, TV, mobile and general communications. The generator consists of a three-stage RF unit, together with a modulating oscillator and power supply, all housed in a single cabinet which may be readily adapted for rack mounting.



202H

Specifications

Radio frequency characteristics

RF range: total range: 54 to 216 MHz; number bands: 2; band ranges: 54 to 108 MHz 108 to 216 MHz.

RF accuracy (after 1 hour warm-up): main dial: ±0.5%; electronic vernier: ±(10% + 1 kHz).

RF stability: <0.01% per hour (after two hour warm-up).

RF output: range: 0.1 μV to 0.2 V (across external 50-ohm load at panel jack); accuracy: ±10%, 0.1 μV to 50 K μV; ±20%, 50 K μV to 0.2 volts; auto level set: holds RF monitor meter to "red line" over band.

Impedance: 50 ohms.

VSWR: <1.2.

Spurious output: All spurious RF output voltages are at least 30 dB below desired fundamental.

RF leakage: sufficiently low to permit measurements at 0.1 μV.

Amplitude modulation characteristics

AM range: internal: 0 to 50%; external: 0 to 100%.

AM accuracy: ±10% of reading at 400 Hz at 30% and 50% AM.

AM calibration: 30, 50, 100%.

AM distortion: <5% at 30%, <8% at 50%, <20% at 90%.

AM fidelity: ±1 dB, 30 Hz to 200 kHz.

External AM requirements: approximately 60 volts rms into 500 ohms for 100% AM.

Frequency modulation characteristics

FM deviation range: internal or external, 0 to 250 kHz in 4 ranges.

FM deviation accuracy: ±5% of full-scale (for 400 Hz sine wave).

FM calibration: 0 to 7.5 kHz in increments of 0.5 kHz, 0 to 25 kHz in increments of 1 kHz, 0 to 75 kHz in increments of 5 kHz, 0 to 250 kHz in increments of 10 kHz.

FM distortion (at 400 Hz mod. freq.): <0.5% at 75 kHz (100 MHz), <1% at 75 kHz (54 to 216 MHz), <10% at 250 kHz (54 to 216 MHz).

FM fidelity: ±1 dB, 5 Hz to 200 kHz.

Signal-to-noise ratio: >50 dB below 10 kHz (31.6 Hz peak deviation).

External FM requirements: <3 volts rms into 2 K ohms for 250 kHz deviation.

DC FM input: permits control of output frequency over a limited range with an external dc voltage.

Pulse modulation characteristics

PM source: external, PM rise time: ≤0.6 μs.

PM decay time: <0.8 μs.

Modulating oscillator characteristics

OSC frequency: 50 Hz, 400 Hz, 1000 Hz, 3000 Hz, 7.5 kHz, 10 kHz, 15 kHz, 67 kHz.

OSC accuracy: ±5%.

OSC distortion (at FM terminals): <0.5%, 50 Hz to 15 kHz; <1.0%, 67 kHz.

Physical characteristics

Dimensions: 16¾" wide, 10¼" high, 18⅜" deep (425 x 260 x 467 mm).

Weight: net 45 lbs (20,3 kg), shipping 66 lbs (29,7 kg).

Power: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 100 W.

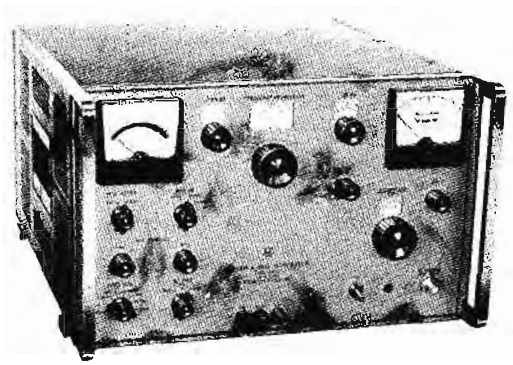
Accessory furnished: 00502B Patching Cable.

Price: HP 202H, $1475.

FM-AM SIGNAL GENERATOR

FM, AM, CW and pulse coverage, 195 to 270 MHz
Model 202J

The HP 202J FM-AM Signal Generator covers the frequency range from 195 to 270 MHz and is designed for the testing and calibration of FM telemetering receiving systems in the 215 to 260 MHz band.



202J

Specifications

RF characteristics

RF range: 195 to 270 MHz.

RF accuracy: main dial: ±0.5%; electronic vernier: ±(10% + 1 kHz) after one-hour warm-up.

RF stability: <0.02% per hour, after two-hour warm-up.

RF output: range: 0.1 μV to 0.2 V (across external 50-ohm load at panel jack); accuracy: ±10%, 0.1 μV to 50 k μV; ±20%, 50 k μV to 0.2 V; auto level set: holds RF monitor meter to "red line" over band; impedance: 50 ohms; VSWR: <1.2; spurious output: all spurious RF output voltages are at least 25 dB below desired fundamental.

RF leakage: sufficiently low to permit measurements at 0.1 μV.

AM characteristics

AM range: internal, 0 to 50%; external, 0 to 100%.

AM accuracy: ±10% of reading at 400 Hz at 30% and 50%.

AM calibration: 30, 50, 100%.

AM distortion: <5% at 30%, <8% at 50%, <20% at 90%.

AM fidelity: ±1 dB, 30 Hz to 200 kHz.

External AM requirements: approx. 50 V rms into 7500 ohms for 100% AM.

FM characteristics

FM deviation range: internal, 0 to 300 kHz in 4 ranges; external, 0 to 300 kHz in 4 ranges.

FM deviation accuracy: ±5% of full scale (indication proportional to pk-pk modulating waveform at 400 Hz).

FM calibration: 0 to 15 kHz in increments of 0.5 kHz, 0 to 30 kHz in increments of 1 kHz, 0 to 150 kHz in increments of 5 kHz, 0 to 300 kHz in increments of 10 kHz.

FM non-linearity: <1.5% at 150 kHz, <5% at 300 kHz, ("least squares" departure from straight line passing through origin.)

FM fidelity: ±1 dB, 5 Hz to 500 kHz; ±3 dB, 3 Hz to 1 MHz.

Spurious FM: total rms spurious FM from 60 Hz power source is at least 60 dB below 150 kHz (<150 Hz).

External FM requirements: <1 V rms into 100 k ohms in parallel with less than 50 pF for 150 kHz deviation.

PM characteristics: source: external; rise time: <0.25 μs; fall time: <0.8 μs.

Modulation oscillator characteristics: frequency: 50 Hz, 400 Hz, 1700 Hz, 3900 Hz, 10.5 kHz, 30 kHz, 70 kHz, 100 kHz; accuracy: ±5%; distortion: <0.5%.

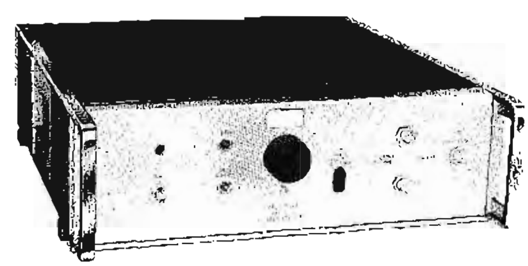
Power: 105 to 125 or 210 to 250 V, 50 to 400 Hz, 100 W.

Price: HP 202J, $1595.

Model 207H univerter

0.1 to 55 MHz for 202H and 202J Signal Generators

The HP 207H Univerter, a frequency converter with unity gain, is designed for use with the HP 202H and 202J Signal Generators to provide additional frequency coverage from 100 kHz to 55 MHz, including commonly used intermediate frequencies.



207H

Major Specifications

(when used with 202H and 202J Signal Generators)

RF range: 100 kHz to 55 MHz (with 199.9 to 145 MHz input from 202H; 200.1 to 255 MHz input from 202J).

RF output: 1 μV to 0.1 V and 0.01 μV to 1 mV across external 50-ohm load at panel jack; >1 V with 0.1 V input and 300-ohm output load.

Modulation: duplicates FM and AM modulation of 202H or 202J with no appreciable distortion for input levels <0.05 V.

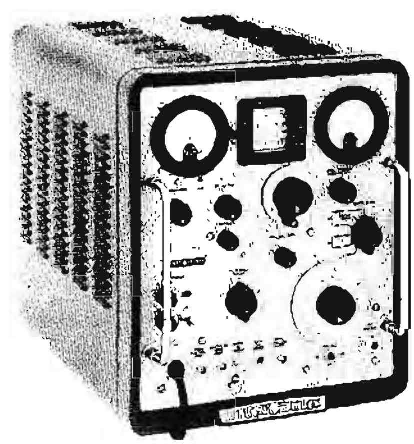
Power: 105 to 125 V or 210 to 250 V, 50 to 400 Hz, 50 W.

Price: 207H, $595.

VHF SIGNAL GENERATORS

Improved versatility and value 10-480 MHz

Models 608C/D/E/F; 8708A



608F

Description

Models 608E and 608F provide high-quality, versatile performance with distinctive ease of operation. The 608E provides an output of up to 1 volt over the range from 10 to 480 MHz, and the 608F provides an output of up to 0.5 volt from 10 to 455 MHz.

The 608E is an improved version of the popular and time-proven HP 608C/D Signal Generators. The instrument is a master oscillator-power amplifier (MOPA) type with a broadband buffer amplifier stage between the oscillator and power amplifier circuits for isolation. The MOPA design permits optimization of the oscillator stage for high stability of 0.005% per 10 minutes, minimum residual FM, and low harmonics without restricting the modulation characteristics. Modulation is applied to the power amplifier stage with negligible effect on the oscillator frequency.

Modulation capability

The use of feedback in the power amplifier section yields excellent amplitude modulation characteristics. Up to 95% modulation can be achieved with modulating frequencies ranging from 20 Hz to 20 kHz. Envelope distortion is very low, less than 2% at 30% AM and less than 5% at 70% AM; thus you can make more accurate measurements of the distortion characteristics on receivers or detectors. Internal modulation oscillators of 400 Hz and 1000 Hz are provided, and the modulation percentage can be set and read directly on the accurate front panel modulation meter. The buffer amplifier stage between the master oscillator and power amplifier holds incidental FM with AM to a minimum, ensuring accurate measurements.

Accurate output level

Output levels of the Models 608E/F are accurately attenuated to provide continuously adjustable calibrated output from 0.1 microvolt to 1 volt rms (608E) or 0.5 volt rms (608F) into a 50-ohm load. Direct calibration is provided in both volts and dBm (to —127 dBm) and the output calibration is accurate within 1 dB at any frequency or level setting. The output system of the 608E/F is a well matched 50-ohm circuit which minimizes mismatch ambiguities as a factor in overall measurement accuracy. The extremely wide range of output amplitude control makes the 608E/F very useful for driving bridges and filters as well as complete receiver measurements including sensitivity, selectivity, and image rejection.

Models 608E/F provide an auxiliary RF output; this fixed level (180 millivolts rms minimum) CW signal is for use with an HP 5245L Counter for very accurate indication of carrier frequency. On the 608F, this output is also for use with the 8708A Synchronizer. Using the auxiliary RF output does not place any restriction on the modulation capabilities nor on the main RF output level. The units also contain a crystal calibrator to provide frequency checkpoints at every 1 or 5 MHz throughout the frequency range.

High settability

The fine frequency vernier is an electronic fine tuning adjustment of the output frequency. Frequency settability with better than 10 ppm resolution is possible to obtain precise settings for critical tests. When used with the internal crystal calibrator, 608E frequency accuracy can be increased by a factor of 50 (factor of 100 for the 608F) over the main dial calibration of 1% without the use of an external frequency meter.

608F/8708A combination

The Model 8708A Synchronizer is an easy-to-use frequency stabilizer that allows the 608F to be phase-locked from 50 kHz to 430 MHz. Full AM and output level features of the 608F are retained during phase-lock. The 8708A increases frequency stability by a factor of 250 with the extra benefit of 8708A precise tuning resolution for settability to 2 parts in 10^7. The 608F/8708A combination also permits narrowband frequency and phase modulation to be applied with very low distortion.

Specifications, 608E/F

Frequency characteristics

Range: 608E: 10 - 480 MHz in 5 bands (10-21, 21-43, 43-95, 95-215, and 215-480 MHz. 608F: 10 - 455 MHz in 5 bands (10-21, 21-44, 44-95, 95-210, and 210-455 MHz).

Accuracy: 608E: ±0.5%. 608F: ±1%.

Drift: 608E: less than 50 parts in 10^6 per 10 minute period after one hour warmup. 608F: less than 50 parts in 10^6 per 10 minute period after one hour warmup; stability when used with 8708A Synchronizer: 5×10^{-8}/minute; 2×10^{-7}/10 minutes; 2×10^{-6}/day; 2×10^{-7}/°C (0° to 55°C); 2×10^{-7}/10% line voltage change.

Frequency control input (608F ONLY): BNC female connector for "Frequency Control Output" from 8708A Synchronizer can also be used for external frequency control; voltage change from —2 to —32 volts changes frequency approximately 0.2% at low end of each band and approximately 2% at high end; nominal 4 kΩ input impedance, direct-coupled; voltage limits, 0 to —50 V.

Resettability: 608E: main frequency control resettability better than ±0.1% after initial warmup; Fine Frequency Adjust provides approximately 25 kHz settability at 480

MHz (proportionately finer adjustment at lower frequencies). 608F: main frequency control resettability better than ±0.1% after initial warmup; Fine Frequency Adjust provides approximately 25 kHz settability at 455 MHz (proportionately finer adjustment at lower frequencies).

Tuning control: frequency control mechanism provides a main dial calibrated in megahertz and a vernier dial for interpolation purposes; total scale length, approximately 45 inches; calibration, every other megahertz 130 to 270 MHz; every 5 MHz above 270 MHz.

Crystal calibrator: provides frequency check points every 1 MHz up to 270 MHz or every 5 MHz over the range of the instrument; headphone jack provided for audio frequency output (headphones not included); crystal frequency accuracy better than 0.01% at normal room temperatures; cursor on frequency dial adjustable over small range to aid in interpolation adjustment; calibrator may be turned off when not in use.

Residual FM: less than ±5 parts in 10^7 peak.

Harmonic output: at least 35 dB below the carrier for harmonic frequencies below 500 MHz.

Output characteristics

Output level: 608E: continuously adjustable from 0.1 μV to 1.0 volt into a 50-ohm resistive load; output attenuator calibrated in volts and dBm (0 dBm = 1 mW in 50 ohms).

608F: continuously adjustable from 0.1 μV to 0.5 volt into a 50-ohm resistive load; output attenuator calibrated in volts and dBm (0 dBm = 1 mW in 50 ohms).

Accuracy: within ±1 dB of attenuator dial reading at any frequency when RF Output Meter indicates "ATTENUATOR CALIBRATED."

Leveling: internal feedback circuit retains "ATTENUATOR CALIBRATED" reference on RF Output Meter over wide frequency ranges (typically octave bands); adjustment of front panel AMP. TRIMMER control (only) for maximum RF output indication automatically restores initial carrier level for greater frequency changes.

Impedance: 50Ω with a maximum SWR of 1.2 for attenuator setting below −7 dBm.

RFI: meets all conditions specified in MIL-I-6181D; permits receiver sensitivity measurements down to at least 1.0 μV.

Auxiliary RF output: 608E: fixed level CW signal from RF Oscillator (minimum amplitude 180 mV rms into 50 ohms) provided at front panel BNC female connector for use with external equipment (e.g., frequency counter).

608F: fixed level CW signal from RF Oscillator (minimum amplitude 180 mV rms into 50 ohms) provided at front panel BNC female connector for use with HP 8708A Synchronizer or other external equipment (e.g., frequency counter).

Modulation characteristics

(Front panel AMP TRIMMER control adjusted for maximum indication on RF Output Meter and RF Output Meter set to "ATTENUATOR CALIBRATED.")

Internal AM

Frequency: 400 and 1000 Hz, ±10%; modulation signal available at front panel BNC female connector for synchronization of external equipment.

Modulation level: 608E: 0 to 95%, modulation at carrier levels 0.5 volt and below; continuously adjustable with front panel MOD LEVEL control.

608F: 0 to 95% modulation with Output Attenuator at 0.224 volt (1 mW) or below; continuously adjustable with front panel MOD LEVEL control.

Carrier envelope distortion: less than 2% at 30% AM and less than 5% at 70% AM.

External AM

Frequency: 20 Hz to 20 kHz.

Modulation level: 608E: 0 to 95% modulation at carrier levels of 0.5 volt and below; continuously adjustable with front panel MOD LEVEL control; input required, 1-10 volts, rms (1000Ω input impedance).

608F: 0 to 95% modulation with Output Attenuator at 0.224 volt (1 mW) or below; continuously adustable with front panel MOD LEVEL control; input required, 1-10 volts, rms (1000Ω input impedance).

Carrier envelope distortion: less than 2% at 30% AM, less than 5% at 70% AM (modulation source distortion less than 0.5%).
External control of carrier level can be achieved through application of dc voltage in EXT AM mode.

Modulation meter accuracy: ±5% of full scale 0 to 80%, ±10% from 80% to 95% (for INT AM or 20 Hz to 20 kHz EXT AM).

Incidental frequency modulation (at 400 and 1000 Hz modulation): less than 1000 Hz peak at 50% AM for frequencies above 100 MHz; for frequencies below 100 MHz, less than 0.001% at 30% AM.

External pulse modulation:

Rise and decay time: from 40 MHz to 220 MHz, combined rise and decay time less than 4 μs; above 220 MHz combined rise and decay time less than 2 μs.

On-off ratio: at least 20 dB for pulsed carrier levels of 0.5 volt and above.

Input required: positive pulse, 10-50 volts peak, input impedance 2000Ω.

General:

Power: 115 or 230 V ±10%, 50 to 400 Hz; approximately 220 W.

Dimensions: cabinet: 13¼" wide, 16⅜" high, 21" deep (337 x 416 x 533 mm); rack mount: 19" wide, 13-31/32" high, 18⅜" deep behind panel (483 x 335 x 467 mm).

Weight:

Cabinet mount: net, 62 lb (28 kg); shipping, 74 lb (33,4 kg).

Rack mount: net, 62 lb (28 kg); shipping, 83 lb (37,4 kg).

Accessories available:

11508A output cable provides 50 ohms termination and standard binding posts at the end of a 24-inch (610 mm) length of cable; allows direct connection of the signal generator to high impedance circuits. $18.

11509A Fuse Holder provides protection for the output attenuator when the Model 608E/F is used for transceiver tests. $25.

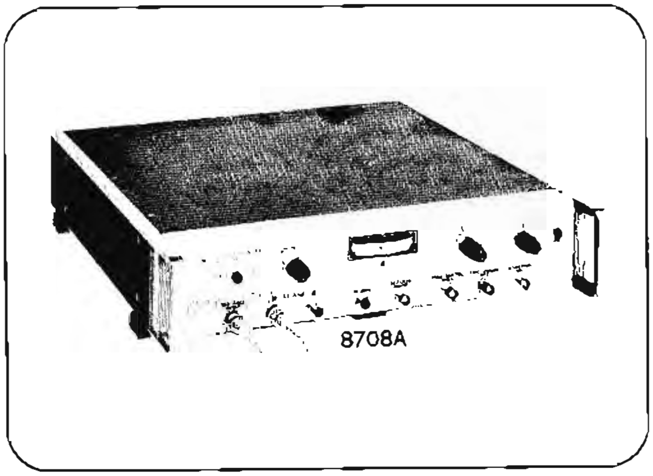
10514A Mixer for use as nanosecond pulse modulator or balanced modulator. $95.

Price: Model 608E (cabinet), $1500, Model 608ER (rack mount), $1540; Model 608F (cabinet), $1650, Model 608FR (rack mount), $1690.

SYNCHRONIZER

Improved versatility and value 50 kHz – 430 MHz

Model 8708A



HP Model 8708A Synchronizer

The 8708A Synchronizer is a phase-lock frequency stabilizer that allows you to obtain crystal-oscillator frequency stability in the 606B (and to 430 MHz in the 608F) Signal Generator. The outstanding AM and output level control capabilities of the signal generators are retained. Phase-locking eliminates microphonics and drift, resulting in a frequency stability of 2×10^{-7} per 10 minutes, an increase by a factor of 250. The 8708A includes an ultrafine frequency vernier which can tune the reference oscillator over a range of ±0.25% permitting frequency settability to 2 parts in 10^7. This high order of stability and settability can be achieved over continuous frequencies in the 606B and 608F range, eliminating phase-locking at only discrete points. This provides a very stable, yet tunable signal generator that satisfies many critical applications including measurements on SSB and narrowband receivers.

An external 20 MHz frequency reference can be used; the resultant stability is that of the external reference. Use of an external reference, however, results in just fixed discrete lock points (unless the reference is frequency tunable ±0.25% around 20 MHz).

Narrowband frequency and phase modulation with very low distortion (better than 1% linearity) of the 606B and 608F Signal Generators can be applied through the 8708A. Narrowband sweeping of the carrier under very stable conditions is valuable for filter or amplifier skirt response tests as well as Q studies of frequency selective circuits.

Specifications, 8708A

Frequency range: 50 kHz to 430 MHz; phase-locks 606B (608F to 430 MHz) Signal Generator at any carrier frequency*, with 2×10^{-7} settability.

Input signal level (signal to be stabilized): proper signal level automatically provided by 606B and 608F; general requirements into 50 Ω at less than 20% distortion:
- 10 to 215 MHz: 180 to 500 mV rms
- 215 to 400 MHz: 280 to 450 mV rms
- 400 to 430 MHz: 250 to 450 mV rms

Frequency reference: internal or external 20 MHz (±0.25%).

External reference requirements:

When signal to be synchronized is between 50 kHz and 20 MHz: 180 to 400 mV rms (<20% distortion) into 50 Ω. When signal to be synchronized is between 10 and 430 MHz: 0.1 to 2 V rms into 50 Ω.

Internal frequency reference stability:

Short term (RMS deviation): 5×10^{-8}/minute; 2×10^{-7}/10 minutes.

With temperature: 2×10^{-7}/°C, 0 to 55°C.

With line voltage: 2×10^{-7}/10% line voltage change.

(Note: stability in "External Reference" mode is that of external reference source).

Spectral purity (stabilized RF output of 606B or 608F Signal Generator):

Spurious signals: non-harmonically related signals greater than 60 dB below carrier.

Signal-to-AM noise ratio**: >70 dB.

Signal-to-phase noise ratio**: >60 dB, 10 MHz and below; $>60 \text{ dB} - 20 \log \frac{f \text{ MHz}}{10}$, above 10 MHz.

RMS fractional frequency deviation: less than 5×10^{-8} averaged over 10 ms (30 kHz noise bandwidth).

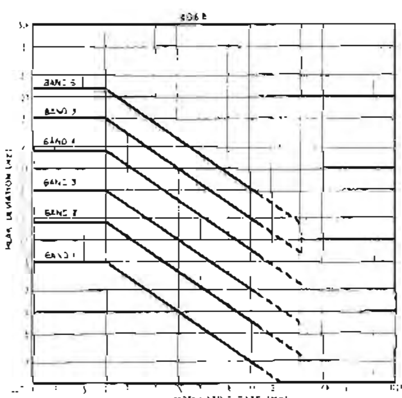
Frequency control output: frequency control voltage directly compatible with 606B and 608F Signal Generators; output voltage range, −2 to −32 volts (max).

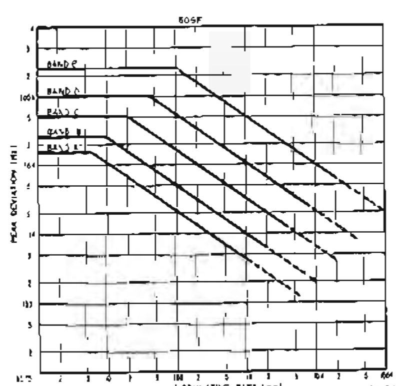
Modulation

Frequency modulation: maximum modulation rates and frequency deviation for ≤1% distortion:

*Using 8708A Internal Reference, or external reference adjustable over 0.5% frequency range. With fixed frequency external reference, interval between lock points varies from 62.5 Hz at 50 kHz to 500 kHz above 210 MHz.

**In a 30 kHz band centered on the carrier, excluding a 1 Hz band centered on the carrier.

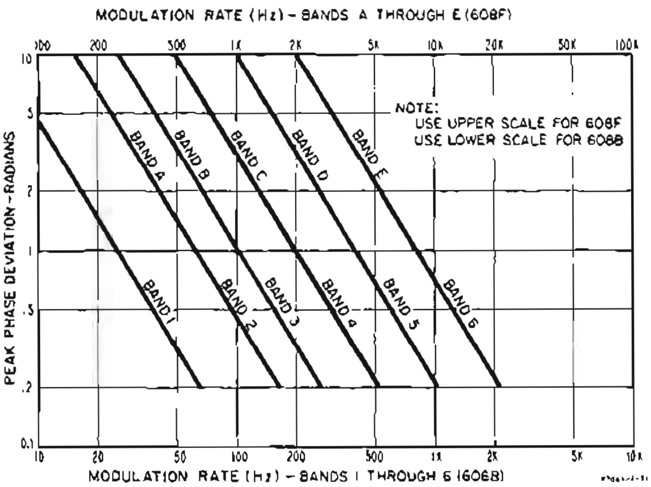




Modulation sensitivity (ac or dc—Mod. level control at maximum): (0.5 kHz/V) (carrier freq. in MHz).

Note: dc input limits, 0 to 10 volts (input connector biased at +10 V from a 10-kΩ source).

Phase modulation: maximum modulation rate and phase deviation for ≤1% distortion:



Modulation sensitivity (ac only—Mod. level control at maximum): (0.01 radian/V) (carrier freq. in MHz).

Deviation monitor: dc output voltage which is proportional to frequency and phase deviation; output voltage, deviation ratio varies with carrier frequency, output voltage range approximately −1 to +3 V.

RFI: meets all conditions specified in MIL-I-6181D.

Warm-up time: 1½ hr.

Power: 115 or 230 V ±10%, 50 to 400 Hz; approximately 48 W.

Dimensions: 16¾" wide, 3-25/32" high, 18⅜" deep (425 x 96 x 467 mm); hardware furnished for rack mount, 19" wide, 3-15/32" high, 16⅜" deep behind panel (483 x 88 x 416 mm).

Furnished: interconnecting cables for use with 606B and 608F Signal Generators.

Weight: net, 27 lb (12,2 kg); shipping, 31 lb (14 kg).

Price: Model 8708A, $1800.

VHF Signal Generators
Models 608C and 608D

The Model 608C/D are designed as broadly applicable VHF signal generators. Both units feature internal modulation of 400 and 1000 Hz standard test tones for routine AM applications, and can be externally modulated up to 95%. Versatile modulation capabilities allow pulse and transient testing of VHF receivers. Accuracy of measurements is enhanced by 608C/D minimum incidental FM with AM, modulation distortion, and frequency drift. Models 608C/D feature calibrated RF output attenuation down to 0.1 μV, and provide high quality pulses as short as 1 μs at RF frequencies above 100 MHz.

The Model 608C is a high power, stable and very accurate generator for general lab and field use, providing 1 volt maximum RF output and broad frequency coverage from 10 to 480 MHz.

Maximum output of the 608D is 0.5 volt through the range of 10 to 420 MHz. A built-in crystal calibrator provides accurate frequency check points at 1 and 5 MHz intervals.

Major specifications, 608C,D

Frequency range: 608C, 10 to 480 MHz in 5 bands; 608D, 10 to 420 MHz in 5 bands.

Frequency dial calibration accuracy: 608C, ±1%; 608D, ±0.5%.

Resettability: better than ±0.1% after warm-up.

Frequency drift: <0.005% over a 10 minute interval after initial warm-up (15 to 35°C ambient).

Output level: 608C, 0.1 μV to 1 V into 50Ω; 608D, 0.1 μV to 0.5 V into 50Ω; attenuator dial calibrated in volts and dBm; (0 dBm equals 1 mW).

Output voltage accuracy: ±1 dB into 50Ω.

Generator impedance: 50 ohms; maximum SWR 1.2.

Internal AM: 400 Hz ±10% and 1000 Hz ±10%.

External AM: 0 to 95% at output levels of 0 dBm and below at modulation frequencies 20 Hz to 20 kHz; input requirements, 0.5 V rms across 15 kΩ.

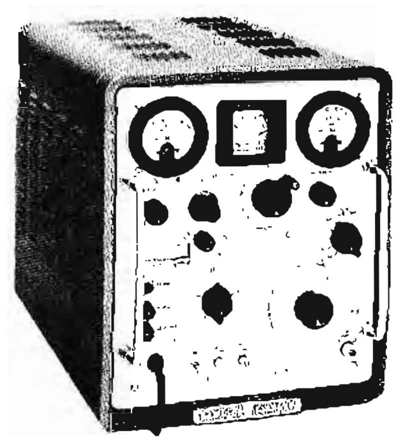
Modulation meter accuracy: ±10% of full scale, 30% to 95% modulation.

Envelope distortion: less than 5% at 30% sine-wave modulation; less than 10% at 50% sine-wave modulation.

External pulse modulation: positive 5 V peak pulse required, 40 to 220 MHz; combined rise and decay time of RF pulse less than 4 μs. Above 220 MHz, combined rise and decay time of RF pulse less than 1 μs. Pulse on-off ratio at least 20 dB.

Incidental FM: 608C, <0.0025% at 30% AM, 21 to 480 MHz; 608D, <1000 Hz peak at 50% AM above 100 MHz, <0.001% at 30% AM below 100 MHz.

Price: HP 608C, $1350 (cabinet); HP 608CR, $1390 (rack mount); HP 608D, $1450 (cabinet); HP 608DR, $1490 (rack mount).



608C

VHF OSCILLATOR

10 to 500 MHz; to 1000 MHz with Accessory Probe

Model 3200B

The HP 3200B VHF Oscillator provides low cost, stable, 10 to 500 MHz RF for testing receivers and amplifiers, and driving bridges, slotted lines, antennas, and filter networks. Good pulse modulation sensitivity allows standard audio oscillators to be used to provide usable square-wave modulation; a 2.5-volt sine wave will provide adequate drive for this type application. The 3200B can also serve as a local oscillator for heterodyne detector systems and as a marker source for swept systems. An optional accessory Frequency Doubler Probe, HP 13515A, provides additional frequency coverage from 500 to 1000 MHz.

Though the oscillator stability is specified as .002% for a 5-minute period after warmup, typical data indicates that, under controlled conditions, stabilities of 0.0001% are attainable at some frequencies.

Effective RF shielding permits measurements at levels down to 1 μV.

A front panel vernier control varies the plate voltage in the oscillator, electrically refining the attenuator piston setting.

RF is read on an expanded slide-rule type scale. The oscillator may be precisely tuned by means of a mechanical vernier activated by the main tuning control.

The 3200B is well suited for bench use and may be adapted for standard 19-inch rack mounting.

3200B

13515A

Specifications

Frequency range: 10 to 500 MHz in six bands: 10 to 18.8 MHz; 18.5 to 35 MHz; 35 to 68 MHz; 68 to 130 MHz; 130 to 260 MHz; 260 to 500 MHz.

Frequency accuracy: within ±2% after ½ hour warmup.

Frequency calibration: increments of less than 4%.

Frequency stability (after 4-hour warmup under 0.2 mW load): short term (5 minutes) ±0.002%; long term (1 hour) ±0.02%; line voltage (5-volt change) ±0.001%.

RF output:

Maximum power (across 50-ohm external load): >200 mW (10 to 130 MHz); >150 mW (130 to 260 MHz); >25 mW (260 to 500 MHz).

Range: 0 to >120 dB attenuation from maximum output.

Load impedance: 50 ohms nominal.

RF leakage: sufficiently low to permit measurements at 1 μV. RFI: meets requirements of MIL-I-6181D.

Amplitude modulation: externally modulated.

Range: 0 to 30%.

Distortion: <1% at 30% AM.

External requirements: approximately 20 volts rms into 600 ohms for 30% AM, 200 Hz to 100 kHz.

Pulse modulation: externally modulated.

External requirements: 2.5-volt negative pulse into 2000 ohms.

Power: 105 to 125 V or 210 to 250 V, 50 to 400 Hz, 30 W.

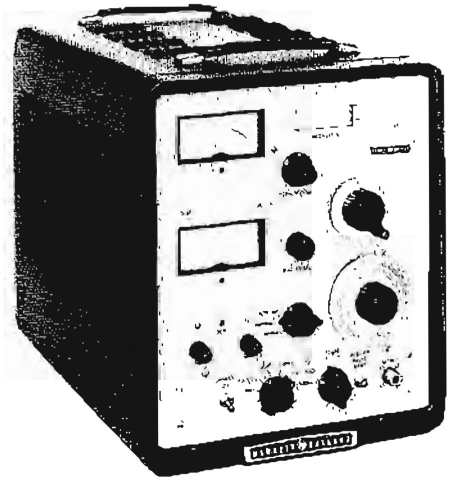
Dimensions: 7⅝" wide, 6½" high, 13⅛" deep (194 x 165 x 333 mm).

Weight: net 15 lbs (6,8 kg), shipping 19 lbs (8,6 kg).

Accessories available: 13515A Frequency Doubler Probe; 00501B, 00514B, 00517B Output Cables; 00502B, 00506B Patching Cables.

Price: HP 3200B, $525; HP 13515A, $95.

UHF SIGNAL GENERATOR
All-purpose UHF signal generator, 450 to 1230 MHz
Model 612A



612A

Here is an all-purpose, precision signal generator particularly designed for utmost convenience and applicability throughout the important UHF-TV frequency band. It is ideally suited for measurements in UHF-television broadcasting, studio-transmitter links, citizen's radio and public service communications systems. The HP 612A also covers the important frequencies used in aircraft navigation aids such as DME, TACAN and airborne transponders. Accessory modulators, available from many of the manufacturers of these navigational aids, enable the 612A to provide the complex modulation patterns required for testing and aligning these systems. In the laboratory, the 612A is a convenient power source for driving bridges, slotted lines, antennas and filter networks. In addition, the HP 8731 PIN Modulators can be used with the 612A to obtain RF pulses with 30 ns rise time and 0.1 μs minimum duration—with on-off ratios approaching 80 dB.

MOPA circuit

The master oscillator-power amplifier circuit in the HP 612A provides 0.5 volt into 50 ohms over the full frequency range of 450 to 1230 MHz. There is very low incidental FM (less than 0.002% at 30% AM) and excellent modulation capabilities by all frequencies from 20 Hz to 5 MHz. The degree of modulation is easily read from the large percent modulation meter. The instrument can be amplitude-modulated (either internally or externally), and provision is made for external pulse modulation as well. Pulse modulation can be applied to the amplifier or directly to the oscillator when high on-off signal ratios are required (signal may be completely cut off between pulses). Modulation can be up or down from a preset level to simulate TV modulation characteristics accurately.

Advanced design

The oscillator-amplifier circuit in the 612A employs high-frequency pencil triodes in a cavity-tuned circuit for precise tracking over the entire band. Noncontacting cavity plungers are die-cast to precise tolerances, then injection-molded with a plastic filler for optimum Q. The frequency drive is a direct screw-operated mechanism, free from backlash. A waveguide-beyond-cutoff piston attenuator and crystal monitor circuit are used to ensure accurate, reliable output down to 0.1 μV. The attenuator is calibrated over a range of 131 dB and has been carefully designed to provide a constant impedance-versus-frequency characteristic. The SWR of the 50-ohm output system is less than 1.2 over the complete frequency range.

Specifications

Frequency range: 450 to 1230 MHz in one band; scale length approximately 15 inches (381 mm).

Calibration accuracy: within ±1%; resettability better than 5 MHz at high frequencies.

Output voltage: 0.1 μV to 0.5 V into 50-ohm load; calibrated in V and dBm (0 dBm = 1 mW).

Output accuracy: ±1 dB, 0 to −127 dBm over entire frequency range.

Internal impedance: 50 ohms; maximum reflection coefficient, 0.091 (1.2 SWR, 20.8 dB return loss).

Amplitude modulation: above 470 MHz, 0 to 90% at audio frequencies, indicated by panel meter; accuracy ±10% of full scale, 30 to 90% modulation.

Incidental FM: less than 0.002% for 30% AM.

Internal modulation: 400 and 1000 Hz ±10%; envelope distortion less than 3% at 30% modulation.

External modulation: 20 Hz to 5 MHz; above 470 MHz, 2 V rms produces 85% AM at modulating frequencies up to 500 kHz, at least 40% AM at 5 MHz; modulation may be up or down from the carrier level or symmetrical about the carrier level; positive or negative pulses may be applied to increase or decrease RF output from the carrier level.

Pulse modulation

Pulse 1 (pulse applied to amplifier): positive or negative pulses, 4 to 40 V peak produce an RF on-off ratio of at least 20 dB; minimum RF output pulse length, 0.2 μs.

Pulse 2 (pulse applied to oscillator): positive or negative pulses, 4 to 40 V peak; no RF output during off time; minimum RF output pulse length, 1 μs.

RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D; permits receiver sensitivity measurements down to 1 μV.

Power: 115 or 230 volts ±10%, 50 to 400 Hz, 215 watts.

Dimensions: cabinet: 13½" wide, 16½" high, 21½" deep (343 x 419 x 546 mm); rack mount: 19" wide, 13-31/32" high, 20¼" deep behind panel (483 x 355 x 514 mm).

Weight: net 56 lb (25,4 kg), shipping 68 lb (30,5 kg) (cabinet); net 56 lb (25,4 kg), shipping 77 lb (34,4 kg) (rack mount).

Accessories available: 11500A RF Cable Assembly, $15; 10503A Video Cable Assembly, $7; 360B Low-Pass Filter (may be used where harmonic output must be reduced to a minimum, as in slotted line measurements), $70.

Price: HP 612A, $1500 (cabinet); HP 612AR, $1540 (rack mount).

SIGNAL GENERATORS; SOURCES

Stable, easy to use, cover 800 to 4500 MHz

Models 8614A, 8616A; 8614B, 8616B

Advantages:

- High frequency accuracy, digital dial
- Precision attenuator, digital dial
- Amplitude modulation capability and automatic power leveling in the signal generators
- At least 10 mW output
- Compact, only 5¼" (133 mm) high

Use to measure:

- Receiver sensitivity, signal-to-noise ratio
- Standing-wave ratios
- Transmission line, antenna characteristics
- Conversion gain

The HP 8614A and 8616A Signal Generators are easy-to-use instruments which provide stable, accurate signals from 800 to 2400 MHz (8614A) and from 1800 to 4500 MHz (8616A). Both frequency and attenuation are set on direct-reading digital dials, while function is easily selected by pushbuttons. Selectable functions include CW, leveled output, square-wave modulation, and external amplitude, pulse or frequency modulation. Amplitude, frequency and square-wave modulation can be accomplished simultaneously with or without leveling.

Two outputs

Two RF power outputs are simultaneously available from separate front-panel connectors. One provides at least 10 mW (2 mW above 3000 MHz) or a leveled output from 0 to −127 dBm. The leveled output is flat within ±0.75 dB (8614A) or ±1.0 dB (8616A) across the respective bands with no resetting of the attenuator or power monitor.

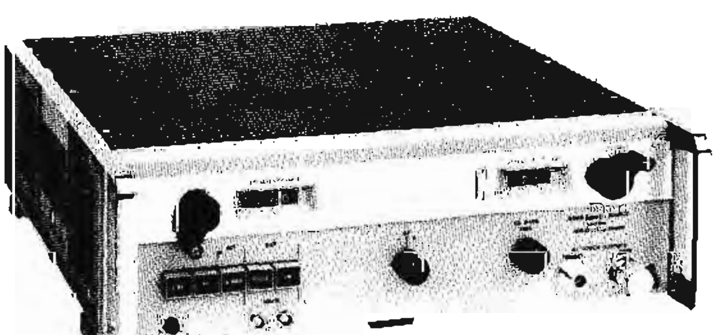
The second output is at least 0.5 mW across the band and is independent of attenuator setting. This signal can be used for phase-locking the signal generators when extreme stability is desired, or it can be monitored with a frequency counter for extreme frequency resolution. In any case, the second output can be utilized without adversely affecting the primary output.

Modulation capabilities

A unique PIN diode modulator permits amplitude modulation from dc to 1 MHz or furnishes RF pulses with a 2 μs rise time. This broad modulation bandwidth permits remote control of output level or precise leveling using external equipment. The internal leveling is also obtained by using a PIN modulator.

When up to one watt output is required above 1 GHz, the HP 489A (1 to 2 GHz) or HP 491C (2 to 4 GHz) Microwave Amplifiers (see Amplifiers) serve as ideal power boosters. The HP 8731 and 8732 Series PIN Modulators, driven by the HP 8403A Modulator are available for use with the signal generators when a sophisticated high-speed, low-jitter, modulation system is required.

8614A

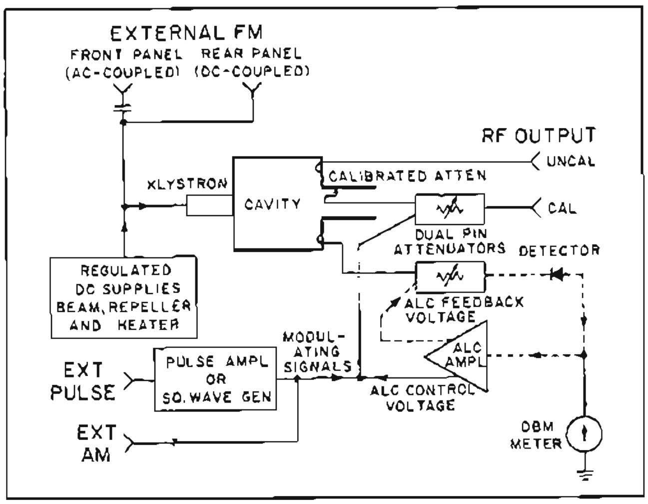


8614B

Signal Sources

The HP 8614B and 8616B retain the convenience of the "A" models. Functions are selected by pushbuttons, and frequency and attenuation are set on digital dials. Although the signal sources do not have power monitors or internal PIN diode modulation, relative power measurements can be made, using the precision attenuator. Modulation capabilities include internal square-wave modulation, plus external pulse and frequency modulation. For added convenience, a friction clutch arrangement permits setting the attenuator dial to any suitable reference while output power is held constant. Thus the attenuator can be calibrated directly in dBm or insertion loss.

The versatility of the HP 8614B and 8616B makes them suitable for both laboratory and general-purpose measurements. Indeed, these signal sources can be used in many applications previously requiring signal generators.



Simplified block diagram of HP 8614A and 8616A Signal Generators. The dashed line shows the leveling control circuit.

Specifications

Frequency range: 8614A and 8614B, 800 to 2400 MHz; 8616A and 8616B, 1800 to 4500 MHz.

Leveled output: constant within ±0.75 dB (8614A) and ±1.0 dB (8616A) across entire frequency range at any attenuator setting below 0 dB; output power can be adjusted from the normal calibrated level with the Automatic Level Control; not available with 8614B and 8616B.

Frequency calibration accuracy: 8614A, ±5 MHz; 8614B, ±5 MHz or ±0.5%, whichever is greater; 8616A, ±10 MHz; 8616B, ±10 MHz or ±0.5%, whichever is greater.

Vernier: △F control has a minimum range of 1.5 MHz for fine tuning (1.0 MHz for 8614B, 8616B).

Frequency stability

With temperature: approximately 0.005%/°C change in ambient temperature.

With line voltage: less than 0.003% change for line voltage variation of ±10%.

Residual FM: 8614A and 8616A, less than 2500 Hz peak; 8614B, less than 0.0003% peak; 8616B, less than 6 kHz peak.

RF output power

8614A: +10 dBm (10 mW) to −127 dBm (0.1 μV) into a 50-ohm load; output attenuator dial directly calibrated in dBm from 0 to −127 dBm.

8614B: at least 15 mW max., controlled by attenuator.

8616A: +10 dBm (10 mW) to −127 dBm (0.1 μV) into a 50-ohm load, 1800 to 3000 MHz; +3 dBm (2 mW) to −127 dBm (0.1 μV) into a 50-ohm load, 3000 to 4500 MHz; output attenuator directly calibrated in dBm from 0 to −127 dBm.

8616B: at least 15 mW maximum, 1800 to 3000 MHz; at least 3 mW maximum, 3000 to 4500 MHz; controlled by attenuator.

All models: a second, uncalibrated RF output (approximately 0.5 mW) is provided on the front panel.

RF output power accuracy (with respect to attenuator dial)

8614A: ±0.75 dB + attenuator accuracy from 0 to −127 dBm, including leveled output variations.

8616A: ±1 dB + attenuator accuracy from 0 to −127 dBm, including leveled output variations.

Attenuator accuracy

8614A: +0, −3 dB from 0 to −15 dBm; ±0.2 dB ±0.06 dB/10 dB from −15 to −127 dBm.

8614B and 8616B: ±0.2 dB ±0.06 dB/10 dB below −10 dBm.

8616A: +0, −1 dB from 0 to −10 dBm; ±0.2 dB ±0.06 dB/10 dB from −10 to −127 dBm.

All models: direct-reading linear dial, 0.2 dB increments.

Internal impedance: 50 ohms nominal.

Reflection coefficient:

8614A: less than 0.33 (2.0 SWR, 9.5 dB return loss).
8614B: less than 0.2 (1.5 SWR, 14 dB return loss).
8616A: less than 0.33 (2.0 SWR, 9.5 dB return loss).
8616B: less than 0.26 (1.7 SWR, 11.7 dB return loss).

Modulation

Internal square wave: 950 to 1050 Hz.

Square-wave sync: square wave can be synchronized with a +1 to +10 volt signal applied to the Pulse input.

External AM (8614A and 8616A only): dc to 1 MHz.

Incidental FM (8614A and 8616A only): negligible for power levels below −10 dBm.

External pulse:

8614A and 8616A: 50 Hz to 50 kHz, 2 μs rise time, +20 to +100 volts input.

8614B and 8616B (below 4000 MHz): 50 Hz to 500 kHz; +25 to +50 volts peak input; minimum RF pulse width, 300 ns; RF rise time, typically 200 ns.

External FM: (a) front-panel connector capacitively coupled to klystron repeller; input impedance, 220 kΩ shunted by approximately 300 pF; (b) rear-panel connector is dc-coupled to the klystron repeller.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, approximately 125 watts.

Dimensions: 16¾" wide, 5½" high, 18⅜" deep (426 x 141 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 5-7/32" high, 16⅜" deep behind panel (483 x 133 x 416 mm).

Weight: 8614A: net 42 lb (18,9 kg); shipping 48 lb (21,6 kg), 8614B and 8616B: net 38 lb (17,1 kg); shipping 43 lb (19,4 kg), 8616A: net 44 lb (19,8 kg); shipping 50 lb (22,5 kg).

Price: HP 8614A, $2200; HP 8614B, $1600; HP 8616A, $2200; HP 8616B, $1600.

Option 01.: External modulation input connectors on rear panel in parallel with front-panel connectors; RF connectors on rear panel only; add $25.

UHF SIGNAL GENERATORS

Direct-reading, direct control, 800 to 4200 MHz

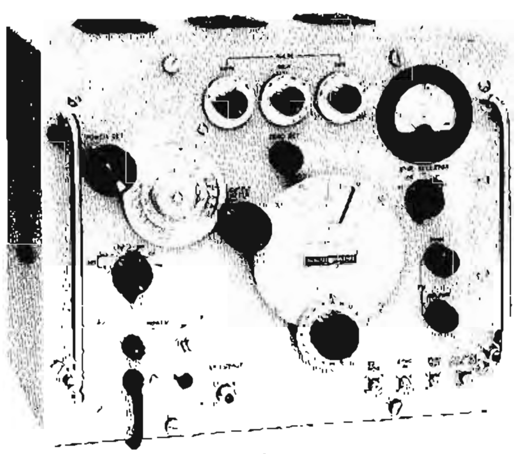
Model 614A, 616B

Ease of operation, direct-reading one-dial frequency control, high stability and accuracy and broad frequency coverage are all advantages of these widely used signal generators.

The 614A covers frequencies from 800 to 2100 MHz, has constant internal impedance with less than 1.6 SWR, and ouput accuracy of ±1 dB over the range of —10 dBm to —127 dBm. The 616B gives complete coverage of frequencies from 1.8 to 4.2 GHz, has constant internal impedance with less than 1.8 SWR, and output accuracy of ±1.5 dB from —7 dBm to —127 dBm.

On both instruments, operation is extremely simple. Carrier frequency is set and read directly on the large tuning dial. No voltage adjustments are necessary during operation because of the coupling device which causes oscillator repeller voltage to track frequency changes automatically. Oscillator output is set and read directly on a simplified dial. Output may be continuous or pulsed, or frequency-modulated at power line frequency. Pulse modulation may be provided externally or internally. Internal pulsing may be synchronized with either positive or negative external pulses, or sine waves.

The oscillator portion of both the 614A and 616B consists of a reflex klystron in an external coaxial resonator. Frequency of oscillation is determined by a movable plunger which varies the resonant frequency of the resonator. Oscillator output is monitored by a temperature-compensated thermistor bridge circuit which is virtually unaffected by ambient temperature conditions. Voltage output is read directly. A logging scale on the frequency dial provides a resettability of 0.1%.



614A

Specifications

Frequency range: 614A, 800 to 2100 MHz; 616B, 1.8 to 4.2 GHz.

Frequency accuracy: ±1%.

Frequency stability: 0.005%/°C change in ambient temperature; line voltage changes of ±10% cause 0.01% frequency change.

Output power range (into 50-ohm load): 614A, 0.5 mW or 0.158 volt to 0.1 μV (—3 to —127 dBm) from 800 to 900 MHz, 1 mW or 0.224 volt to 0.1 μV (0 to —127 dBm) from 900 to 2100 MHz; 616B, 1 mW or 0.224 volt to 0.1 μV (0 to —127 dBm).

Power accuracy (at the end of 6-ft output cable, terminated in 50-ohm load): 614A, within ±1 dB from —10 to 127 dBm; 616B, within ±1.5 dB from —7 to —127 dBm.

Internal impedance: 614A, 50 ohms, reflection coefficient less than 0.23 (1.6 SWR, 12.7 dB return loss); 616B, 50 ohms, reflection coefficient less than 0.285 (1.8 SWR, 10.9 dB return loss).

Modulation: internal or external pulse or FM.

Internal pulse modulation: pulse repetition rate variable from 40 to 4000 per sec; pulse length variable from 1 to 10 μs; delay variable from 3 to 300 μs between synchronizing signal and RF pulse.

External pulse modulation: ext —: —40 to —70 V, 1 to 2500 μs wide, ext +: +40 to +70 V, 1 to 400 μs wide, square wave: ±40 to ±70 V p-p, 40 to 4000 Hz.

Trigger pulses out: (1) simultaneous with RF pulse; (2) in advance of RF pulse, variable from 3 to 300 μs (both approximately 1 μs rise time, amplitude +10 to +50 volts).

External synchronization: pulses, ±10 to ±50 volts, 1 to 20 μs wide; may also be synchronized with sine waves.

Frequency modulation: oscillator sweeps at power line frequency; deviation and phase adjustable; maximum deviation approx. 3 MHz p-p.

RFI: Conducted and radiated leakage limits are below those specified in MIL-I-6181D.

Power: 115 or 230 volts ±10%, 50 to 400 Hz, approx. 160 watts.

Dimensions: cabinet: 17¼" wide, 13⅝" high, 13½" deep (438 x 346 x 343 mm); rack mount: 19" wide, 13-31/32" high, 12⅛" deep behind panel (483 x 355 x 308 mm).

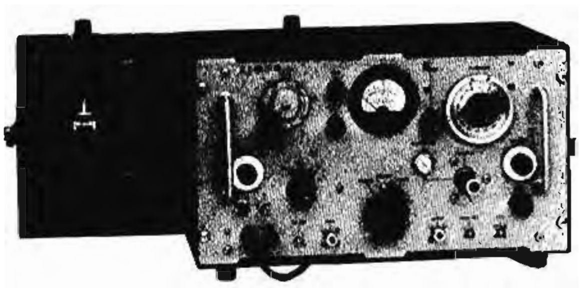
Weight: net 59 lb (26,5 kg); shipping 72 lb (32,4 kg).

Accessory furnished: 11500A RF Cable Assembly.

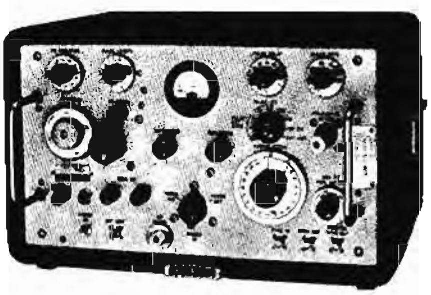
Accessories available: 614A: 360C Low-Pass Filter, $f_c = 2200$ MHz, $65; 10503A Video Cable Assembly, $7; 616B: S281A Waveguide-to-Coax Adapter, 2.6 to 3.95 GHz, $65; G281A Waveguide-to-Coax Adapter, 3.95 to 5.85 GHz, $50; 360D Low-Pass Filter, $f_c = 4.1$ GHz, $60.

Price: HP 614A or HP 616B, $2100 (cabinet); HP 614AR or HP 616BR, $2140 (rack mount).

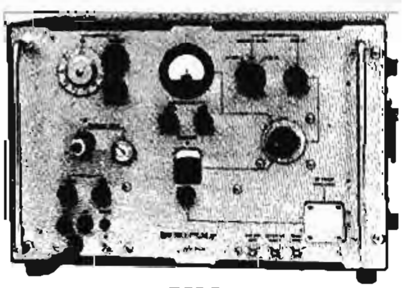
RF TEST SETS
For testing transmitters, receivers
Models 623B, 624C, 5636



623B



624C



5636

Advantages:

Direct reading of power, frequency

Stable accurate input, output attenuators

Compact package for portability in field

Uses:

Measure receiver sensitivity, selectivity

Test transmitter tuning power level

Each of these test instruments consists of a combination signal generator, frequency meter and power meter and permits measurement of receiver sensitivity and selectivity, transmitter tuning and power level. Each is easy to use, fast and accurate.

The HP model 623B SHF Test Set is an ideal one-piece unit for measuring receiver sensitivity or selectivity, transmitter tuning or power level. It is particularly adapted to testing complete communications, control, and video relay station equipment in the range of 5925 to 7750 MHz, using any of 3 klystrons. Its klystron source can be frequency modulated and externally pulse modulated.

From 8.5 to 10.0 GHz, the 624C X-Band Test Set provides a one-piece unit particularly adaptable for testing complete radar, gunfire control systems, or radio beacon equipment. It has internal frequency modulation capability and provision for a 35 Hz to 3.5 kHz pulse, FM, or square wave external modulation.

Nearly overlapping the frequency ranges of the 623B and 624C, the 5636 H-Band-Test Set more than covers the entire government communications band. It performs the same task but offers greater output power and a wider power measurement range than the 623B and 624C.

Model	Frequency range (MHz)	Frequency meter range (MHz)	Output power (dBm)	Output attenuator range (dB)	Internal modulation	External modulation	Power measurement range (CW)	Panel height	Shipping Weight Price
623B	5925-6575 or 6575-7175 or 7125-7750	5820-7780	0 (1 mW)	70	FM, 1 kHz	FM, pulse, square-wave, 30 Hz to 100 kHz	−6 to +3 dBm	11½" (292 mm)	76 lbs. $3100 (transit case)
5636	7100-8500	7100-8500	15 (30 mW)	100	FM, 1 kHz	FM, pulse, square-wave, 30 Hz to 100 kHz	−6 to +40 dBm	14" (355 mm)	98 lbs. $4450 (transit case)
624C	8500-10,000	8500-10,000	0 (1 mW)	100	FM at power line frequency; pulse, 35 to 3500 pps	FM, pulse, square-wave, 35 to 3500 Hz	−6 to +28 dBm	10½" (266 mm)	78 lbs. $3100 (cabinet or rack)

SHF SIGNAL GENERATORS

Multiple-purpose instruments, 3.8 to 11 GHz

Models 618C, 620B

Advantages:

Direct-reading frequency dial
Direct-reading output in voltage or dBm
Internal FM, CW, pulsed or square-wave modulation
Broadband coverage
Wide frequency range
High stability, high accuracy

Use to measure:

Receiver sensitivity
Selectivity or rejection
Signal-to-noise ratio
Antenna gain
Transmission line characteristics

The Models 618C and 620B SHF Signal Generators provide versatility, accuracy, and stability in the range from 3.8 to 11 GHz. Thus such measurements as sensitivity, selectivity, signal-to-noise ratio, SWR, and antenna gain are made with ease. Frequency is set on a large, direct-reading dial. A ΔF vernier control provides ultra-fine tuning capability. There is also a provision for remote fine tuning.

A calibrated output from 0 to —127 dBm (0.224 volts to 0.1 microvolt) is also set on a large, direct-reading dial. The dial is calibrated in both dBm and volts, permitting measurements in terms of either and eliminating any computation in converting from one to the other. In addition, the zero set control for the power monitor has been eliminated, simplifying measurements by reducing the number of steps required. A second, uncalibrated output is available. This auxiliary output is at least 0.3 milliwatt and is independent of attenuator setting. Thus it can be used for phase-locking the signal generator when crystal-oscillator stability is required, or it can be monitored with a frequency counter for extreme frequency resolution.

Reflex klystron oscillator

The 618C and 620B Generators both feature oscillators of the reflex klystron type, with external resonant cavity. Oscillator frequency is determined by a movable plunger which varies the length of the cavity. Oscillator output is monitored by a temperature-compensated detector circuit. This circuit operates virtually unaffected by ambient temperature conditions. Identical piston attenuators couple power to the monitor and output terminal. The power monitor attenuator is linked to the output attenuator cursor to compensate for klystron output variation as frequency is changed.

Broad modulation capabilities

Modulation includes internal pulse, square-wave, and frequency modulation plus external pulse and frequency modulation. Internal pulse and square-wave repetition rates are continuously variable from 40 to 4000 pps, and pulse width is variable from 0.5 to 10 microseconds. Synchronization pulses are available simultaneously with the RF pulse or in advance of the RF pulse from 3 to 300 microseconds. The internal pulse and square-wave modulation can be synchronized with external sine waves or pulses of either polarity, or external pulses can themselves be used as the modulating signal.

For internal frequency modulation, each generator has a sawtooth sweep variable from 40 to 4000 Hz with deviation adjustable up to about 5 MHz peak-to-peak. External FM is accomplished through one of two input connectors. The front-panel input is capacitively coupled to the repeller of the klystron oscillator for standard FM applications. The rear-panel input is dc-coupled to the klystron to permit phase-locking of the oscillator.

Specifications

Output

Frequency range: 618C: 3,800 to 7,600 MHz covered in a single band; 620B: 7 to 11 GHz covered in a single band; repeller voltage automatically tracked and proper mode automatically selected.

Calibration: direct reading; frequency calibration accuracy better than $\pm 1\%$.

Vernier: ΔF control has a minimum range of 0.5 MHz for fine tuning; remote ΔF connector on rear panel permits fine tuning with external potentiometer; tuning range at least 1.5 MHz with potentiometer ≥ 2 megohms.

Frequency stability: with temperature: less than 0.006%/°C change in ambient temperature; with line voltage: less than 0.02% change for line voltage variation of $\pm 10\%$; residual FM: <15 kHz peak.

Output range: 1 milliwatt or 0.224 volt to 0.1 microvolt (0 dBm to —127 dBm) into 50 ohms; directly calibrated in microvolts and dB; coaxial type N connector.

Output accuracy: within ± 2 dB from —7 to —127 dBm, within ± 3 dB from 0 to —7 dBm, terminated in 50-ohm load; temperature-compensated detector circuit monitors RF oscillator power level; an auxiliary, fixed-level RF output (at least 0.3 mW) is provided on the front panel for use with other equipment such as a frequency counter or phase-lock instrumentation.

Source impedance: 50 ohms nominal; reflection coefficient less than 0.33 (2 SWR, 9.6 dB return loss).

Modulation

Modulation: internal or external pulse, FM, and square-wave.

Internal pulse modulation: repetition rate variable from 40 to 4,000 pps, pulse width variable ½ to 10 microseconds.

Sync out signals: simultaneous with RF pulse, positive; in advance of RF pulse, positive, variable 3 to 300 microseconds (better than 1 microsecond rise time and 25 to 100 volts amplitude into 1,000-ohm load).

618C

External synchronization: sine wave: 40 to 4,000 Hz, 5 to 50 V rms; pulse: 40 to 4,000 pps, 5 to 50 V peak, positive or negative, 0.5 to 5 μs wide, 0.1 to 1 μs rise time.

Internal square-wave modulation: variable 40 to 4,000 Hz, controlled by "pulse rate" control.

Internal frequency modulation: sawtooth sweep rate adjustable 40 to 4,000 Hz; frequency deviation to 5 MHz peak-to-peak over most of the frequency range.

External pulse modulation: pulse requirements: amplitude from 5 to 50 volts positive or negative, width 0.5 to 2,500 microseconds.

External FM: frequency deviation approximately 5 MHz peak-to-peak over most of the band; sensitivity approximately 20 V/MHz at front-panel connector, approximately 10 V/MHz at rear-panel connector (mating connector supplied); front-panel connector is capacitively coupled to klystron repeller; rear-panel connector is dc-coupled to klystron repeller and is suitable for phase-lock control input.

General

RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D.

Power source: 115 or 230 volts ±10%, 50 to 60 Hz, 230 watts.

Dimensions: cabinet: 17½ in. wide, 13⅞ in. high, 19⅝ in. deep behind panel (445 x 353 x 499 mm); rack mount: 19 in. wide, 13³¹⁄₃₂ in. high, 19 in. deep behind panel (483 x 355 x 483 mm).

Weight: net, 69 lb (31,1 kg); shipping 90 lb (40,5 kg).

Accessory furnished: 11500A Cable Assembly, 6 feet (1830 mm) of RG-214A/U 50-ohm Coax, terminated on each end by type N male connectors.

Price: Model 618C (cabinet mount), $2350. Model 618CR (rack mount), $2390. Model 620B (cabinet mount), $2350. Model 620 BR (rack mount), $2390.

SHF SIGNAL GENERATORS

Direct-reading, high power, 10 to 21 GHz

Models 626A, 628A

Advantages:

- Direct-reading frequency control
- Direct-reading output control
- 10 mW output over full range
- CW, FM or pulse modulation
- Internal square-wave modulation
- Broad pulsing capabilities
- Low internal SWR
- High stability
- Operate to 40 GHz with HP 938, 940 Frequency Doubler Sets

Use to measure:

- Receiver sensitivity
- Selectivity or rejection
- Signal-to-noise ratio
- Transmission line characteristics

Here are two HP signal generators which extend the measuring versatility, convenience and accuracy of HP VHF signal generators to 21 GHz. The 626A covers frequencies 10 to 15.5 GHz, and the 628A covers frequencies 15 to 21 GHz. In design and operation, the instruments are similar to HP generators for lower frequency ranges. Operation is very simple. Carrier frequency is set and read directly on the large tuning dial. No voltage adjustment is necessary during tuning because repeller voltage is tracked with frequency changes automatically. Oscillator output also is set and read directly, and no frequency correction is necessary throughout operating range. A frequency logging scale permits frequency to be reset within 0.1%.

The high power output of these signal generators make them ideally suited for driving HP 938A and 940A Frequency Doubler Sets (18 to 26.5 GHz and 26.5 to 40 GHz respectively). These doubler sets retain the modulation and stability of the driving source and have accurate power monitors and attenuators.

Versatile modulation

Both the 626A and 628A offer internal and external pulse modulation, as well as internal square-wave modulation and FM. Pulse repetition rate is continuously variable from 40 to 4000 pps, and pulse width is variable from 0.5 to 10 μs. Sync out signals are simultaneous with the RF pulse, or in advance of the RF pulse by any time span from 3 to 300 μs. The pulse generators may be synchronized with an external sine wave and also with positive or negative pulse signals.

For internal FM, both instruments feature a sine-wave sweep at power line frequency. Frequency deviation is variable up to 10 MHz peak-to-peak. For external FM, the generators have capacitive couplings to the klystron oscillator repeller.

Figure 1 shows the basic circuits of the HP signal generators. The reflex klystron oscillator is tuned by a plunger driven by the direct-reading frequency dial and control. Repeller voltage is automatically tracked, so that correct operating potentials are maintained over the entire frequency range. Klystron output is introduced into a power monitoring meter. The directional coupler provides uniform coupling over the entire frequency range. A rotary attenuator which follows the coupler assures high accuracy and stability, because the attenuation is governed by a precise

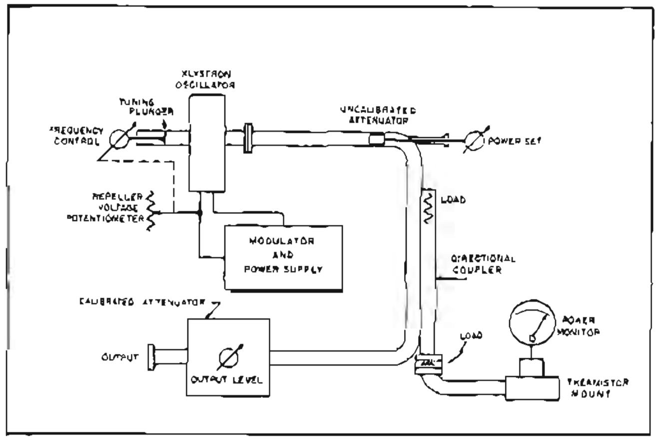


Figure 1. Basic circuit, HP 626A, 628A.

mathematical law related to the angular rotation of the attenuator. The conductivity of the attenuating film does not affect the attenuation; thus, the output of the generator is independent of humidity, temperature or the effect of long-term aging. The attenuator also provides low SWR over the complete frequency range. On both HP 626A and 628A, the output connector is waveguide. Adapters furnished permit the instruments to be connected to WR-42, WR-62 or WR-90 waveguide. Thus, the generators can be employed with all EIA (RETMA) and JAN guides suitable for the 10 to 21 GHz range.

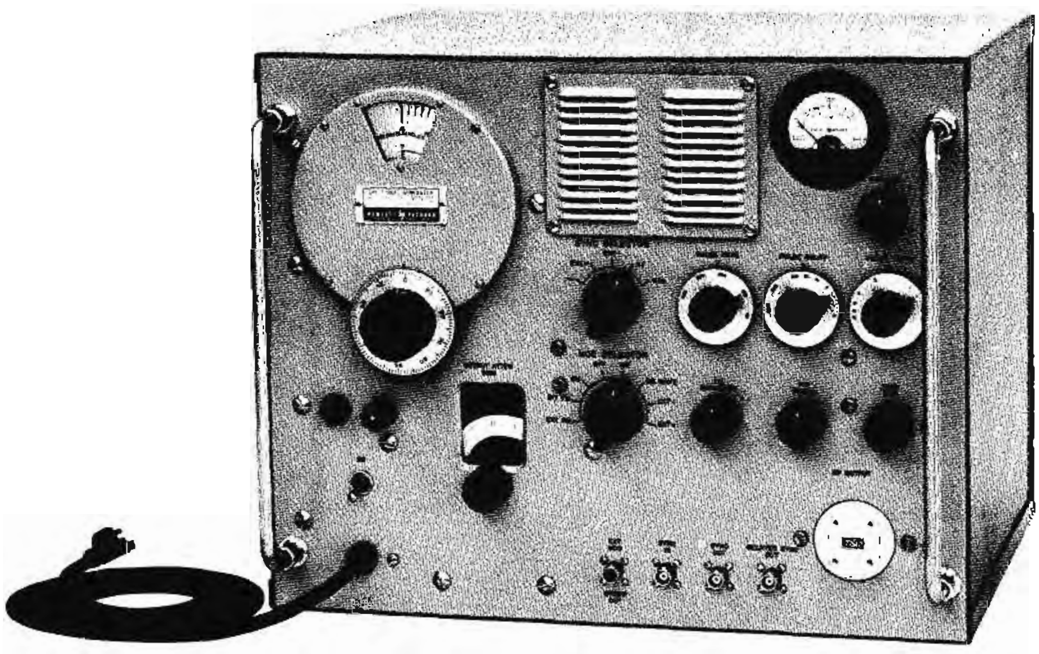
Specifications

Frequency range: 626A, 10 to 15.5 GHz; 628A, 15 to 21 GHz.

Frequency calibration: dial direct-reading in GHz, accuracy better than ±1%.

Output range: 10 mW to 1 nW (+10 dBm to −90 dBm. 0 dBm=1 mW); attenuator dial directly calibrated in output dBm.

Source impedance: 50 ohms nominal; reflection coefficient: 626A, less than 0.43 (2.5 SWR, 7.3 dB return loss) at +10 dBm, 0.15 (1.35 SWR, 16.5 dB return loss) at 0 dBm and below; 628A, less than 0.43 (2.5 SWR, 7.3 dB return loss) at +10 dBm, 0.091 (1.2 SWR, 20.8 dB return loss) at 0 dBm and below.



628A

Output monitor accuracy: better than ±1 dB; temperature-compensated thermistor bridge circuit monitors RF oscillator power level.

Output connector: 626A: 0.850 x 0.475 in. waveguide, WR75, flat cover flange; 628A: 0.590 x 0.335 in. waveguide, WR51, flat cover flange.

Output attenuator accuracy: better than ±2% of attenuation in dB introduced by output attenuator.

Leakage: less than minimum calibrated signal generator output.

Modulation: internal or external pulsed, FM, or square-wave.

Internal pulse modulation: repetition rate variable from 40 to 4000 pps; pulse width variable 0.5 to 10 μs.

Internal square-wave modulation: variable 40 to 4000 Hz controlled by "pulse rate" control.

Internal frequency modulation: power line frequency, deviation up to 10 MHz p-p.

External pulse modulation: pulse requirements: amplitude 15 to 70 volts peak positive or negative; width 1 to 2500 μs.

External frequency modulation: provided by capacitive coupling to repeller of klystron; maximum deviation approximately 10 MHz p-p.

Sync out signals: positive 20 to 50 volts peak into 1000-ohm load; better than 1 μs rise time; (1) simultaneous with RF pulse, positive; (2) in advance of RF pulse, positive, variable 3 to 300 μs.

External synchronization: (1) sine wave, 40 to 4000 Hz, amplitude 5 to 50 volts rms; (2) pulse signals 0 to 4000 pps, 5 to 50 volts amplitude, positive or negative; pulse width 0.5 to 5 μs; rise time 0.1 to 1 μs.

Power: 115 or 230 volts ±10%, 50 to 60 Hz approx. 200 watts.

Dimensions: cabinet: 17" wide, 14" high, 15" deep (432 x 356 x 381 mm); rack mount: 19" wide, 14" high, 12-13/16" deep behind panel (483 x 356 x 313 mm).

Weight: 626A,AR: net 61 lb (28,1 kg), shipping 76 lb (34,2 kg); 628A,AR: net 57 lb (26,4 kg), shipping 76 lb (34,2 kg).

Accessories furnished: 626A (a) MX 292B Waveguide Adapter, WR-75-to-WR-90 guide; (b) MP 292B Waveguide Adapter, WR-75-to-WR-62 guide; 628A (a) NP 292A Waveguide Adapter, WR-51-to-WR-62 guide; (b) NK 292A Waveguide Adapter, WR-51-to-WR-42 guide.

Accessories available: 10503A Video Cable Assembly, $7; for 626A: M362A Low-Pass Filter, $350.

Price: HP 626A or 628A, $3600 (cabinet); HP 626AR or 628AR, $3640 (rack mount).

FREQUENCY DOUBLER SETS

Generate stable signals to 40 GHz

Model 938A, 940A

Hewlett-Packard Model 938A and Model 940A Frequency Doubler Sets bring you low-cost signal-generation capability in K- and R-bands (18 to 40 GHz). Model 938A supplies power from 18 to 26.5 GHz when it is driven by a 9 to 13.25 GHz source; Model 940A supplies power from 26.5 to 40 GHz when it is driven by a 13.25 to 20 GHz source.

These frequency doubler sets consist of broadband crystal harmonic generators suitably mounted in a waveguide section, a power monitor, a broad stopband low-pass filter and a precision attenuator. They may be driven by klystrons, by signal generators such as HP Models 626A and 628A, or by sweep oscillators such as HP Model 8690B with 8694A,B or 8695A RF Units.

Since Model 938A and Model 940A are broadband instruments, the input signal may be CW, pulsed, or swept. Thus, the frequency doubler sets retain all the versatility of the driving source.

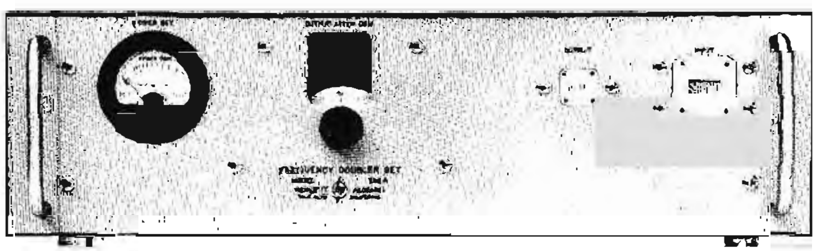
Output monitor

Models 938A and 940A have power monitors and precision rotary-vane attenuators for accurately setting output level over a range from 0 to —100 dB. Output power depends on input power and is typically 0.5 to 1 mW when a 626A, 628A, or 8690B is used as a driving source. Further, since Models 938A and 940A contain a power monitor, output power is known even though an uncalibrated signal source is used.

Signal generator or swept-frequency operation

Models 938A and 940A have the same output versatility as the driving source. For instance, if you drive Model 938A with Model 626A you may have CW output, pulse-modulated output with a repetition rate from 40 to 4000 pps, square-wave-modulated output with modulation frequencies from 40 to 4000 Hz, or 60 Hz (power line frequency) FM output. In addition, pulsed output may be synchronized with external signals or output may be externally pulse or frequency modulated.

To obtain a swept-frequency output, you simply drive the frequency doubler set from a swept-frequency source such as Model 8690B with 8694A,B or 8695A RF Unit.



938A

Specifications

Frequency range: 938A, 18 to 26.5 GHz; 940A, 26.5 to 40 GHz.

Conversion loss: less than 18 dB at 10 mW input.

Output power: depends on input power supplied; approx. 0.5-1 mW when used with typical 626A, 628A Signal Generators.

Maximum input power: 100 mW.

Output monitor accuracy: ±2 dB.

Output attenuator accuracy: ±2% of reading or ±0.2 dB, whichever is greater.

Attenuator range: 100 dB.

Output reflection coefficient: approximately 0.33 (2 SWR, 9.5 dB return loss) at full output; less than 0.2 (1.5 SWR, 14 dB return loss) with attenuator set to 10 dB or more attenuation.

Input flange: 938A, M-band flat cover flange for WR-75 waveguide; 940A, N-band flat cover flange for WR-51 waveguide.

Output flange: 938A, UG-595/U flat cover flange for WR-42 waveguide (K-band); 940A, UG-599/U flat cover flange for WR-28 waveguide (R-band).

Dimensions: cabinet: 19¼" wide, 5⅜" high, 18" deep (489 x 137 x 457 mm).

Weight: net 20 lb (9 kg); shipping 35 lb (15,8 kg).

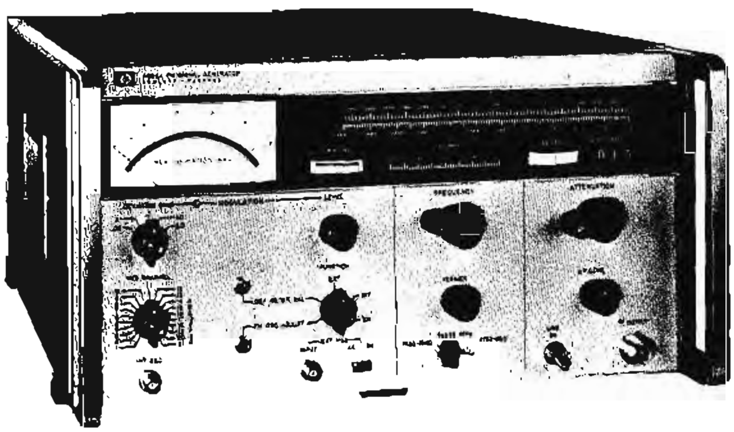
Accessories available: 938A, X281A Waveguide-to-Coax Adapter, 8.2 to 12.4 gc, $35; MX292B and MP292B Waveguide-to-Waveguide Adapters, $50 and $40 respectively (1 each furnished with 626A); 11504A X-band Flexible Waveguide, $35; 11503A P-band Flexible Waveguide, $48; 940A, MP292B and NP292A Waveguide-to-Waveguide Adapters, $40 each (1 each furnished with 628A); 11503A P-band Flexible Waveguide, $48.

Complementary equipment: 938A, 626A Signal Generator; 8690B Sweep Oscillator with 8694A,B and 8695A RF Unit. 940A, 626A and 628A Signal Generators; 8690B Sweep Oscillator with 8695A RF Unit.

Price: HP 938A or HP 940A, $2250 (cabinet).

FM SIGNAL GENERATOR
Covers both new telemetry bands
Model 3205A

The Model 3205A FM Signal Generator is a self-contained, completely solid-state instrument designed for use in the measurement and calibration of FM telemetry receivers in the 1435 to 1540 MHz and 2200 to 2300 MHz frequency bands. Peak FM deviation of the RF output on one of five different ranges is indicated on a calibrated deviation meter. The generator has its own deviation meter calibration system that does not require external instrumentation. A calibrated RF output level, adjustable from −10 dBm to −127 dBm is also included. An internal modulation oscillator permits selection of channels 1 through 21 of the standard IRIG (Inter-range Instrumentation Group) subcarrier frequencies used for telemetry systems.



3205A

Specifications

RF characteristics

Frequency range: band 1, 1430 to 1540 MHz; band 2, 2150 to 2310 MHz.

Frequency accuracy (main dial): ±0.3%.

Vernier: 40 logging divisions, approx. ±2 MHz.

Frequency stability (after ½ hour warm-up with modulation input ac coupled): short term, 40 PPM per 10 minutes; long term, 150 PPM per hour; temperature coefficient, <30 PPM per °C.

RF output (main): −10 to −127 dBm.

RF output levelling: 1.5 dB pk-pk maximum excursion across each band.

Spurious output: non-harmonically related, >50 dB below main output on either band; harmonically related, >20 dB below main output.

Modulation characteristics

FM deviation: ±3 MHz.

Modulation frequency response: ±1 dB (referenced to 10 kHz) from dc (dc coupled) or 5 Hz (ac coupled) to 750 kHz; +2, −3 dB to 2 MHz.

FM non-linearity:

Band 1:
- <0.5% at ±.5 MHz deviation (f_{mod} to .5 MHz)
- <1.0% at ±1 MHz deviation (f_{mod} to 1 MHz)
- <7.0% at ±3 MHz deviation (f_{mod} to 2 MHz)

Band 2:
- <0.3% at ±.5 MHz deviation (f_{mod} to .5 MHz)
- <0.7% at ±1 MHz deviation (f_{mod} to 1 MHz)
- <4.0% at ±3 MHz deviation (f_{mod} to 2 MHz)

FM calibration: 30 kHz to 3 MHz full scale in 5 ranges; accuracy, ±5% of full scale ($f_{mod} = 5$ Hz to .5 MHz); internal deviation calibrator provides 1% calibrate point at .667 MHz on band 1 and 1.00 MHz on band 2.

Residual FM: less than 1.5 kHz on band 1, 2.0 kHz on band 2, measured in a 1.5 MHz equivalent rectangular bandwidth.

External FM input: impedance: 600 ohms shunted by less than 45 pF (75 pF, option 001); sensitivity: band 1, <1.5 V rms for 1 MHz deviation; band 2, <1 V rms for 1 MHz deviation.

Internal modulation oscillator: frequencies: IRIG proportional subcarrier channels 1 through 21; accuracy: ±2%; THD: <0.5%.

Dimensions: 16¾″ wide, 8¾″ high, 18⅜″ deep, (425 x 222 x 467 mm).

Weight: net 52 lbs (23,4 kg); shipping 67 lbs (30,2 kg).

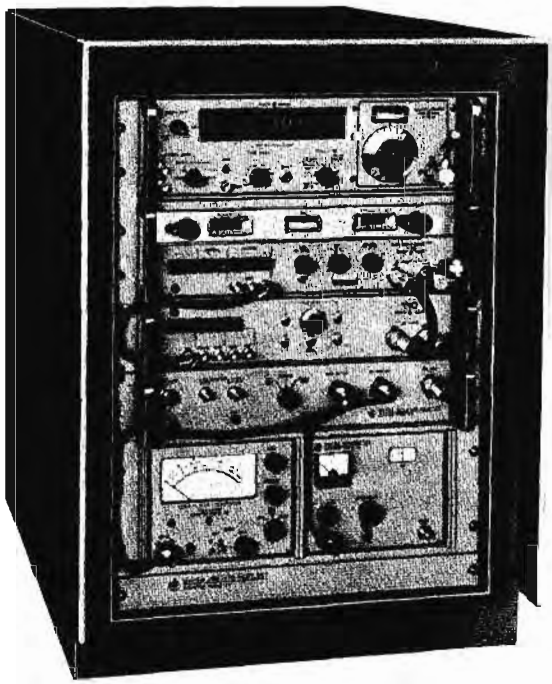
Power: 115 or 230 V ±10%, 50 to 400 Hz, 50 watts.

Price: $5,750.

Option 001: all front panel connectors moved to rear panel. Add $50.

SIGNAL SOURCES

DME/ATC TEST SET
Calibrates DME and ATC equipment
Model 8925A



8925A

The HP 8925A DME/ATC Test Set is specifically designed for testing and calibrating DME (Distance Measuring Equipment) and ATC (Air Traffic Control) transponder aircraft equipment. When used with suitable modulators, the test set will also simulate some TACAN and IFF signals. Completely self-contained (except for video modulators), the system consists of a continuously tuneable signal generator (HP H01-8614A), direct-reading frequency counter (HP 5245L), solid-state modulator (HP H01-8403A), frequency converter (HP 5254A), wavemeter (HP 8905A), peak power measuring system (HP 8900B), and all necessary circuitry for interconnection to the radio set under test (HP 13505A).

Specifications

Radio frequency characteristics

RF range: 962 to 1213 MHz.

RF accuracy: determined by ability to set to desired reading on counter.

RF settability: better than 100 kHz.

RF stability: temperature, approx 0.005% per degree C; line voltage, <0.003% (±10% line voltage change).

RF output: range: −10 to −100 dBm cross external 50-ohm load at output jack, accuracy:

Attenuator setting	ATC (1015 to 1045 MHz)	DME (962 to 1213 MHz)
−10 to −17 dBm	+0.7 to 1.2 dB	+1.1 to 1.6 dB
−17 dBm	±0.6 dB	±1 dB
−17 to −100 dBm	±(0.8 + 0.06 per 10 dB) dB	±(1.2 + 0.06 per 10 dB) dB

Leveled output: (fixed atten. position) ATC, ±0.2 dB; DME, ±0.6 dB; impedance: 50 ohms; VSWR: 1.35:1.

Pulse modulation characteristics

PM source: suitable external video modulators.

Pulse shape: with suitable modulators, meets general requirements of DME/ATC.

Side-lobe suppression: the second pulse of a train of 2 (or 3) pulses may be varied +1 to −10 dB from the first pulse when its leading edge is ≧2 μs from the first pulse leading edge; calibrated SLS control accurate to ±0.5 dB.

Simulated bearing input: audio frequency input to BNC jack under TACAN button will simulate bearing modulation to a depth of 55% max. (3.8 dB above pulse tips).

Power measurement characteristics

RF range: 962 to 1213 MHz; RF power range: 100 to 2000 watts peak (ARINC units), 10 to 200/100 to 2000 watts peak (Gen. Aviation and ARINC units) available as factory modification with accessory attenuator; RF power accuracy: ±1.2 dB from calibration curve).

Frequency measurements characteristics

RF range: 1070 to 1110 MHz; RF accuracy: ±0.5 MHz; direct meter indication for peak power 250 to 1000 watts at 25°C; video output for external scope indication for input peak power down to approx 10 watts.

Monitor characteristics

Signal generator monitor (Monitor-Sig Gen), heterodyne monitor (Het Mon): frequency range: 1018 to 1032 MHz (for beating oscillator 1025 ±1 MHz); output level: 0.5 volts peak min at −10 dBm RF level (at IF center frequency); load impedance: 150 ohms nominal; bandwidth: 9 MHz nominal (equivalent low-pass bandwidth 4 MHz); linearity: ±0.5 dB (−10 to −20 dBm RF level).

Diode monitor (Diode Mon): frequency range: 962 to 1213 MHz; output level: 0.1 V peak min at −10 dBm RF level; low-pass bandwidth: 5 MHz nominal.

Transmitter monitor (Monitor-Xmtr): output level: approx 0.2 V peak for 200 watts peak input (100 to 2000 watts peak power range), 20 watts peak input (10 to 200 watts peak power range); load impedance: 150 ohms nominal; bandwidth: 10 MHz nominal; linearity: ±1 dB for 200 to 2000/20 to 200 watts peak input; transmitter interlock: terminals are provided for de-energizing the transmitter when the system internal load is removed from the transmitter antenna.

Dimensions: 23" wide, 32¼" high, 26" deep (584 x 819 x 660 mm).

Weight: net 310 lbs (139,5 kg); shipping 350 lbs (157,5 kg).

Power: 105 to 125 or 210 to 250 volts, 50 to 60 Hz, 400 W.

Price: HP 8925A, $12,135.

Options: 01: less 5245L/5254A Counter, $8,860; 02: less cabinet, $11,545; 03: dual power range (10 to 200/100 to 2000 watts), add $100; 04: HP 5246L Counter instead of HP 5245L, $11,435, specify by option number.

SIGNAL GENERATORS
Test and calibrate aircraft VOR and ILS
Models 211A, 232A

211A Signal Generator

The HP 211A Crystal-Monitored Signal Generator is specifically designed for the testing and calibrating of aircraft VOR and ILS localizer radio receiving equipment operating within the frequency range from 88 to 140 MHz. It also may be used for laboratory and development work where a precision-type amplitude-modulated RF signal source is required.

232A Signal Generator

The FAA Instrument Landing System for aircraft includes a glide slope receiver for indicating the proper rate of descent. The HP 232A Glide Slope Signal Generator was designed for use in testing and calibrating these glide slope receivers.

Specifications, 211A

Radio frequency characteristics

RF range: master oscillator: 88 to 140 MHz in one range; crystal oscillator: 110.1 and 114.9 MHz.

RF output: range: 0.1 μV to 0.2 volt (across external 50-ohm load); impedance: 50 ohms; spurious output: all spurious RF output voltages are better than 40 dB below desired output.

Amplitude modulation characteristics: AM range, 0 to 100% in two ranges.

Physical characteristics

Dimensions: 211A and 211AP1 (Power Supply): 19½" wide, 10½" high, 9½" deep (495 x 267 x 241 mm).

Weight: net 63 lbs (28,4 kg); shipping 86 lbs (38,7 kg).

Power: 105 to 125 V, 50 to 60 Hz, 150 W.

Price: HP 211A, 211AP1, $2900.

Specifications, 232A

Radio frequency characteristics

RF range: (A) 329.3 to 335 MHz in increments of 0.3 MHz; (B) 20.7 MHz; other frequencies between 15 and 30 MHz available on special order.

RF accuracy: ±0.0065% (crystal controlled).

RF output: range: 1 μV to 0.2 V (across external 50-ohm load); accuracy: ±10% approximately; impedance: 50 ohms.

RF leakage: sufficiently low to permit measurement at 1 μV.

Amplitude modulation characteristics

Am range: internal: 0 to 100% in two ranges; external: 0 to 100% in two ranges.

AM calibration: increments of 2%, 0 to 50%; increments of 10%, 0 to 100%.

Demodulated output: available at front-panel posts through 2 μF capacitor.

Modulating oscillator characteristics

OSC frequency: (A) 1000 Hz; (B) 90 and 150 Hz in the following tone ratios: 0 dB, ±0.5 dB, ±1 dB, ±2 dB, ±3.3 dB, ± infinite dB (calibrate).

Physical characteristics

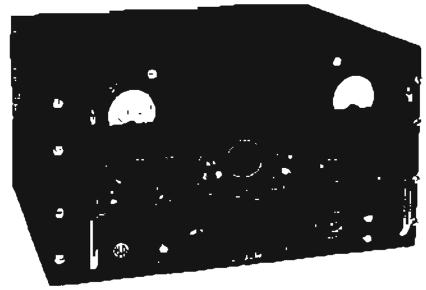
Dimensions: 20⅞" wide, 10½" high, 12" deep (511 x 267 x 305 mm).

Weight: net 64 lbs (28,8 kg); shipping 75 lbs (33,8 kg).

Power: 105 to 125 V, 60 ±1 Hz, 150 W.

Price: HP 232A, $3200.

Option 01: 105 to 125 V, 50 Hz, 150 W; add $50.



232A

211A

SPECTRUM GENERATOR/DOUBLER

Versatile broadband operation

Models 10511A, 10515A

HP 10511A Spectrum Generator

The Hewlett-Packard 10511A Spectrum Generator is a passive device that generates a train of 1 nanosecond wide pulses when driven by a sinusoidal signal source. The 10511A was specifically designed as an accessory to the HP 5100A Frequency Synthesizer. However, it is useful with any 50Ω source that can provide the proper input signal.

With a sine wave input, in the frequency range of 10 MHz to 75 MHz, a spectrum of harmonics is generated. This spectrum contains all harmonics of the input frequency to the 1 GHz region. To extract a desired harmonic, a 50Ω bandpass filter can be cascaded with the 10511A to give a sinusoidal output. The HP 230A Power Amplifier (tuned) may be used for higher level outputs for harmonics up to 500 Hz.

Operation of the 10511A with the 5100A without a bandpass filter on the output produces a pulse train whose repetition rate is precisely controlled. The 10511A, with a tuned filter, produces precise CW frequencies between 50 MHz and 500 MHz.

Specifications 10511A

Input requirements

Frequency range: 25 to 50 MHz.*

Drive level: 1 to 3 volts RMS available to 50Ω.

Output

Pulse width: 1 nanosecond, ± 15% at mid-amplitude.

Pulse height: 0.75 volt minimum for minimum drive level.

Impedance: 50Ω (nominal).

Available harmonic power: —19 dBm minimum for any harmonic number between 1 and 10.

General

Dimensions: 3 in. long, 1⅝ in. dia. (76 x 41 mm).

Weight: net, 3 oz (85 grams). Shipping, 1 lb (0,45 kg).

Price: model 10511A, $150.00.

*Useful operation is obtained for input frequencies from 10 MHz to 75 MHz.

HP 10515A Frequency Doubler

The Hewlett-Packard Model 10515A Frequency Doubler is an ideal accessory for use in extending the usable frequency range of signal generators, frequency synthesizers or other signal sources. Operating on input frequencies of 0.5 MHz to 500 MHz it provides a doubled output in the range of 1 MHz to 1 GHz. This 50 ohm device uses a full-wave rectifier circuit which is extremely flat over its entire frequency range. The frequency response is very flat (< ± 1 dB over entire range typically), and undesired harmonics are very well suppressed.

The output of this unit does not have an internal dc return so that it will provide a very broadband ac to dc conversion only if not dc terminated. This mode of operation is useful for detection of low level amplitude modulations.

The 10515A may be used with the following Hewlett-Packard instruments (this is only a partial listing):

5100A Frequency Synthesizer	606A Signal Generator
5102A Frequency Synthesizer	3200B VHF Oscillator
5103A Frequency Synthesizer	608 Signal Generators
5105A Frequency Synthesizer	

Specifications 10515A

Frequency range: 0.5-500 MHz input; 1-1000 MHz output.

Impedance: 50Ω nominal (source and load).

Input signal voltage: 0.5 - 3.0 V_{RMS}.

Input signal power: 180 mW (maximum).

Conversion loss:*

<12 dB (typically <11 dB) for >1 volt

<13 dB (typically <12 dB) for >0.5 volt

Suppression of 1st and 3rd harmonic of input:*

>30 dB for 0.5 to 50 MHz input (typically >35 dB).

>10 dB for input to 500 MHz (typically >15 dB).

Connectors: input: BNC male; output: BNC female.

Dimensions: diameter: 0.7" (18 mm); length: 2.5" (64 mm).

Weight: net, approximately 2 oz (56 grams); shipping, 1 lb (0,45 kg).

Price: model 10515A, $120.00.

*With a 50 ohm resistive load and a single input frequency. Suppression values are referred to the desired output level.

Sweepers are used to present a dynamic or real time display of the amplitude and/or phase response of a device under test. When a sweeper is used in testing devices, it can quickly provide important information that might otherwise require laborious time-consuming tests. For example, in the design of a feedback amplifier, point-by-point measurements are time-consuming; and, if the amplifier design is changed, it is necessary to repeat the test to see the effects of the change.

The sweeper avoids this problem by sweeping the frequency range of interest so that the response of the device under test can be displayed. When selecting a sweeper, consider the characteristics needed: sweep frequency range, linearity, flatness, and dial accuracy. Other considerations are linear or log sweep, variable sweep speed, blanking, and pen lift.

Hewlett-Packard sweepers include frequencies from 0.1 Hz to 40 GHz, and most of the above mentioned requirements are described in the instrument's specifications. Table 1 on page 415 briefly describes the characteristics of all Hewlett-Packard sweepers and associated plug-in units. The following paragraphs discuss these sweepers beginning with the lowest frequency models.

Model 3305A

The 3305A is a log sweep plug-in for the 3300A Function Generator mainframe. This combination provides a low-frequency, wideband sweep generator in addition to the other features of a versatile plug-in function generator.

The 3305A sweeps up to 4 decades in a single sweep covering frequencies from 0.1 Hz to 100 kHz in three overlapping ranges (0.1 Hz-1 kHz, 1 Hz-10 kHz, 10 Hz-100 kHz). The start and stop frequencies can be independently adjusted to any point on any one range. The sweep of the preset frequencies allows logarithmic frequency plots to be made, and a good approximation to a linear sweep can be obtained when the sweep width is small. A linear sawtooth output is available for the X-axis of oscilloscopes or X-Y recorders. This sweep plug-in also includes signal blanking and pen lift during retrace.

The 3305A has four modes of operation: 1) automatically repetitive sweeps, 2) a single sweep per trigger pulse (local or remote), 3) manual sweep, and 4) remotely programmed or swept up to 4 decades by setting the start control to a desired frequency and applying an external voltage.

High-accuracy sweep generator

The Hewlett-Packard 675A is an essential tool for the design, test or production engineer. With it an engineer can test such broadband circuits as amplifiers and attenuators over a 3½-decade range in one 10-kHz to 32-MHz sweep, without changing plug-in units. In addition, because the instrument has exceptional frequency stability and low residual frequency modulation, it can measure the response of narrowband circuits, high-Q filters, and crystals. The generator's start-stop and center frequency sweeps have ±1% end point accuracy, eliminating the need to calibrate each sweep setting individually.

For most lab applications the 675A offers meaningful measurements of amplitude versus frequency without the use of markers because its dial accuracy and linearity permit readings directly from the oscilloscope graticule or X-Y recording coordinates. For additional accuracy the 1-MHz and 100-kHz harmonic markers are available. Problems of FM on a CW signal or jitter display during sweep are solved by the 675A with residual FM less than 70 Hz peak. The 675A is ideally suited for applications such as testing narrowband and broadband amplifiers, filters, (bandwidth 1000 Hz or greater) and attenuations, and transmitter and receiver alignment. Test laboratories with automatic measurement systems will also benefit from the versatility, and programmability the 675A offers.

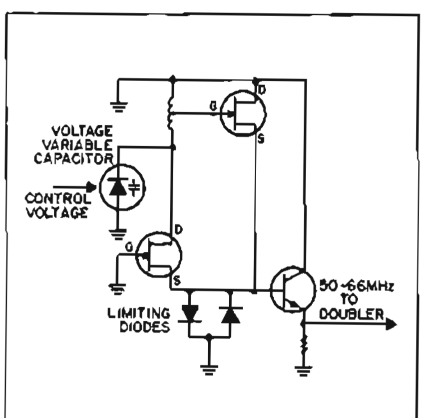


Figure 1. Equivalent circuit of the variable-frequency oscillator.

Behind these unusual capabilities is the voltage tuned oscillator (VTO) shown in Figure 1. Field-effect transistors are used to provide the high-Q in the tank circuit ensuring good frequency stability and low residual FM. A temperature-controlled oven minimizes frequency variations. The generator output is the difference frequency between the output of the VFO (ranging from 100 to 132 MHz) and the output of a 100-MHz crystal oscillator. A voltage proportional to the generator's output is derived from a peak detector with exceptionally flat frequency response. This voltage is used for output monitoring and also feeds an (ALC) automatic leveling loop. An ALC modulator directly controls the 100-MHz signal to the mixer and, thus, the amplitude of the final output signal. A voltage-variable capacitor allows for electronic, rather than mechanical, tuning. Depending upon the function selected, the tuning voltage is derived by summing ramps and/or adjustable signals. During sweep operation, front panel controls select the dc and ramp voltage required. In CW operation, the dc voltage alone sets the output frequency.

Phase and amplitude detector

A new Phase and Amplitude Tracking Detector (HP 676A) combined with the HP 675A Sweeping Signal Generator offers an amplitude response of 80 dB dynamic range, accompanied by 360° (or multiples thereof) of phase measurement capability. This 675A/676A combination is an ideal network analyzer for both narrowband and broadband frequency sweeps. Transfer characteristics, impedance plots, dynamic input and output impedance, system flatness, return loss, time delay, small signal analysis, and open- and closed-loop response are some of many possible network analyzer applications. A great advantage that the 676A Tracking Detector has over most broadband detectors used in sweeping signal generators is that the 676A detects only the fundamental swept output of the sweeper, thus eliminating unwanted harmonic responses. The 676A and 675A compare a device under test against a known standard and display amplitude and phase information simultaneously on an oscilloscope.

The 676A is a two-channel phase and amplitude tracking detector. The swept signal generated by the 675A is split into two equal channels by the power divider of the 676A, and then excites the device under test in each channel. The detected outputs from each channel are then compared for phase and amplitude difference. A very important feature of the 676A is the narrow (8 kHz) tracking "window" through which the detector sees incoming signals. Because the window tracks along the frequency scale locked to the 675A sweep, the 676A sees only the fundamental of the 675A, thus providing 80 dB of dynamic range. The window is the 8 kHz bandpass of the 676A IF strip. The IF amplifier has a logarithmic gain characteristic providing an output proportional to the log of the input. Since the same local oscillator is used for both channels, any phase difference between channels is eliminated.

A typical application of network analysis is shown in Figure 2. Other applications are shown on pages 418 and 468.

Figure 2a demonstrates the 675A's and 676A's ability to portray on an oscilloscope an 80-dB bandpass of a Chebishev filter. Simultaneously the 675A and 676A has the ability to portray minute aberrations over an expanded portion (Figure 2b) as well as the complete bandpass of the filter. 1-MHz markers are easily identified in Figures 2a and 2b.

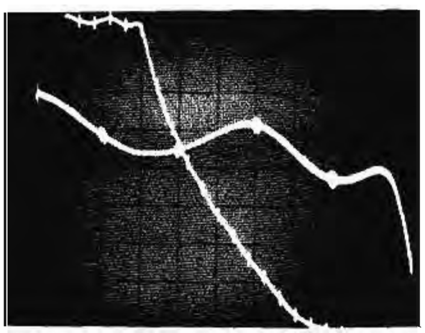


Figure 2. (a) Amplitude response of filter from 100 kHz to 20 MHz at 10 dB/cm. (b) Amplitude response of same filter 100 kHz to 5 MHz at 1 db/cm.

Wideband RF and microwave sweepers

Application Note 65 covering the use and accuracy of swept frequency techniques for attenuation, impedance, power, and frequency calibration measurement provides an up-to-date compendium of the latest developments in microwave swept measurements. This Note may be obtained from any Hewlett-Packard field office at no charge.

The HP 8690 Series Sweep Oscillators cover the frequency range 400 kHz to 110 MHz and 1 to 40 GHz. They provide calibrated broad and narrow sweeps, and markers which amplitude-modulate the RF may be used on either. The markers also may be used as end points of a second broadband sweep. Manual sweep reduces X-Y recorder set-up time, and push-buttons greatly simplify operation. The RF output frequency may be swept slowly enough for presentation on an X-Y recorder or fast enough for no-flicker presentation on an oscilloscope.

The 8690 Series sweep oscillators have been designed to incorporate plug-in RF units enabling the operator to change frequency bands quickly. This eliminates the need for duplicate equipment to cover each RF or microwave band. The 8690B Main-frame provides two independent broad-band sweeps, start-stop, marker sweep, and one precision narrow band sweep, a calibrated Δf sweep. Included is internal square-wave modulation with a range of 950 to 1,050 Hz plus external AM and FM. External FM permits frequency-programming, including externally controlled sweeps over the whole range or any part of it.

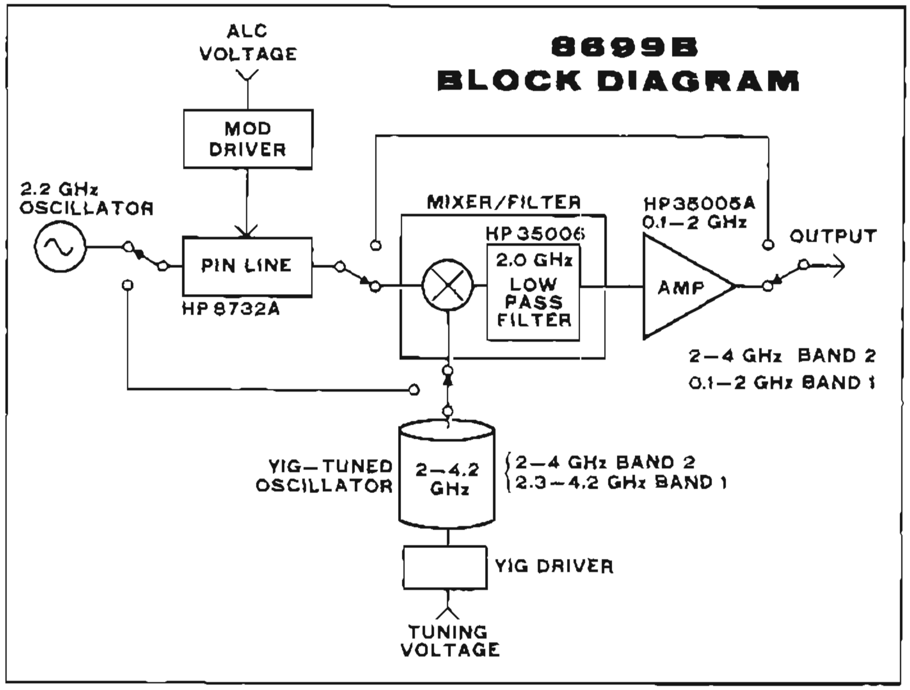


Figure 3. 8699B 100 MHz to 4 GHz RF Unit Block Diagram.

New microcircuit, YIG-tuned RF unit

The 8699B all-solid-state RF Unit (page 430) for the 8690B covers the entire 100-MHz to 4-GHz spectrum in only two ranges. This makes the 8690-Series Sweep Oscillators uniquely superior, with BWO coverage available all the way to 40 GHz and RF coverage down to 400 kHz with the 8698B.

Design of the 8699B is shown in Fig. 3. The use of an extremely broadband microcircuit amplifier allows signals to be mixed at low levels, keeping spurious responses down, but still providing adequate power over more than five octaves. The YIG-tuned oscillator is inherently linear, eliminating the need for complicated frequency-shaping networks. The result is $\pm 0.5\%$ linearity over the entire range.

The significant impact of Hewlett-Packard's microcircuit technology is exemplified by the 8699B's performance in the heterodyne mode: Hewlett-Packard hybrid microcircuit capability makes manufacture of the broadband amplifier and rapid cutoff filter possible. The use of Hewlett-Packard microwave chip transistors and s-parameter design methods has resulted in this YIG-tuned solid-state oscillator that has no match on the market today.

Swept signal generator design
Wide frequency range

The HP 8601A Generator/Sweeper and the 8698B RF Unit plug-in for the 8690B Sweep Oscillator achieve very wide frequency coverage on each band using a beat frequency technique. A 200-MHz signal from a crystal-controlled oscillator is modulated before becoming the linear input to a balanced mixer. A voltage-tuned oscillator (VTO) operating between 200.1 (200.4 in 8698B) and 310 MHz drives the mixer. The difference frequency is filtered and fed to a thin-film video amplifier whose maximum output is 100 mW (+20 dBm). A detector at this output provides a dc signal (proportional to RF level) to the meter (8601A) and to one input of a differential amplifier. The other input is a voltage reference comprised of level, calibrator, AM, and blanking commands. The output of this amplifier to the modulator completes the automatic level control (ALC) loop. The level vernier controls signal level over a 13-dB range, and an output attenuator provides 10-dB steps.

Low harmonic distortion

To reduce harmonic distortion, the video amplifier provides 100 mW (+20 dBm) output at the +20 dBm attenuator setting only; other settings provide +10 dBm at the input to the attenuator.

Linearity

VTO nonlinearities are avoided by a feedback loop containing a very linear 0.1 (0.4 in 8698B) to 11 MHz pulse count discriminator. In the 1- to 110-MHz range, the unmodulated RF output of a second balanced mixer is frequency-divided by ten and applied to the discriminator (low range operation bypasses the divider). The discriminator output voltage is one input of a second differential dc amplifier. The other input is the tuning command voltage. The output of this amplifier controls the frequency of the VTO in such a way that a very linear voltage-to-frequency characteristic is obtained. The bandwidth of the frequency control loop is reduced for CW and manual operation on the 1- to 110-MHz range to improve spectral quality.

CW and sweep modes

In CW, a calibrated precision potentiometer across the extremely stable power supply provides a low-noise tuning voltage. In swept and FM modes, the tuning voltage is obtained from a monolithic (operational) amplifier maintained at constant temperature by a solid-state oven. This amplifier sums the various control voltages.

Crystal calibrator

The crystal calibrator mixes harmonics of a 5-MHz crystal with the output of the frequency control loop mixer. The markers are applied to the ALC loop to produce "dips" in the CW output at 5-MHz intervals.

Auxiliary output

The input to the discriminator is also an auxiliary output, allowing the CW frequency to be monitored by an inexpensive low-frequency counter.

Models 8691A/B through 8697A RF Units contain voltage tuned backward wave tubes covering the frequency range 1 GHz to 40 GHz. RF units in the 1 to 12.4 GHz range can be provided with PIN diode attenuators which permit all of the amplitude modulation functions, including leveling, to be performed independently of the backward-wave tube. The result is virtual elimination of frequency pulling, which, in turn, results in extremely high frequency accuracy and linearity and very low incidental FM.

Control unit, RF unit holder, and signal multiplexer

A simple and inexpensive solution to the problem of broadband sweep capability (more than an octave) is offered by Hewlett-Packard's Model 8706A Control Unit with the Model 8707A RF Unit Holder (see page 432 and 433). When used with the Model 8690B Sweep Oscillator and appropriate RF units, a compact, bench-top multiband source is formed.

The Model 8706 Control Unit, with its nine band selector buttons, replaces the usual RF unit as a plug-in for the sweep oscillator mainframe. It supplies power for and controls as many as three Model 8707A RF Unit Holders, each of which accommodates three RF units. A system with three Model 8707A's can be used to select instantly all or part of the complete 400 kHz to 40 GHz range.

Units may be programmed by either front panel control unit pushbutton selection or sequentially by remote contact closure to ground. The 8706A also can provide voltages for control of remote circuits, relays, etc. By utilizing these voltages to program a coaxial switch, for example, you can channel the output signals of several RF units through a single system output connector. Multi-band tests can then be made quickly and easily; changing RF units and cable connections is handled automatically at the touch of a button. The Model 8705A Signal Multiplexer ideally satisfies this switching requirement to allow time-saving broadband measurements. It switches RF signals up to 12.4 GHz from three 8690-Series RF Units to a choice of two RF output ports.

Unnecessary operation of BWO tubes should be avoided to prolong their life. At the same time it is desirable to have the output of any RF unit quickly available. The 8706A/8707A sweep system maintains the BWO's on standby, removing the high voltage when not in use to extend tube life. When a single band is not to be used over some period of time, for example, during a laboratory setup procedure, an individual RF unit may be easily turned off, minimizing all aging effects.

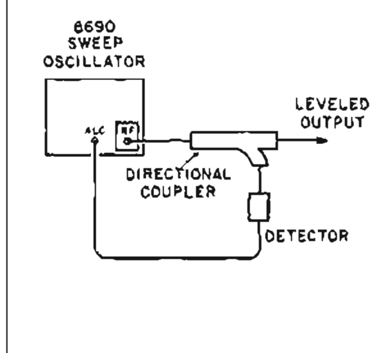


Figure 4. Basic closed-loop leveling system.

Leveled output from sweep oscillators

The development of closed-loop feedback systems for leveling sweep oscillator output power has greatly expanded the practical scope of swept-frequency measurements. The basic closed-loop system is shown in Figure 4.

The HP 8690 Series Sweep Oscillators contain a leveling amplifier for automatic level control (ALC); the power variation that occurs at the system output is primarily determined by coupler and detector variation. For coaxial systems, Hewlett-Packard has developed the 780 Series Directional Detectors (page 297) which consist of a high directivity, flat directional coupler combined with a high sensitivity, flat-response crystal detector. System flatness of better than ±0.3 dB over octave bandwidths is typical, using Hewlett-Packard directional detectors.

To level output power in waveguide systems, HP 752 Series Waveguide Directional Couplers (page 299) and 424A Series Waveguide Crystal Detectors (page 307) are used. With better than 40 dB directivity, 752 Series Couplers in leveled systems provided good equivalent source match—nominally 1.02 SWR. Waveguide couplers will typically exhibit ±0.5 dB coupling variation over the band. In conventional reflection or transmission measurement systems employing two couplers, this variation of

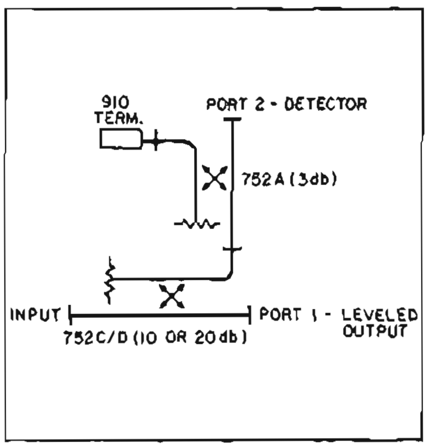


Figure 5. "Back-to-back" waveguide coupler arrangement for extremely flat output.

coupling with frequency is of little consequence because both couplers demonstrate the same coupling characteristics; hence, the variations with frequency effectively cancel. Where a greater degree of leveling is needed in waveguide, a pair of 752 couplers are connected "back-to-back" as in Figure 5. In this configuration the insertion loss of the 3 dB coupler (752A) follows a curve directly opposite to the coupling curve of the mainline 752C or D coupler. The resulting power relationship between port 1 and port 2 is flat to better than ±0.2 dB over full waveguide bands.

Swept-frequency systems, reflectometer systems

Probably the major usage of sweep oscillators is in reflectometer systems for broadband measurement of reflection and transmission characteristics. Leveling the signal source brings new latitude of readout to the user, for measurement results can be read directly rather than on a ratio basis. Sophisticated instrumentation systems employing the principles of reflectometry such as HP 8540-series Automatic Network Analyzer system described on page 478, rely upon the 8690B Series Swept Oscillators for frequency accuracy and operational simplicity.

Higher power systems

Typical backward-wave oscillators supply leveled power outputs in the

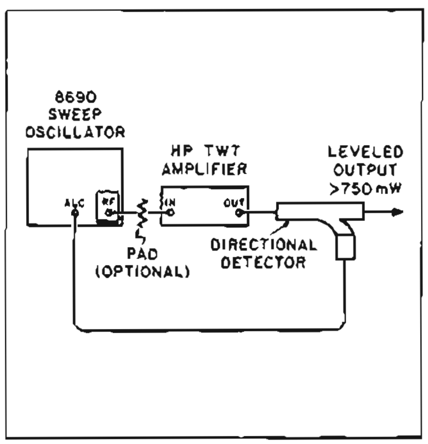


Figure 6. The E15-8690A system generates high-level (750 mW), flat output power. The pad between the sweep oscillator and the TWT amplifier is used to keep the signal level into the amplifier below that which would saturate the TWT.

milliwatt region. Applications such as RFI-susceptibility tests and high attenuation swept measurements often require 750 mW outputs. The E15-8690 system shown in the block diagram in Figure 6 will provide better than 750 mW from 1 to 12.4 GHz.

Special calibration systems

Leveled systems have also been designed to level on the net forward power applied to a device, permitting the examination, for example, of the efficiency and calibration factor of coaxial and waveguide devices.

Swept frequency display devices

Especially useful is the new HP 1416A plug-in for the 140A and 141A Oscilloscopes. Designed expressly for use in leveled reflectometer systems using square-law detectors, the 1416A provides an accurate 30 dB of dynamic range when used with HP 423A and 424A Series Crystal Detectors. It also provides excellent resolution; sensitivity of 0.5 dB/cm permits close examination of results. The 1416A is particularly effective with the 141A variable persistence oscilloscope as a readout device for a swept slotted line measurement system.

Stabilized sweep oscillator systems

Applications such as microwave spectroscopy and high-Q swept frequency cavity measurements have brought about the need for phase-locked fixed or swept frequency operation of the 8690 Series sweep oscillators.

Hewlett-Packard stabilized sweep oscillator systems are available for swept and CW operation or CW operation only in the coaxial (1 to 12.4 GHz) and waveguide bands (12.4 to 40 GHz). In these systems an 8690B Sweep Oscillator with appropriate interchangeable RF unit is phase-locked to a 240-400 MHz reference oscillator. The reference oscillator stability is thereby transferred to the sweep oscillator. The reference oscillator is continuously tunable, so the sweep oscillators can be stabilized at any frequency in their respective ranges quickly and easily; there are no crystals to change.

Phase-locking the system is simple. The desired frequency is set on the sweeper dial and the reference oscillator is then tuned to obtain the desired sweeper frequency on the counter (although the counter indicates sweeper frequency, it counts the reference oscillator). The sweeper is then tuned to the appropriate lock point. The wide spacing of the lock points (240 to 400 MHz) makes picking the right lock point easy.

Table 1. Hewlett-Packard sweepers

HP model	Freq. range	Max output	Flatness	Residual FM	Sweep linearity	Sweep time	Sweep modes: Auto	Sweep modes: Single	Sweep modes: Manual	Built-in markers	Page
3300A (.01 Hz–100 kHz) Function Generator, 2 sweeper plug-ins											
3304A	0.1 Hz–100 kHz	5 V rms into 600Ω	±1% to ±3%		1% (linear)	0.01–100 s	Yes	No	No	No	340
3305A					logarithmic			Yes	Yes		416
675A (10 kHz–32 MHz) Sweeper, 1 range, no plug-ins*											
675A	10 kHz–32 MHz	1 V rms into 50Ω	±0.15 dB to ±1 dB	70 Hz peak	±0.5% of sweepwidth	0.01–100 s	Yes	Yes	Yes	Opt	417, 418
3211A (100 kHz–110 MHz) Sweep Oscillator, 6 plug-ins											
3212A	100 kHz–30 MHz			<±5 kHz	±10%						
3213A	8–16 MHz					0.01–0.1 s continuous					
3214A	12–28 MHz	>0.7 V rms into 50Ω	±0.25 dB	<±0.005% center freq	≈1%–±10%		Yes	Yes	No	Opt	422
3215A	20–45 MHz					1–10s (single)					
3216A	30–70 MHz										
3217A	50-110 MHz										
8601A	100 kHz–1 MHz 1 MHz–110 MHz	2.24 V rms into 50Ω	±0.25 dB over full range	<50 Hz pk <500 Hz pk	±0.5%	Fast: 6 to 60 sweep/sec var slow: 8 to 80 sec/sweep var.	Yes	Yes	Yes	Yes	387, 420, 421
8690B (0.4 MHz to 40 GHz) Convertible Sweep Oscillator—see plug-ins below											
Plug-in RF units for 8690B											

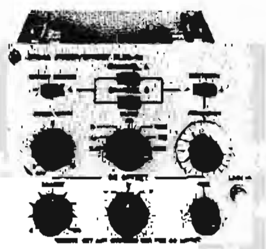
Freq. range	HP model	Max output	Flatness	Residual FM	Sweep linearity	Sweep time	Sweep modes: Auto	Sweep modes: Single	Sweep modes: Manual	Built-in markers	Page
04–11 MHz 1–110 MHz	8698B	1.0 V rms into 50Ω	±0.25 dB	<150 Hz–<500 Hz peak	±0.5% of sweepwidth	0.01–100 s	Yes	Yes	Yes	Yes	423 to 430
100 MHz–2 GHz 2 GHz–4 GHz	8699B	+13 dBm into 50Ω +10 dBm into 50Ω	±1.5 dB external lev ±0.3 dB external lev	<10 kHz pk in 10 kHz bw	±0.5% of sweepwidth						
1–2 GHz	8691A	≥100 mW	±0.2 dB	<30 kHz peak	±1%						
1–2 GHz	8691B	≥70 mW	±0.1 dB	<10 kHz peak	±10 MHz						
2–4 GHz	8692A	≥70 mW	±0.2 dB	<30 kHz peak	±1%						
2–4 GHz	8692B	≥40 mW	±0.1 dB	<15 kHz peak	±10 MHz						
1.7–4.2 GHz	H01-8692B	≥15 mW	±0.1 dB	<20 kHz peak	±13 MHz						
4–8 GHz	8693A	≥30 mW	±0.2 dB	<50 kHz peak	±1%						
4–8 GHz	8693B	≥15 mW	±0.1 dB	<15 kHz peak	±20 MHz						
3.7–12.4 GHz	H01-8693B	≥5 mW	±0.1 dB	<20 kHz peak	±25 MHz						
8–12.4 GHz	8694A	≥50 mW		<60 kHz peak							
7–12.4 GHz	H01-8694A	≥25 mW	±0.2 dB	<60 kHz peak	±1%						
7–11 GHz	H02-8694A	≥25 mW		<60 kHz peak							
8–12.4 GHz	8694B	≥30 mW		<15 kHz peak	±30 MHz						
7–12.4 GHz	H01-8694B	≥15 mW	±0.1 dB	<20 kHz peak	±40 MHz						
7–11 GHz	H02-8694B	≥15 mW		<20 kHz peak	±30 MHz						
12.4–18 GHz	8695A	≥40 mW		<150 kHz							
18–26.5 GHz	8696A	≥10 mW	±0.2 dB	<200 kHz	±1%						
26.5–40 GHz	8697A	≥5 mW		<350 kHz							

*676A Phase/Amplitude Tracking Detector (see page 419).

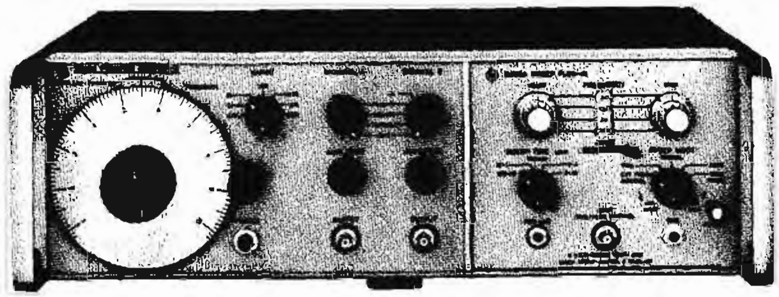
SWEEP PLUG-IN FOR 3300A

Logarithmic 4-decade or linear 1-decade

Models 3305A, 3304A



3304A



3305A shown in 3300A

HP 3304A one-decade linear sweep plug-in

The 3304A plug-in for the 3300A Function generator provides narrow sweeping or over a decade of sweeping on any one range. A sawtooth output is available for external single direction sweep while internally sweeping the main frame. For more details and specifications refer to pages 372 and 373.

HP 3305A 4-decade log sweep plug-in

The 3305A Sweep Plug-in combined with the 3300A Function Generator is an automatic, manually or externally triggered 4-decade sweeper and an external, 4-decade frequency-controlled signal source.

Four-decade logarithmic sweep

The 3300A/3305A will sweep logarithmically between any two frequencies in one of the three (4-decade) ranges—0.1 Hz to 1 kHz, 1 Hz to 10 kHz, and 10 Hz to 100 kHz. Calibrated independent start-stop controls greatly simplify setting desired sweep end points. Adjustable sweep time from 0.01 to 100 seconds provides sweep times slow enough for accurate response testing of low-frequency high-Q systems and fast enough for good visual displays of higher frequency responses. A frequency range greater than the audio band can be swept without any range switching or display equipment readjustment.

The manual sweep, vernier adjustment of frequency between the start-stop limits, allows close observation of a small portion of a response curve. This manual control also permits measurement of a critical frequency with counter accuracy and simplier set-ups for oscilloscopes or X-Y recorders.

Programming

For automated testing, the 3300A/3305A frequency can be analog-programmed over any one of the 4 decade ranges. Also, a single sweep can be externally triggered.

Sweep output

X-axis readjustment is eliminated since the sweep output amplitude is independent of start-stop, sweep time and sweep width settings.

Specifications, 3305A*

Frequency range: 0.1 Hz to 100 kHz in 3 overlapping ranges.

Sweep width: limits adjustable 0 to 4 decades in any of three 4-decade bands—0.1 Hz to 1 kHz, 1 Hz to 10 kHz, 10 Hz to 100 kHz.

Start-stop dial accuracy: ±10% of setting.

Sweep modes

Automatic: repetitive logarithmic sweep between start and stop frequency settings.

Manual: vernier adjustment of frequency between start and stop frequency settings.

Trigger: sweep between start and stop frequency settings and retrace with application of external trigger voltage or by depressing front-panel trigger button.

Trigger requirements: ac coupled, positive-going, at least 1 V peak with >2 V per ms rise rate.

Maximum input: ±90 V peak.

Sweep time: 0.01 s to 100 s in 4 decade steps; continuously adjustable vernier.

Retrace time: <0.003 s for 0.1 to 0.01 s sweep times, <0.03 s for 1 to 0.1 s sweep times, <4 s for 100 to 1 s sweep times.

Blanking: oscillator disabled during retrace.

Pen lift: terminals shorted during sweep, open during retrace in auto and trigger modes for 100 to 1 s sweep times.

Sweep output: linear ramp at Channel B output (plug-in); amplitude adjustable independently of sweep width; max. output >15 V p-p into open circuit, >7 V p-p into 600Ω.

External frequency control

Sensitivity: 6 V/decade (referenced to start setting), ±24 V max.

V-to-F conversion accuracy: for each 6 V change in programming voltage, frequency changes 1 decade ±5% of final frequency.

Input impedance: 400 kΩ ±5%.

Maximum rate: 100 Hz.

General

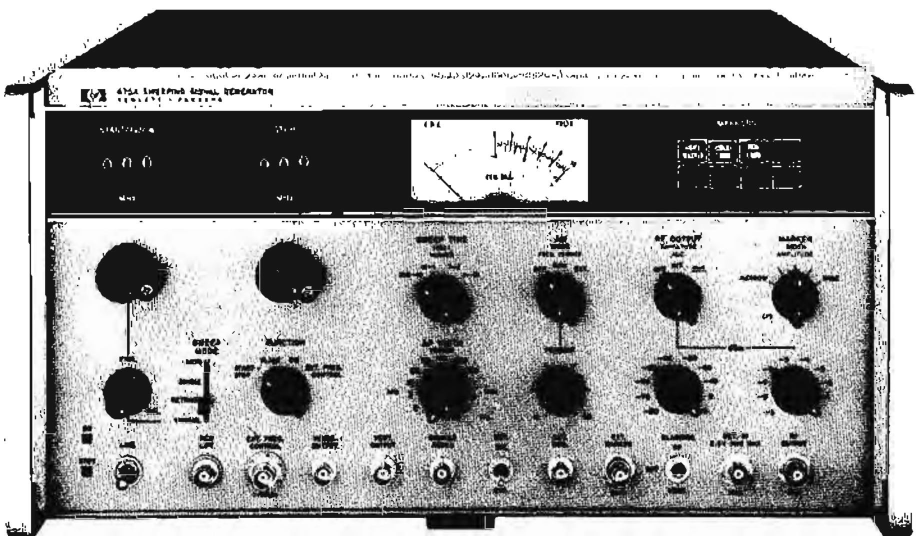
Dimensions: 6 1/16" wide, 4 3/4" high, 10 1/4" deep (154 x 121 x 260 mm).

Weight: net 4 lbs 6 oz (2 kg); shipping 6 lbs 6 oz (2,9 kg).

Price: HP 3305A, $975; HP 3304A, $265.

*Refer to pages 372 and 373 for information on the 3300A and other plug-ins.

SWEEP SIGNAL GENERATOR
10 kHz to 32 MHz in one range; 0.15 dB flatness
Model 675A



675A

Description

The HP 675A sweeper, when employed for the 10 kHz-32 MHz range, has such accuracy and linearity that it can be used as a sweeper for an overall "look" as well as a CW generator for detailed analysis. Sweep end points and CW frequencies can be set with an accuracy of 0.5% of full scale. The 675A's sweep linearity is better than 0.5% of sweep width, permitting the graticule of a monitoring oscilloscope to be used as a frequency scale for easy location of response points and center frequencies. Counter accuracy can be obtained using the auxiliary output on the rear panel. Manual sweep permits measurement of frequency at important points, such as peaks or 3 dB and 6 dB points.

Frequency stability of the 675A is exceptional. Residual FM is less than 70 Hz peak, especially important for narrow-band sweeping measurements on devices with sharp cut-off characteristics, such as high-Q filters. This stability, especially important in repetitive production tests, was achieved by housing the RF oscillator in an oven.

Output amplitude over the 200 kHz-32 MHz range is held constant within ±0.15 dB (at 1 V) by a sensitive automatic leveling control (ALC) loop. Output leveling is accomplished either with an internal detector or, if long cables are used between generator and tested device, by an external detector. Because of good leveling and the precision of the frequency sweeps, responses of tested devices can be determined precisely without resorting to point-by-point measurements. Output waveform distortion is low; harmonics are >30 dB below the fundamental; other frequencies are >50 dB below. Features offered by the 675A make it an extremely functional tool.

3½ decade range

Frequency response tests on broadband circuits can be performed over a 3½ decade range without switching or plug-in changes. Sweep width is 10 kHz-32 MHz or any portion thereof. Sweep end points are set with three-place digital dials plus an interpolation scale with markings every 0.02 MHz. For precision narrow-band sweeps, center frequency is set with one control while another calibrated control sets sweep width from 1 kHz to 10 MHz.

In single-sweep operation, voltage remains at the end of the trace until manually reset. Setup of the oscilloscope trace or X-Y recorder at frequency end points is speeded and simplified by this ability to retain the sweep at either end of its travel. (For X-Y recorder use, an automatic pen-lift-during-retrace output is provided.)

Programming

The 675A is a programmable signal source. A dc-coupled input is provided, and frequency over the full sweeping range can be controlled by an analog signal. The amplitude can be programmed over a 10 dB range.

Blanking

To provide a display baseline, there are two types of blanking—conventional, in which output RF is turned off during retrace, and "vertical" in which the vertical output channel is grounded during retrace, allowing the RF to remain at all times. Vertical blanking avoids the transients sometimes caused in circuits under test when the RF is switched on and off.

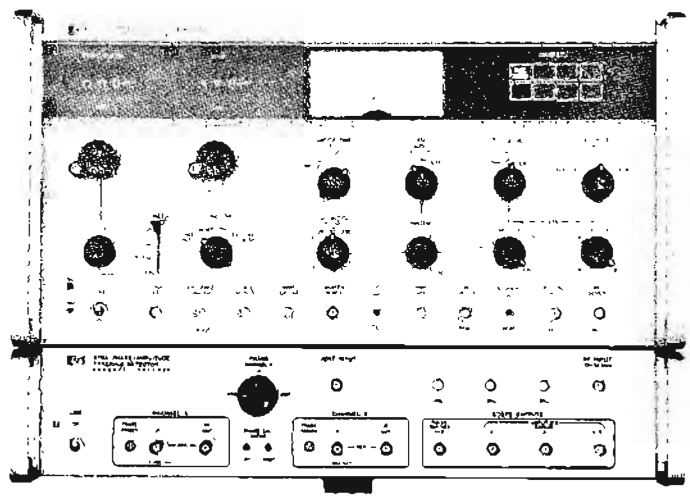
Markers

When greater precision is required than the horizontal linearity of conventional scopes, markers are available as an option. There is provision for up to five crystal markers and two frequency-comb markers. Marker width and amplitude can be varied with front panel controls (standard on 675A) thus adjusting the markers with even the narrowest sweep widths. Capability is also provided for making the markers appear horizontally for easier identification of steeply-rising response curves. Sweep specifications are found on page 419 (refer to page 386 for Signal Generator data).

TRACKING DETECTOR

Network analyzer: concurrent phase & amplitude

Model 676A



Description

The 676A is a two-channel, phase and amplitude detector, specifically designed to operate with the 675A Sweeping Signal Generator. The swept signal generated by the 675A is split into two channels by the 676A and then excites the device under test in each channel. The detected outputs from each channel are then compared for phase and amplitude difference.

Network analyzer

This is the first Network Analyzer (675A and 676A) of its kind to provide swept phase and amplitude information over the 10 kHz to 32 MHz range. Both laboratory and production oriented, the 675A Sweeping Signal Generator and 676A Phase/Amplitude Tracking Detector system provides an amplitude response with 80 dB dynamic range, accompanied by 360° (or multiples of) phase measurement capability. Because the swept frequency can be chosen anywhere in the prescribed range, this technique is amenable to both narrow and broadband frequency sweeps for both amplitude and phase.

Transfer characteristics, impedance plots, dynamic input and output impedance, system flatness, return loss, time delay, small signal analysis, open and closed loop response are some of the applications that are made practical by amplitude and phase information obtained through a swept technique.

Amplitude and phase

Four scope outputs (A, B, A-B, PHASE A-B) are provided at the front panel of the 676A Tracking Detector. A and B represent 80 dB of log amplitude dynamic range (50 mV/dB) for each channel. A-B is the log difference of the two channels. The PHASE A-B is a dc voltage linearly proportional (10 mV/degree) to phase from 0° to 360°.

Phase is also conveniently calibrated using the 5° or 100° "PHASE CAL CHECK" buttons. With the "PHASE CHANNEL A" control, continuous 0° to 360° phase shift is provided in channel A. For more phase resolution the sensitivity of the scope can be increased to provide 1°/cm, for example, with the "PHASE CHANNEL A" control providing a variable phase offset.

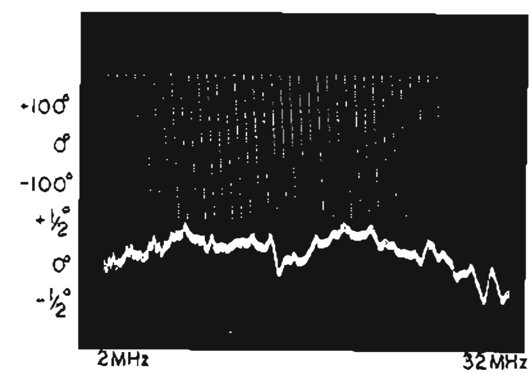


Figure 1. Phase response showing <1° phase resolution.

Figure 1(a) illustrates the pulse response of a 1000 ft cable viewed on an oscilloscope using the 675A and 676A. Exact length of a cable can be calculated from total phase shift over a given frequency increment. Figure 1(b) shows the difference in phase response between two "identical" 1000 ft cables. Variations indicate that the two cables do not have equal electrical lengths at every frequency. Phase shifts of less than 1° are clearly shown.

The dual channel approach is particularly useful when a device under test is compared to a "standard" device. Both PHASE A-B and amplitude difference (A-B) are available as scope outputs for time saving and convenient comparison testing. A-B is useful for expanding the amplitude display to a fraction of a dB/cm. The "standard" device may be an accurate attenuator, or as shown in Figure 1, the device may be a roll of cable.

Specifications
Model 675A Sweeping Signal Generator
Model 676A Phase/Amplitude Tracking Detector

675A Specifications*

Frequency range: 10 kHz to 32 MHz in one range.
Output: maximum, +13 dBm (1 V rms into 50Ω, 2 V rms open circuit); continuously adjustable. Impedance: 50Ω.

RF flatness**	10 kHz – 50 kHz	50 kHz – 200 kHz	200 kHz – 1 MHz – 10 MHz – 32 MHz
Unleveled:	±1 dB	±1 dB	
Internally leveled:		±1 dB	±0.15 dB
Externally leveled:	±0.15 dB	±0.15 dB	±0.15 dB

System flatness**: Using Internal RF Detector,

internally leveled:	10 kHz – 50 kHz	50 kHz – 200 kHz	200 kHz – 1 MHz – 10 MHz – 32 MHz
	±1 dB	±0.4 dB	±0.25 dB

Using External RF Detector†

externally leveled††:	10 kHz – 100 kHz – 1 MHz – 10 MHz – 32 MHz
	±0.25 dB

Internal detector output (vertical): at least 1.2 V dc for 1 V rms.
Attenuator
Range: 99 dB in 10 and 1 dB steps.
Accuracy: ±0.3 dB, +10 db to −12 dB; ±0.4 dB, −13 dB to −89 dB, +6 μV constant error.
Output monitor
Range: −3 to +3 dB (0.5 V to 1 V).
Accuracy: ±0.3 dB, 200 kHz to 32 MHz.
Distortion
Harmonic: >30 dB down from fundamental.
Spurious: >50 dB down from fundamental.
Residual (line related) FM: <70 Hz peak.
Spurious FM: <60 Hz rms.
Auxiliary output (rear panel): 100 MHz to 132 MHz unleveled.

Sweep functions

Linearity: ±0.5% of sweep width ±100 Hz.
Start-stop: sweeps up or down from start to stop frequency settings.
F_o/ΔF: sweeps ΔF centered on F_o setting.
F_o range: 10 kHz to 32 MHz. F_o accuracy: ±0.5% of full scale.
ΔF width: continuously adjustable from 200 Hz to 10 MHz, or calibrated steps in 1-2-5 sequence from 1 kHz to 10 MHz.
ΔF width accuracy: ±5% of calibrated steps ±100 Hz.
Sweep modes
Auto: repetitive sweeps; **single:** beginning-ton-end sweep.
Retrace: end-to-beginning retrace.
Manual: manual control of sweep and retrace.
NOTE: specials with 60 Hz line lock in either 50Ω or 75Ω are available. Price on request.
Sweep time: 0.01 s to 100 s ±20%; in 4 decade steps, with vernier.
Horizontal output: 0 to +5 V dc.

Blanking

RF: RF output off during retrace.
Vertical: vertical output shorted to ground during retrace.
Pen lift: terminal shorted during sweep, open during retrace.
Crystal markers (optional): 100 kHz, 1 MHz harmonic comb and/or up to 5 fixed frequencies • from 100 kHz to 32 MHz • HP 11300A single frequency marker (frequency must be specified).
Accuracy: ±0.005% of frequency.
Width: adjustable 5 steps, 4 kHz to 100 kHz.
External marker: front-panel BNC input (50Ω impedance), 50 mV to 500 mV rms.

Signal generator functions (Refer to page 386).

General
Power: 115 or 230 V ±10%, 50 to 400 Hz, 80 W max.
Dimensions: 16¾" wide, 8¾" high, 18⅜" deep (425 x 221 x 467 mm), rack mount kit for 19" rack is included.
Weight: net 46 lbs (20,8 kg); shipping 51 lbs (23,2 kg).

Accessories furnished: HP 11048B 50Ω Feed-Thru Termination.
Accessories available: HP 11300A Single-Frequency Marker (frequency must be specified), $75 ea. (For factory installation of one to five markers, add $25.
HP Model 11097A RF Detector, $30.
Maximum input: 2.5 V rms; input impedance: 50Ω; output: positive, >1.2 V for 1 V rms input into 500 kΩ load; frequency range: 10 kHz to 32 MHz; flatness: ±0.25 dB at 1 V level, 10 kHz to 32 MHz used with the 675A and 11098A.
HP Model 11098A Leveling Detector, $30.
Flatness: 675A RF output, ±0.15 dB at 1 V level, (negative), maximum input: 2.5 V rms. Price: HP 11098A, $30.
Price: HP 675A, Sweeping Signal Generator, $2250.
Option 01: with 1 MHz harmonic marker, add $75.
Option 02: with 100 kHz harmonic marker, add $75.
Option 03: with 100 kHz and 1 MHz harmonic markers, add $125.

676A Tentative Specifications*

(when used with 675A)

System flatness

	Unleveled (10 kHz – 200 kHz)	Internally Leveled (200 kHz – 32 MHz)
	±0.8 dB	±0.8 dB

RF output (channel A and B)
RF "OUT" level: +2 dBm max (0.28 V rms into 50Ω) for each channel with 675A level set to +13 dBm max.
Isolation (between channels): 16 dB.
Impedance: 50Ω.
RF input (channel A and B)
Dynamic range: 80 dB; impedance: 50Ω; isolation: >85 dB between channels.
Amplitude
Range: 80 dB channel A and B, and A-B.
A and B level: (display) 4.2 V dc adjustable over ±5% range at +2 dBm RF output. (50 mV per dB with CAL adjustment).
Accuracy: output level of each channel is proportional to log of input ±1.5 dB over 80 dB dynamic range.
Noise: <−83 dBm with input terminated in 50Ω.
Spurious: <−83 dBm with input terminated in 50Ω.
A-B level: derived by analog subtraction of A and B outputs. ±4.2 V dc.
Dynamic range: 80 dB for each channel (25 kHz to 32 MHz). 55 dB for each channel (10 kHz to 25 kHz).
Phase
Range: +180° to −180° at 360° multiples. Phase can be shifted continuously from 0° to 360° with phase control.
PHASE A-B level: 3.6 V at +180° and 0 V at −180° adjustable over ±5% range, with voltage linearly proportional to phase. (10 mV/degree with CAL adjustment.)
Accuracy:
Frequency dependency: ±1°, 100 kHz to 32 MHz; ±2°, 10 kHz to 100 kHz; **amplitude dependence:** ±5° over entire 80 dB dynamic range.
Jitter: <5° average at 80 dB down.
PHASE CAL CHECK accuracy: 100° ±1.0°; 5° ±0.2°.
General
Accessories furnished: cables to connect 676A to 675A.
Power: 115 or 230 V ±10%, 50 to 400 Hz, 80 W max.
Weight: net 46 lbs (20,8 kg); shipping 51 lbs (23,2 kg).
Dimensions: 16¾" wide, 3-15/32" high, 18⅜" deep (425 x 85.2 x 467 mm). Joining brackets to connect to the 675A are included.
Price: HP 676A, Phase/Amplitude Tracking Detector, $1275.

*For complete specifications refer to Data Sheet.
**1 volt level. 0 dB reference is point midway between max p-p deviations.
†11097A RF Detector.
††11098A Leveling Detector.

GENERATOR/SWEEPER

Small, ultra-versatile broadband source

Model 8601A

8601A

Two instruments in one

Covering 100 kHz to 110 MHz, the 8601A Generator/Sweeper combines the high linearity and flatness of a precision sweeper with a signal generator's frequency accuracy and wide range of calibrated power levels. Though it's small and lightweight, it does the work of two instruments easily and conveniently.

As a signal generator (see page 387), the 8601A output is accurate to ±1 dB from +13 dBm to −110 dBm. Harmonics and spurious signals are very low. The digital frequency dial is accurate to ±1% of frequency; higher accuracy is achieved with 0.01% crystal checkpoints at 5 MHz intervals. Internal modulation is 1 kHz, AM or FM, or you can modulate externally.

As a sweeper, the 8601A offers a new approach to swept measurements. Elaborate marker systems are no longer needed for accurate frequency identification. The 8601A takes the messy trace and the ambiguity out of swept measurements by substituting linearity and frequency accuracy for markers.

Three convenient sweep modes

The FULL mode sweeps more than a two-decade band from either 0.1 to 11 MHz or 1 to 110 MHz with flatness of ±0.25 dB, providing a fast look at the complete frequency response of the device under test.

In the VIDEO mode, the 8601A will sweep from the bottom of the band to the frequency selected on the digital readout. This feature is valuable for those who wish to look at the response of a low pass filter or video amplifier.

SYMMETRICAL mode provides five calibrated sweep widths for each band and a vernier for continuous sweep width adjustment. The center frequency is selected on the digital readout. When the sweep width is in a calibrated position, the horizontal gain of an oscilloscope or recorder may be adjusted so that the ends of the sweep coincide with calibrated markings. The sweep can then be defined in MHz/cm, MHz/inch, etc. The center frequency may be set to counter accuracy by turning the sweep width vernier fully counterclockwise and monitoring the auxiliary output (always 100 kHz to 11 MHz regardless of band) with a low frequency counter. A simple low frequency counter, the HP H01-5321A, is especially designed to complement the 8601A.

Versatility

All sweep modes may be run in FAST sweep for oscilloscope work, SLOW for recording, or MANUAL. Triggering may be manual, line-synchronized, or free-running. This wide range of sweep modes, rates, and triggering makes the 8601A a truly versatile sweeper, suitable for nearly any low-frequency sweeper application.

Low residual FM

Frequency-lock circuits lead to low residual FM (total noise including line related components in 10 kHz bandwidth is less than 500 Hz rms on high band, 50 Hz rms on low band) enabling narrow band measurements previously impossible with conventional low-frequency sweepers.

Applications

The 8601A satisfies a wide range of laboratory and production applications. A partial list is given here.

Filters. Filter testing is easy with the 8601A. Low pass filters are examined rapidly using the VIDEO sweep. Bandpass filters and circuit Q can be measured down to 10-kHz bandwidths on the high range and 1 kHz on low range before residual FM interferes. Calibrated SYMMETRICAL sweep and power output provide fast and accurate identification of center frequency and 3 dB points.

Active circuits. Amplifier bandpass, IF strip response, phase shift, and other frequency-dependent device measurements are no problem for the 8601A due to its excellent flatness, broad range, and frequency accuracy.

Components. Components can be tested with confidence for attenuation, insertion loss, and frequency response. The 8601A is also suitable for use with VSWR bridges and hybrid detectors.

Receiver measurements. Usable sensitivity can be measured down to 1 microvolt due to the 8601A's low leakage. Front-end response of a receiver may be observed with SYMMETRICAL sweep and passband sensitivity recorded by noting the attenuator setting for frequencies in the passband. Discriminator and IF strip alignment is accomplished by using the 8601A as an IF source, or through the front end of a receiver.

FM distortion and signal-to-noise measurements are good down to −40 dB (1%). Similar AM measurements can be made when the 8601A is used with the Model 10534A Mixer/Modulator and an audio oscillator.

8601A Specifications

Frequency characteristics

Coverage: low range, 0.1-11 MHz; high range, 1-110 MHz.

Accuracy: (In CW, stop frequency of VIDEO sweep, and center frequency of SYMMETRICAL sweep.)

- Low range, ±1% of frequency or ±10 kHz, whichever is greater.
- High range, ±1% of frequency or ±100 kHz, whichever is greater.

GENERATOR/SWEEPER
Small, ultra-versatile broadband source
Model 8601A

Settability: vernier settability, ±0.01%; range, ±0.1%; coarse settability using 10 turn pot is 5 kHz, low range; 50 kHz, high range.

Linearity: ±0.5%, full and video sweep.

Drift in CW:
(0.01% +500 Hz)/10 min., high range, after 1 hr. warm-up.
(0.01% +50 Hz)/10 min., low range, after 1 hr. warm-up.
0.025%/°C temperature change.
0.001%/V line voltage change.
Less than 5 minutes to stabilize for any frequency change on each band.

Harmonics and spurious signals (CW above 250 kHz, output levels below +10 dBm on the +10 dBm attenuator step or below): harmonics at least 35 dB below carrier. Spurious signals at least 40 dB below carrier.

Residual FM in CW:
Line related components:
Less than 50 Hz peak, low range.
Less than 500 Hz peak, high range.
Noise in 10-kHz bandwidth including line related components:
Less than 50 Hz rms, low range.
Less than 500 Hz rms, high range.

Incidental FM with 30% AM:
Less than 100 Hz peak, low range.
Less than 1 kHz peak, high range.
Incidental FM in CW is negligible.

Residual AM: AM noise modulation index (rms, 10 kHz bandwidth) is <−50 dB. (Typically −60 dB at 25°C.)

Incidental AM: incidental AM modulation index is <−55 dB with 75 kHz deviation.

Output characteristics

Level: +20 to −110 dBm. 10-dB steps and 13-dB vernier provide continuous settings over entire range. Meter monitors output in dBm and rms volts into 50Ω.

Accuracy: ±1 dB accuracy for any output level from +13 dBm to −110 dBm.

Flatness: ±0.25 dB over full range, ±0.1 dB over any 10-MHz portion.

Impedance: 50Ω, SWR <1.2 on 0 dBm step and below.

RF leakage: low leakage permits receiver sensitivity measurements down to 1 microvolt.

Sweep characteristics

Full: approximately 0.1-11 MHz and 1-110 MHz independent of dial setting.

Video: sweep extends from low end of range to frequency dial setting. Start frequency accuracy is ±1% of stop frequency, or ±100 kHz, high range; ±10 kHz low range.

Symmetrical: center frequency may be tuned to any point on either range.

Sweep width: 0-1 MHz low range; 0-10 MHz high range. There are 5 calibrated sweep width positions as well as an uncalibrated vernier to provide continuous adjustment.

Sweep width accuracy: ±5% of sweep width or ±1 kHz on low range; ±5% of sweep width or ±10 kHz on high range, whichever is greater.

Sweep speeds: fast, typically 6 to 60 sweeps per second, variable. Slow, typically 8 to 80 seconds per sweep, variable. Manual, continuous tuning over present limits.

Trigger modes: manual trigger with reset, line-synchronized, or free-running.

Amplitude modulation

Internal AM: 30% ±5% at 1 kHz, less than 3% distortion. Typically <1% distortion for output readings on upper half of meter scale.

External AM: 0 to 50%, up to 400 Hz. 0 to 30%, up to 1 kHz. Applied through external AM input on front panel. Sensitivity typically 2 V peak/10% modulation index at 400 Hz (10-50% AM).

Frequency modulation

Internal FM: high range: 75 kHz ±20% peak deviation, 1-kHz rate; low range: 7.5 kHz ±20% peak deviation, 1-kHz rate; less than 3% distortion. Typically <1%.

External FM: sensitivity: 5 MHz per volt ±5%, high range; 0.5 MHz per volt ±5%, low range; negative polarity.
Deviations to the band edges are possible for rates to 100 Hz; voltage to frequency linearity is ±0.5%, allowing remote frequency programming. FM rates to 10 kHz are obtainable with less linearity and accuracy.

Crystal calibrator

Internal 5-MHz crystal allows frequency calibration to ±0.01% at any multiple of 5 MHz.

Auxiliary outputs

Front panel: sweep output: approximately 0 to +7 volts. Auxiliary output: always 0.1-11 MHz for low frequency counter monitoring.

Rear panel: sweep reference output: provides voltage analog to frequency output approximately 0 to +3 V. Uncalibrated RF output: −5 dBm minimum, unmodulated. VTO output: 200.1-310 MHz. Output level −25 dBm, minimum. Blanking: −4 volt pulse concurrent with RF blanking.

General

Power: 115 or 230 V, ±10%, 50-400 Hz, ±10%; approximately 50 watts.

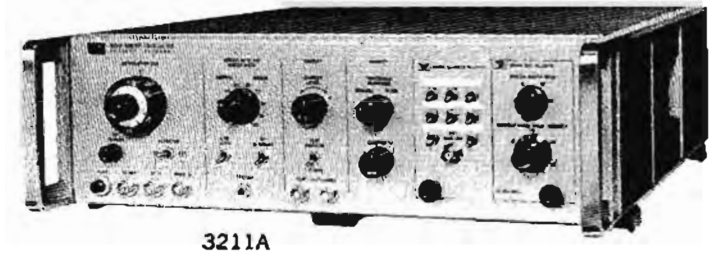
Weight: net, 21 lb (9,5 kg); shipping, 27 lb (12,3 kg).

Dimensions: 7-25/32" wide, 6-3/32" high, 16⅜" deep (190 x 155 x 416 mm).

Complementary equipment:
Frequency Doubler, Model 10515A; extends 8601A's range to 220 MHz with low conversion loss, $120.00.
Double Balanced Mixers, Models 10514A/B, 10534A/B; serves as a mixer, phase detector, balanced modulator, and amplitude or phase modulator. Model 10534A, $70.00.
RF Detector, Model 8471A; flat to ±0.1 dB, over 100 MHz range, SWR typically 1.3, $50.00.
Frequency Counter, Models H01-5321A and 5321B utilize 8601A Auxiliary Output to accurately monitor up to 110 MHz, $655.00 (H01-5321A), $700.00 (5321B).

Price: Model 8601A, $1,975.00.

SWEEP OSCILLATOR
Low-cost, solid-state, plug-in versatility
Model 3211A



3211A

Advantages:

RF and marker plug-ins
Individual on-off marker switches
Continuous or single sweep with variable rate
Continuous sweep width adjustment
Width and level controls to optimize marker display

The HP 3211A Sweep Oscillator, with its 3221A Marker Plug-in and choice of six frequency plug-ins, is a low-cost, versatile, high-performance sweep oscillator ideally suited for use in the design, calibration, and alignment of FM tuners and receivers, and the general testing of IF sections of TV receivers, radar and communication systems, and other video to VHF circuits. Its high output (>.7 V rms) and accurate 59-dB attenuator make the instrument a valuable tool for the testing of both high and low-gain circuits under variable signal conditions.

Specifications (Main Frame)

RF output

Level: greater than .7 V rms into 50-ohm load, greater than 1.4 V rms into open circuit.

Impedance: 50 ohms, 1.2 to 1 VSWR in 0 dB attenuator position; 1.1 to 1 for attenuator settings greater than 10 dB.

Attenuation: 0 to 59 dB in 1 and 10-dB steps. Electrical vernier provides level adjust between 1-dB steps.

Attenuator accuracy: ±.25 dB for 1-dB steps; ±0.5 dB on 10, 20, 30-dB steps; ±1 dB on 40 and 50-dB steps.

Sweep characteristics

Rate: variable; repetive sweep 10 to 100 Hz nominal; single sweep 1 to 10 seconds nominal. Line lock provided.

Blanking: switch selects RF blanking or unblanking during retrace; marker blanking on retrace at all times.

Vertical channel

Detector: half-wave peak detector; input VSWR less than 1.05 to 1; flatness ±.1 dB; video bandwidth 20 kHz; freq. range: 0.5 to 110 MHz.

Output: internal 50-ohm detector, greater than .4 V dc for 1 V rms input; external detector, greater than .4 V dc for 1 V dc input.

Horizontal channel output: 0 to 15 V pk-pk triangular.

Marker characteristics

Type: birdie by-pass; beat note detected and used to generate high-level marker pulse.

Display: front panel control and switch permit either addition of marker pulse to the vertical channel output or Z axis modulation of oscilloscope with 0 to ±20 V pulse.

Dimensions: 16¾" wide, 5½" high, 18⅜" deep (426 x 140 x 552 mm).

Weight: net 30 lbs (13,5 kg); shipping 40 lbs (18,2 kg).

Power: 105 to 125 V or 210 to 250 V, 50 to 1000 Hz, 25 W.

Price: 3211A Sweep Oscillator, $865; 3221A Marker Plug-in, $85; 3212A RF Plug-in, $225; 3213A-3217A RF Plug-ins, $150 ea.; 13511B Marker Oscillators, $40 ea. Complete instrument consists of 3211A Sweep Oscillator, 3221A Marker Plug-in, and one RF plug-in.

Marker Plug-in—Model 3221A

Internal markers: accepts up to 8 crystal-stabilized 13511B marker oscillators. Specify frequencies desired.

External markers: front panel BNC input from CW source or marker generator; input requirements, .1 to .3 V rms into 50 ohms.

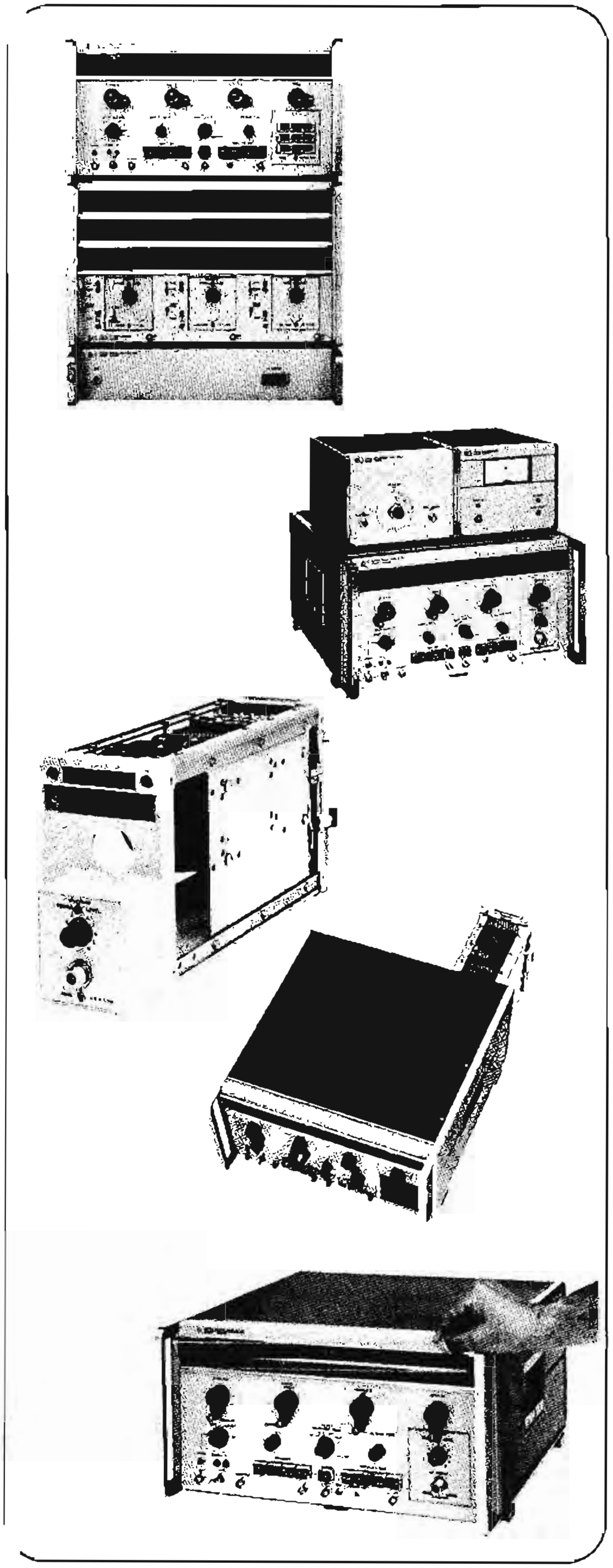
Marker Oscillators—Model 13511B

Frequency: 1 to 110 MHz; accuracy: .005%; output level: 35 mV rms into 50 ohms.

RF Plug-ins

Specification	HP Model Number					
	3212A	3213A	3214A	3215A	3216A	3217A
RF range	100 kHz to 30 MHz	8 to 16 MHz	12 to 28 MHz	20 to 45 MHz	30 to 70 MHz	50 to 110 MHz
Flatness	±.25 dB across 50-ohm load over frequency range of plug-in					
Spurious output	50 dB down	None, 3213A-3217A operate at fundamental frequency				
Harmonic output	30 dB below output level					
Residual FM	<±5 kHz	<±.005% of center frequency				
Sweep width	Continuously adjustable to 100% of frequency range					
Linearity	±10% of absolute frequency at max sweep width	±1% over any 25% of segment of range; ±3% over any 50% segment of range; ±5% over any 75% segment of range; ±10% over full range; measured as percent of absolute frequency				
Price	$225	$150	$150	$150	$150	$150

SWEEP OSCILLATOR
Superior performance, 100 kHz through 40 GHz
Series 8690



Multiband capability provides unprecedented versatility

Here is the first inexpensive solution to broadband swept operation over the complete RF and microwave spectrum: 100 kHz through 40 GHz.

The Model 8706A/8707A RF Unit Control Systems allow programmable selection of multiple RF units by pushbutton or remote contact closure. The 8705A Signal Multiplexer switches RF signals up to 12.4 GHz from three RF units to either of two RF output ports.

The system offers operational simplicity and maximizes BWO life. Multiband tests can be made quickly and easily.

Stabilized systems provide phase-locked signals for sophisticated applications

Phase-locked CW and swept frequency systems from 1 through 40 GHz are available to satisfy the exacting needs of such applications as microwave spectroscopy, high-Q swept frequency measurements, Doppler system sources, and narrow-band receiver or filter testing.

These systems are stabilized at any frequency in their operating range. Short term stability is that of the reference oscillator employed.

Interchangeable RF units offer multiband capability at low cost

Choose from a wide selection of RF units for the 8690B Sweep Oscillator. Units are available to cover the entire 100 kHz through 40 GHz range. The Model 8691D RF unit extends magnetic shielding capability to all seven microwave bands.

PIN diode modulation and leveling is available in "B" and "D" type RF units from 1 to 12.4 GHz. The 8691D and 8691-4B RF units offer exceptionally good frequency accuracy (between 0.25% and 1%) over a wide range of modulation conditions. Frequency pulling is practically nonexistent over a 10 dB dynamic range.

Rear loading uses minimum panel space, permits compact size with full width, high resolution dial

RF units that preserve integral sweeper performance can be changed in seconds without adjustment. One snap of the positive-locking rear handle and the RF unit is installed, ready to provide superior performance over the frequency range your application requires.

The 8690B Sweep Oscillator combines interchangeable RF units with high accuracy, versatility, and ease of operation to bring you all the advantages of single unit sweep oscillators plus economical ultrawide frequency coverage.

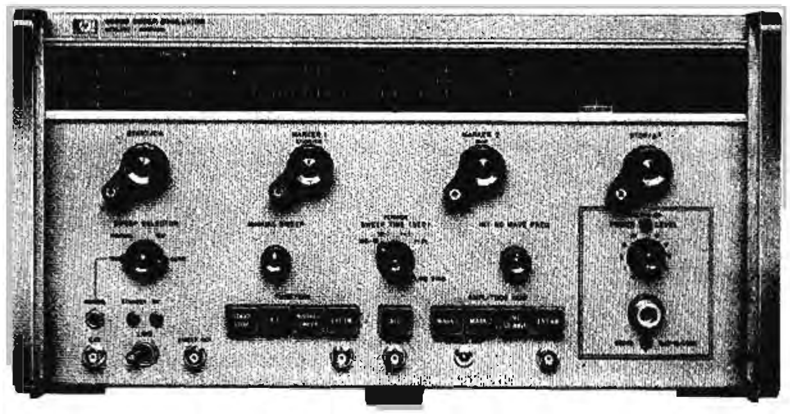
Dials are easy to change, keyed for accurate positioning

The snap-in scale that accompanies each RF unit illustrates the ease of obtaining ultrawide frequency coverage. The high resolution frequency scale is typical of many features that enhance user convenience and allow straightforward operation.

Among the outstanding features that make the 8690B Sweep Oscillator easy to use are pushbutton function selection, logical and easy-to-read frequency settings and operation modes, and independently adjustable sweep modes.

For versatile performance to meet all of your swept measurement needs, there are START/STOP, MARKER, and calibrated ΔF sweeps, all of which offer highest accuracy, linearity, and resolution.

SWEEP OSCILLATOR
Superior performance, 400 kHz through 40 GHz
Series 8690



8690B

8690-series sweep oscillators

The HP 8690B Sweep Oscillator and 8690A/B/D Series RF Units offer you all the advantages of single-unit sweep oscillators plus economical multiband capability. All BWO tubes carry an unconditional 1-year warranty. Careful design of new all-solid-state power supplies results in exceptionally low residual FM and provides rugged protection against system transients.

RF units combine to provide complete 400 kHz to 40 GHz coverage with a choice of features including PIN diode modulation (B and D Models), grid-modulated BWO units (A Models), and optional internal leveling. RF units can be changed quickly and without adjustment. The new all-solid-state 8699B utilizes Hewlett-Packard-unique YIG technology and hybrid microcircuits to achieve greater than 5 octaves of spectrum from 100 MHz to 4 GHz in one RF unit.

Snap-in scales are keyed for easy changing and accurate positioning. The full-width maximum-resolution scale and a carefully designed layout of the front panel controls allow simple, uncomplicated operation. Ease of operation is enhanced by pushbutton function selection, lighted function indicators adjacent to the scale, presentation of all frequency information which may be read at a glance, and simplified X-Y recorder setup through the use of manual sweep control.

Highly accurate, calibrated frequency displays, broadband and narrow band sweeps, external FM for frequency sweep programming, CW operation, automatic triggered or manual sweep control plus leveling in all modes of operation combine to give you unequaled performance and versatility in a space-saving package design.

The Model 8706A Control Unit, which plugs into the sweep oscillator like an RF unit, permits immediate band switching between up to eight selected RF units contained in up to three Model 8707A RF Unit Holders.

Systems capability is enhanced with the introduction of the 8705A Signal Multiplexer. This unit complements the 8706A Control Unit and the 8707A RF Unit Holders by providing automatic or pushbutton switching of multiple RF unit outputs to a choice of either a single output port or multiple output ports.

Sweep oscillator features:
Sweep modes

Automatic, triggered, and manual sweeps are available, in addition to CW operation. Automatic and triggered sweep times are adjustable from 0.01 to 100 seconds, and the triggered sweeps can be synchronized from an external source or started manually from a front panel pushbutton.

To enhance the clarity of oscilloscope presentations, RF power is blanked during retrace to produce a zero base line; however RF is restored before the start of the next sweep to eliminate transients during the early part of the sweep. Oscilloscope photography at slow sweeps is simplified by a front panel sweep indicator that lights automatically during the sweep.

For X-Y recording, an automatic pen lift circuit is provided. The circuit drops the pen during the stabilizing period prior to the sweep and lifts the pen during the second stabilizing period which occurs at the end of the sweep just before retrace. Thus, transients and retrace lines are eliminated from X-Y plots. During manual sweep, a front panel control varies the RF frequency between the limits set on the selected sweep function. With the use of manual sweep, X-Y recorder setup time is just a few seconds.

Sweep functions and monitors

Two independent frequency markers can be set separately on the "start-stop" sweep whose end points can be set anywhere in the band. Independent controls set the start and stop frequencies on the scale. Thus, the set frequency range can be swept up or down, depending only on the setting of the start frequency with respect to the stop frequency.

Two independent frequency markers, set separately on the scale and direct-reading in GHz, can be positioned anywhere in the band. The markers amplitude-modulate the RF output, providing triangular markers sharp enough to give high resolution on narrow sweeps, yet broad enough to be quite visible on the widest sweeps. Marker amplitude can be adjusted from the front panel.

The markers can be used as end points for a second broadband sweep which starts at the Marker 1 frequency and stops at the Marker 2 frequency. The marker sweep is especially advantageous. Extensive Hewlett-Packard design experience using swept-frequency techniques has proven that valuable time can be saved by bracketing circuit discontinuities with the markers. By pressing the marker sweep button, expanded investigation of the frequency range of interest is immediately available. Thus, the two independently adjustable broadband sweeps can be set for study of either broadband or narrow band frequency ranges.

Besides sweeping from a start frequency to a stop frequency, the 8690 provides a continuously calibrated narrow band sweep, the $\triangle$F sweep, which is symmetrical about a center frequency. Calibrated directly in MHz, the $\triangle$F sweep width is continuously adjustable from 0 to 10% of the band. Frequency markers can be applied to the $\triangle$F as well as the start-stop sweep.

Leveling

Leveling minimizes the variations in RF output amplitude with frequency. The 8690's are designed for external, closed-loop leveling. This is accomplished by driving the built-in leveling amplifier with a signal derived by sampling RF output power with a directional coupler and detector. The amplified signal is applied to the modulating circuits in the RF unit to maintain a constant power at the output of the directional coupler. External leveling eliminates the frequency-dependent transmission characteristics of any components between the oscillator and sampling point and also virtually eliminates source mismatch. Thus, leveled power can be established at any point in the system even though it is remote from the source. The degree of leveling is determined primarily by the coupler and detector variation.

Internal leveling is available as Option 01 on all grid-modulated BWO RF units below 12.4 GHz, Models 8691-4A, and on PIN diode attenuator-modulated RF units above 4 GHz, Models 8693-4B. Internally leveled RF units are useful in less critical applications in which transmission variations between oscillator and test point are not significant or when a package free of external elements is desired.

Modulation

All modulation functions are selected by pushbutton, and can be used simultaneously. Included is internal square-wave modulation, 950 to 1050 Hz, plus external AM and FM. External FM permits frequency programming, including externally controlled sweeps over all or any part of the band.

Plug-in RF units

Several types of RF units are available permitting selection to meet any application requirement.

Model 8698B: 400 kHz to 110 MHz

This RF unit is a low-frequency swept signal generator of heterodyne design. It brings 8690B microwave sweeper sophistication, precision, and operating features into the RF region. Features include a calibrated 1% frequency dial, 0.5% linearity, and +13 dBm max leveled output into 50 ohms that is calibrated from +10 to −110 dBm.

A unique frequency control feedback loop maintains very low residual FM and excellent stability over a broad frequency range. The ability to provide highly accurate, calibrated swept displays without the need for markers establishes measurement confidence. A built-in crystal calibrator allows true signal generator frequency accuracy of ±0.01% at 5-MHz intervals.

One narrow band and two broadband continuously adjustable and calibrated sweeps with automatic, triggered, or manual control are available. The unit offers AM and FM modulation capabilities including internal square-wave AM. See page 428.

Model 8699B: 100 MHz to 4 GHz

Here is a high quality signal source covering the entire 100-MHz to 4-GHz range. This range is important for many applications, including the ability to make broadband network analysis measurements efficiently.

Two ranges, 100 MHz to 2 GHz and 2 to 4 GHz, are provided by an inherently linear YIG-tuned solid-state oscillator. This device eliminates the shaping discontinuities encountered in varactor-tuned units, allowing 0.5% linearity over this vast spectrum. The unit contains a PIN modulator for superior modulation and external leveling in addition to keeping down frequency pulling with load impedance changes. A hybrid microcircuit high-gain output amplifier provides high power output while keeping spurious and harmonic content very low.

The Model 8699B is an economical unit, providing more than five octaves of coverage at significantly less expense than many comparable units. The 8699B's range includes L- and S-bands, and is only slightly more expensive than the separate BWO-type units for these bands alone. See page 430.

Models 8691-4A/B and 8691D: 1 to 12.4 GHz

Th 8691D extends BWO magnetic shielding to the 1-2 GHz band. All coaxial "B" and "D" models feature PIN diode attenuators which permit all of the amplitude-modulation functions, including leveling, to be performed independently of the backward-wave oscillator tube. The result is a virtual elimination of frequency pulling, enabling excellent frequency accuracy and linearity, low incidental FM, permitting a wide variety of modulation conditions over a 10-dB dynamic range.

The "A" models contain grid-modulated BWO's. Option 01 internal leveling is available on all RF units covering 1 to 12.4 GHz except the 8691B/D and the 8692B. Models are available on special order to cover every frequency range for which there is a BWO. See page 427.

Models 8695-7A: 12.4 to 40 GHz

Th P-, K-, and R-waveguide bands are covered by the Models 8695A, 8696A, and 8697A, respectively. The units contain grid-modulated BWO's and have a frequency range and linearity of ±1% over a 6-dB power range. Output power variation with external leveling is ±0.2 dB. See page 427.

The Model K04-8690A Calibrator facilitates 8690B Sweep Oscillator calibration. The unit plugs into the 8690B like an RF unit. Circuit points sampled during the calibration procedure are presented on front-panel BNC connectors. The unit switches in standard calibrating circuits, equivalent to those in the RF units, to ensure interchangeability of all RF RF units in the 8690B Sweep Oscillator.

Superior performance, 400 kHz through 40 GHz
Series 8690

Specifications, 8690B Sweep Oscillator (with RF Unit installed)

Frequency range: determined by RF unit.

Sweep functions

Start-stop sweep: sweeps from "start" to "stop" frequency setting.

Range: both settings continuously and independently adjustable over the entire frequency range; can be set to sweep either up or down in frequency.

End-point accuracy: same as RF unit frequency accuracy.

Marker sweep: sweeps from "Marker 1" to "Marker 2" frequency setting.

Range: both settings continuously and independently adjustable over the entire frequency range; can be set to sweep either up or down in frequency.

End-point accuracy: same as RF unit frequency accuracy.

ΔF sweep: sweeps upward in frequency, centered on CW setting.

Width: continuously adjustable from zero to 10% of the frequency band; calibrated directly in MHz.

Width accuracy:* ±10% of ΔF being swept ±1% of maximum ΔF (±20% ±2% respectively with 8691A/B RF Units).

Center-frequency accuracy: same as RF unit frequency accuracy.

Frequency markers: two frequency markers, independently adjustable over the entire frequency range, amplitude-modulate the RF output; amplitude is adjustable from the front panel; the markers are also available for external use.

Accuracy: 1% of full scale for all RF units.

RF unit specifications, series 8690

HP Model	Frequency range	Frequency accuracy at max leveled power	Maximum leveled power	RF power control	Frequency stability: With temperature	Frequency stability: With 10% change in line voltage	Frequency stability: With power level change	Frequency stability: Residual[1] FM	Power variation, external leveling[2]	Output impedance	Output connector	Price	Option 01. Internal leveling: Power variation	Option 01: Equivalent source match	Option 01: Price
8691A	1 to 2 GHz	±1%	≥100 mW	BWO grid	±0.01%/°C	±500 kHz	Typically <20 MHz (for 6 dB)[4]	<30 kHz peak	±0.2 dB	50 ohms	Type N	$1875	±0.4 dB	1.13:1	$315
8691B	1 to 2 GHz	±10 MHz	≥ 70 mW	PIN line	±0.01%/°C	±500 kHz	±500 kHz (for 10 dB)	<10 kHz peak	±0.1 dB	50 ohms	Type N	$2225	—	—	—
8691D[3]	1 to 2 GHz	±10 MHz	≥70 mW	PIN line	±0.01%/°C	±500 kHz	±600 kHz (for 10 dB)	<20 kHz peak	±0.1 dB	50 ohms	Type N	$2325	—	—	—
8692A	2 to 4 GHz	±1%	≥ 70 mW	BWO grid	±0.01%/°C	±500 kHz	Typically <40 MHz (for 6 dB)[4]	<30 kHz peak	±0.2 dB	50 ohms	Type N	$1675	±0.4 dB	1.16:1	$315
8692B	2 to 4 GHz	±20 MHz	≥ 40 mW	PIN line	±0.01%/°C	±500 kHz	±4 MHz (for 10 dB)	<15 kHz peak	±0.1 dB	50 ohms	Type N	$2025	—	—	—
H01-8692B	1.7 to 4.2 GHz	±25 MHz	≥ 18 mW	PIN line	±0.01%/°C	±500 MHz	±4 MHz (for 10 dB)	<20 kHz peak	±0.1 dB	50 ohms	Type N	$2325	—	—	—
8693A	4 to 8 GHz	±1%	≥ 50 mW	BWO grid	±0.01%/°C	±1 MHz	Typically <80 MHz (for 6 dB)[4]	<50 kHz peak	±0.2 dB	50 ohms	Type N	$1575	±0.5 dB	1.25:1	$350
8693B	4 to 8 GHz	±40 MHz	≥ 15 mW	PIN line	±0.01%/°C	±1 MHz	±1 MHz (for 10 dB)	<15 kHz peak	±0.1 dB	50 ohms	Type N	$1950	±0.4 dB	1.25:1	$350
H01-8693B	3.7 to 8.3 GHz	±45 MHz	≥ 5 mW	PIN line	±0.01%/°C	±1 MHz	±1 MHz (for 10 dB)	<20 kHz peak	±0.1 dB	50 ohms	Type N	$2250	±0.4 dB	1.25:1	$350
8694A	8 to 12.4 GHz	±1%†	≥ 50 mW	BWO grid	±0.01%/°C	±1 MHz	Typically <160 MHz[5]	<60 kHz peak	±0.2 dB	50 ohms	Type N	$1575	±1.0 dB	2:1	$375
H01-8694A	7 to 12.4 GHz	±1%†	≥ 25 mW	BWO grid	±0.01%/°C	±1 MHz	Typically <160 MHz[5]	<60 kHz peak	±0.2 dB	50 ohms	Type N	$1850	±1.0 dB	2:1	$400
H02-8694A	7 to 11 GHz	±1%†	≥ 25 mW	BWO grid	±0.01%/°C	±1 MHz	Typically <160 MHz[5]	<60 kHz peak	±0.2 dB	50 ohms	Type N	$1600	±1.0 dB	2:1	$375
8694B	8 to 12.4 GHz	±40 MHz	≥ 30 mW	PIN line	±0.01%/°C	±1 MHz	±1 MHz[6]	<15 kHz peak	±0.1 dB	50 ohms	Type N	$1975	±0.75 dB	1.5:1	$375
H01-8694B	7 to 12.4 GHz	±50 MHz	≥ 15 mW	PIN line	±0.01%/°C	±1 MHz	±1 MHz[6]	<20 kHz peak	±0.1 dB	50 ohms	Type N	$2250	±0.75 dB	1.5:1	$400
H02-8694B	7 to 11 GHz	±40 MHz	≥ 15 mW	PIN line	±0.01%/°C	±1 MHz	±1 MHz[6]	<20 kHz peak	±0.1 dB	50 ohms	Type N	$2000	±0.75 dB	1.6:1	$375

HP Model	8695A	8696A	8697A
Frequency range	12.4 to 18 GHz	18 to 26.5 GHz	26.5 to 40 GHz
Frequency accuracy (over a 6 dB range)	±1%	±1%	±1%
Maximum leveled power	≥40 mW	≥10 mW	≥5 mW
Frequency stability with temperature	±0.01%/°C	±0.01%/°C	±0.01%/°C
With 10% change in line voltage	±10 MHz	±15 MHz	±20 MHz
With 6-dB power level change down from max. leveled power.	Typically <0.25 GHz	Typically <0.36 GHz	Typically <0.53 GHz
Residual FM	<150 kHz	<200 kHz	<350 kHz
Power variation, external leveling[2]	±0.2 dB	±0.2 dB	±0.2 dB
Output connector	UG-419/U	UG-595/U	UG-599/U
Price	$1700	$2500	$4300

Residual FM specifications give peak deviations for modulating components within a 10-kHz bandwidth. Peak deviation may vary ±50% for a 10% line voltage change. Specifications apply for unleveled operation of A Model RF Units and both leveled and unleveled operation in B/D Model RF Units. Specifications for all B/D Model RF Units are typically the same as above when used in an 8707A RF Unit Holder. However, the maximum B/D Model RF Unit specifications are twice the above for use in the 8707A.

2 Excluding coupler and detector variation.

3 8619D has shielded BWO.

4 Down from maximum leveled power.

5 With 6-dB power level change down from maximum leveled power.

6 With 10-dB power level change.

Resolution: better than 0.05% of RF unit bandwidth.

Marker output: triangular pulse, typically −5 V peak into 1000-ohm load.

CW operation: single-frequency RF output selected by START/CW or MARKER 1 control, depending on sweep function selected.

Accuracy: same as RF unit frequency accuracy.

Preset frequencies: start-stop sweep end points and marker frequencies can be used as four preset CW frequencies.

Sweep mode

Auto: sweep recurs automatically.

Manual: front-panel control provides continuous manual adjustment of frequency between end frequencies set in any of the above sweep functions.

Triggered: sweep is actuated by front-panel pushbutton or by externally applied signal <-25 V peak, >1 μs pulse width, and >0.1 V/μs rise.

Sweep time: continuously adjustable in four decade ranges, 0.01 to 100 seconds; can be synchronized with the power line frequency.

Sweep indicator: front-panel indicator lights during the sweep, providing indication of sweep duration on slower sweep times.

Sweep output: direct-coupled sawtooth, zero to approximately +15 V, concurrent with swept RF output; zero at start of sweep, approximately +15 V at end of sweep regardless of sweep width or direction; source impedance, 10,000 ohms.

Frequency linearity:*† same as RF unit frequency accuracy.

Blanking: RF automatically turned off during retrace, turned on after completion of retrace. On automatic sweeps, RF is on long enough before sweep starts to stabilize external circuits and equipment whose response is compatible with the selected sweep rate; blanking disable switch provided.

Blanking output: direct-coupled rectangular pulse approximately −4 V coincident with RF blanking; source impedance approximately 3000 ohms.

Pen lift: for use with X-Y graphic recorders; pen lift terminals shorted during sweep, open during retrace.

Power leveling amplifier: internal dc-coupled leveling amplifier provided. (Not used with 8698B.)

Crystal input: approximately −20 to −350 mV for specified leveling at rated output, for use with negative-polarity detectors such as 780 Series Directional Detectors, 423A and 424 Series Crystal Detectors.

Modulation*

Internal AM: square-wave modulation continuously adjustable from 950 to 1050 Hz on all sweep times; on/off ratio greater than 20 dB at rated output.

External AM:

Frequency response: dc to 350 kHz unleveled, dc to 50 kHz leveled.

Sensitivity: −10 V reduces RF level output at least 30 dB below rated CW output (A Model RF units); 25 dB below rated CW output (B/D Model RF units).

Input impedance: approximately 1000 ohms.

External FM:

Frequency response: dc to 3 kHz.

Sensitivity: deviation from CW setting approximately 6% of the frequency band per volt.

Maximum range: full band for modulation frequencies up to 150 Hz (approximately 17 V p-p input), decreases to about 20% of the band for 3 kHz modulation.

Input impedance: approximately 100,000 ohms.

General

Power: 115 or 230 volts ±10%, 50 to 60 Hz, approximately 350 watts.

Dimensions: 16¾" wide, 9" high, 18⅜" deep (426 x 229 x 467 mm); hardware furnished for rack mount 19" wide, 8-23/32" high, 16⅜" deep behind panel (483 x 221 x 416 mm).

Weight (not including RF unit): net 53 lb (23,9 kg); shipping 71 lb (32 kg).

Furnished: 7½ foot (2290 mm) power cable with NEMA plug; rack mounting kit.

Available:

HP K04-8690A Calibrator (page 425), $350.
HP 8706A Control Unit (page 432), $500.
HP 8707A RF Unit Holder (page 432), $1,050.

Price: HP 8690B, $1,600.

External leveling accessories available

Directional detectors: 780 Series (page 297), 1 to 12.4 GHz, $300 to $350.

Directional couplers: coaxial: 790 Series (page 297), 1 to 8 GHz, $200 to $225; waveguide: 752 Series (page 299), 2.6 to 40 GHz, $145 to $600.

Crystal detectors: coaxial: 423A (page 307), 10 MHz to 12.4 GHz, $135; waveguide: 424A Series (page 307), 2.6 to 18 GHz, $155 to $275 and 422A (page 307), 18 to 40 GHz, $230.

For all 8691-8697 RF units

Magnetic shielding: all 8691-8697 RF Units except 8691A/B have shielded BWO's. All BWO's are unconditionally warranted for 1 year.

Residual AM: at least 40 dB below CW output.

Spurious signals: harmonics, at least 20 dB below CW output; nonharmonics, at least 40 dB below CW output.

Reference output: direct-coupled voltage proportional to RF frequency, approximately 0 V at the low end of the band, increasing approximately 40 V/octave; output impedance, 25,000 ohms.

Leveling indicator: front-panel indicator lights when power level set too high to permit leveling over entire selected sweep range or when operating in unleveled mode.

Equivalent source match

Externally leveled: depends on coupler.

Unleveled: less than 2.5:1.

Power variation, unleveled: <10 dB over the entire band.

Weight

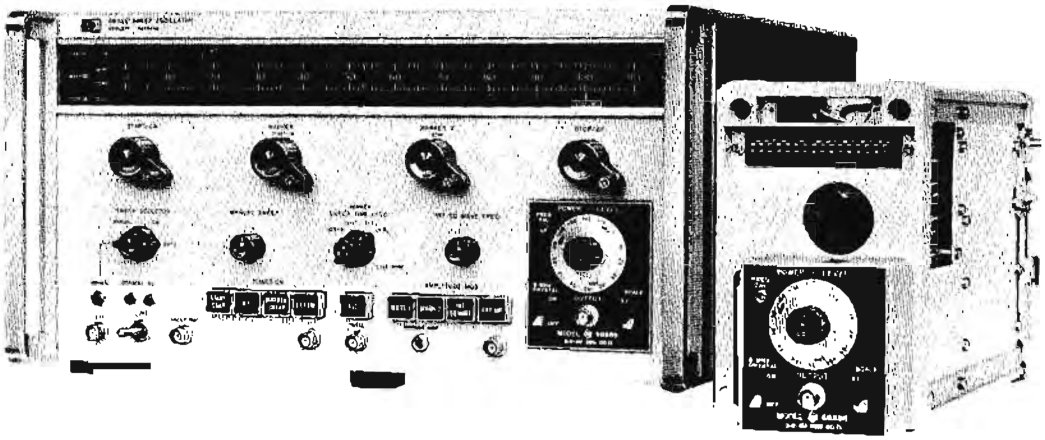
8691A, 8692A: 17 lb (7,6 kg); shipping 25 lb (11,3 kg).
8691B, 8692B: 20 lb (9 kg); shipping 28 lb (12,6 kg).
8691D: 22 lb (10 kg); shipping 30 lb (13,6 kg).
8693A-8697A: 10 lb (4,5 kg); shipping 18 lb (8,1 kg).
8693B, 8694B: 12 lb (5,4 kg); shipping 20 lb (9 kg).

*Listed separately for 8698B; see page 429.
†Correlation between frequency and both the sweep and reference output.

RF UNIT

8690B features in a 400 kHz-110 MHz sweeper

Model 8698B



8698B

NOW! . . . SATISFY LOW FREQUENCY CW AND SWEEP SIGNAL GENERATOR DESIGN AND TEST REQUIREMENTS . . . IF STRIPS — RF COMPONENTS — VIDEO AND OPERATIONAL AMPLIFIERS — RADIO AND TELEVISION CIRCUITS — FILTER PARAMETERS

Description

The Model 8698B RF Unit for the Model 8690B Sweep Oscillator is a low-frequency sweep signal generator. It covers the frequency range from 400 kHz to 110 MHz in two ranges. All of the performance features designed into the 8690B Sweep Oscillator for microwave use are retained with the 8698B RF Sweep Signal Generator.

The all-solid-state Model 8698B RF Unit makes an outstanding low-frequency contribution for several reasons:

- Sweep linearity is exceptionally good, departing less than ±0.5% from a straight-line function, and frequency accuracy is ±1%. Residual FM is very low, less than 150 Hz (low range) and 500 Hz (high range). The user is thus able to define the roll-off characteristics of amplifiers and filters accurately.
- Output power is calibrated from +10 to −110 dBm with vernier adjustment between steps. Calibrated power makes it easier to define gain and loss in networks and amplifiers.
- Maximum output is +13 dBm into a 50-ohm load. Output power at this level enables noise-free measurements on networks with high attenuation.
- A built-in leveling circuit holds the output flat within ±0.25 dB throughout the maximum sweep width (100 MHz) and flat within ±0.1 dB over any 10-MHz portion of the band. This assures accuracy in measuring amplifier and network frequency response.

Operation

Besides the greater precision and higher accuracy that this RF unit brings into the radio frequency range, there are also operating features of special import. Start and stop sweep points are continuously adjustable and calibrated over the full range, and the instrument sweeps up or down in frequency. Two continuously adjustable markers identify the frequencies of any part of the sweep and can also serve as the end points of another sweep. This marker sweep can be used to expand a small portion of a broadband sweep enabling resolution of displayed discontinuities. A △F sweep function sweeps over a calibrated frequency range symmetrically on either side of a selected center frequency.

Design

The accuracy and linearity of the Model 8698B sweep has never before been approached by a sweep oscillator in this frequency range. To achieve this, a frequency comparator technique uses a pulse count discriminator in a frequency-controlling feedback loop. This discriminator generates a voltage proportional to the frequency output of the RF Unit. This voltage is compared to the linear tuning voltage ramp reference furnished by the 8690B Sweep Oscillator. The 8690B voltage comparison results in tuning voltage compensation applied to a voltage-tuned-oscillator (VTO) to ensure an accurate and linear swept frequency output with time. This technique also substantially reduces residual FM. The output frequency will track an externally applied control voltage faithfully at any deviation rate up to 2 kHz and up to the full 110 MHz frequency deviation range.

The 8698B start-stop type sweep, frequency accuracy and linearity eliminate the need for crystal markers to identify sweep width or points intermediate in the sweep. A crystal calibrator is provided for true signal generator accuracy of

0.01% at 5-MHz intervals when required. Frequency settability of ±1%, low residual FM, and calibrated power output permit the 8698B to satisfy many RF signal generator CW applications.

An auxiliary RF output provides a 0.4-11 MHz (low range) or 0.1-11 MHz (high range) signal to allow inexpensive low-frequency counter monitoring of RF output all the way to 110 MHz. Crystal reference counter Models H01-5321A, 5321B, and 5221B are ideally suited for this purpose.

The VTO and Uncalibrated Outputs provide signals for applications requiring external mixing techniques.

Specifications, 8698B installed in 8690B Sweep Oscillator

Frequency range: 0.4 to 11 MHz or 1 to 110 MHz, selected by front-panel switch.

Power output: at least +13 dBm (1.0 V rms) max into 50Ω; calibrated power output adjustable from +10 to −110 dBm in 10-dB steps; 10-dB vernier permits continuous adjustment between steps; source impedance 50Ω.
Output accuracy (vernier in calibrate position): ±1 dB.
Flatness (vernier in calibrate position):*
1 to 110 MHz: ±0.25 dB.
Over any 10 MHz range: ±0.1 dB.

Frequency stability:
With temperature:
0.4 to 11 MHz: ±0.05%/°C.
1 to 110 MHz: ±0.05%/°C.
With 10% line voltage change:
0.4 to 11 MHz: ±5 kHz.
1 to 110 MHz: ±50 kHz.
Residual FM:†
0.4 to 11 MHz: <150 Hz peak.
1 to 110 MHz: <500 Hz peak.

Spurious signals:
Nonharmonics: at least 40 dB below CW output.
Harmonics (vernier in calibrate position): at least 30 dB below CW output from 1 to 110 MHz.

Sweep functions
Start-stop sweep: sweeps from "start" to "stop" frequency setting.
Range: both settings continuously and independently adjustable over the entire frequency range; can be set to sweep either up or down in frequency.
End-point accuracy:
0.4 to 11 MHz: ±1% of full scale.
1 to 110 MHz: ±1% of full scale.
Marker sweep: sweeps from "Marker 1" to "Marker 2" frequency setting.
Range: both settings continuously and independently adjustable over the entire frequency range; can be set to sweep either up or down in frequency.
End-point accuracy:
0.4 to 11 MHz: ±1% of full scale.
1 to 110 MHz: ±1% of full scale.
ΔF sweep: sweeps upward in frequency, centered on CW setting.
Width: continuously adjustable from zero to 10% of the frequency band; calibrated directly in MHz.
Width accuracy:
0.4 to 11 MHz: ±3% of ΔF being swept or ±20 kHz, whichever is greater.
1 to 110 MHz: ±3% of ΔF being swept or ±200 kHz, whichever is greater.
Center-frequency accuracy:
0.4 to 11 MHz: ±1% or ±100 kHz, whichever is greater.
1 to 110 MHz: ±1% or ±500 kHz, whichever is greater.

Linearity: ±0.5% of sweep width.

Frequency markers: two frequency markers, independently adjustable over the entire frequency range, amplitude-modulate the RF output; amplitude is adjustable from the front panel; the markers are also available for external use.
Accuracy:
0.4 to 11 MHz: ±1% of full scale.
1 to 110 MHz: ±1% of full scale.
Resolution: better than 0.05% of RF unit bandwidth.
Marker output: triangular pulse, typically −5 V peak into 1000 ohm load.

*When measured with negative-peak detecting device having 50Ω impedance.
†Power line related components.

Crystal calibrator: internal 5-MHz crystal calibrator allows frequency calibration to ±0.01% at any multiple of 5 MHz.

CW operation: single-frequency RF output selected by START/CW or MARKER 1 control, depending upon sweep function selected.
Accuracy:
0.4 to 11 MHz: ±1% or ±100 kHz, whichever is greater.
1 to 110 MHz: ±1% or ±500 kHz, whichever is greater.
Preset frequencies: start-stop sweep end points and marker frequencies can be used as four preset CW frequencies.

Settability: using Auxiliary output and crystal reference counter; 200 Hz (low range); 2 kHz (high range).

Sweep mode
Auto: sweep recurs automatically.
Manual: front-panel control provides continuous manual adjustment of frequency between end frequencies set in any of the above sweep functions.
Triggered: sweep is actuated by front-panel pushbutton or by externally applied signal <−25 V peak, >1 μs pulse width, and >0.1 V/μs rise.

Sweep time: continuously adjustable in four decade ranges, 0.01 to 100 seconds; can be synchronized with the power line frequency.

Sweep indicator: front-panel indicator lights during the sweep to provide indication of sweep duration on slower sweep times.

Auxiliary outputs:
Sweep output: direct-coupled sawtooth, zero to approx +15 V, concurrent with swept RF output; zero at start of sweep, approx +15 V at end of sweep regardless of sweep width or direction; source impedance, 10 kΩ.
Sweep reference:
0.4 to 11 MHz: approx 1 V/MHz.
1 to 110 MHz: approx 1 V/10 MHz.
Auxiliary RF output: 0.4-11 MHz (low range); 0.1-11 MHz (high range) for low-frequency counter monitoring.
Uncalibrated RF output: CW signal corresponding to front-panel output; output level at least −5 dBm.
VTO output: 200 to 310 MHz CW; output level at least −15 dBm.

Blanking: RF automatically turned off during retrace, turned on after completion of retrace; on automatic sweeps, RF is on long enough before sweep starts to stabilize external circuits and equipment whose response is compatible with the selected sweep rate; blanking disable switch provided.

Blanking output: direct-coupled rectangular pulse approx −4 V coincident with RF blanking; source impedance approx 3000 ohms.

Pen lift: for use with X-Y graphic recorders; penlift terminals shorted during sweep, open during retrace.

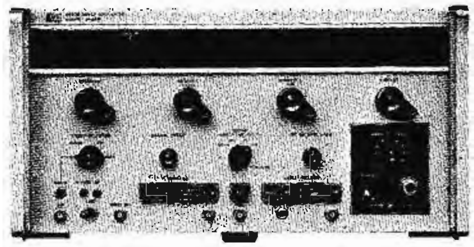
Modulation:
Internal AM: square-wave modulation continuously adjustable from 950 to 1050 Hz on all sweep times.
External AM: bandwidth typically >5 kHz.
External FM:
Max p-p deviation: 110 MHz.
Max rate (any deviation): 2 kHz.
Linearity: ±0.5% of p-p deviation.

Power: 115 or 230 V ±10%, 50 to 60 Hz; approx 350 W.

Weight:
8698B: net 11 lb (5 kg); shipping 20 lb (9 kg).
8690B: net 53 lb (23.9 kg); shipping 71 lb (32 kg).

Price: HP Model 8698B, $1350. HP Model 8690B $1,600.

RF UNIT
Covers 5 Octaves: 100 MHz to 4 GHz
Model 8699B



- Ultra-Broadband Solid-State Sweeper
- All Solid-State
- Linear YIG Tuning
- PIN Leveled
- Economical and Convenient
- Wide Spectrum Sweeps

8699B

Ultra-broadband solid state sweeper

The use of thin-film technology, hybrid microcircuits, and s-parameter design methods has provided an RF unit for the 8690B Sweep Oscillator that covers more than 5 octaves from 100 MHz to 4 GHz. The inherent linearity of a YIG-tuned oscillator produces a very linear swept frequency, and the utilization of integrated circuit oscillator technology provides good frequency stability. A flat, high gain microcircuit amplifier permits high power output with low spurious and harmonic content. Frequency pulling with any load change is less than 500 kHz.

Design

A 2.3- to 4.2-GHz signal from the linear YIG-tuned oscillator mixes with a 2.2-GHz signal from the solid-state fixed oscillator to produce the 100-MHz to 2-GHz output. A PIN modulator is placed before the mixer. This design has the advantage of offering PIN quality modulation down to 100 MHz. When less than maximum power is required, less power is sent to the mixer and output amplifier, keeping spurious signals very low. Feedthrough of the 2.2-GHz oscillator is prevented by an HP microcircuit low-pass filter that has very low insertion loss at 2 GHz but better than 40 dB attenuation above 2.5 GHz.

The high range, 2 to 4 GHz, is provided directly by the YIG oscillator via the PIN modulator.

Specifications

8690B Specifications with RF Unit installed also apply. Refer to page 426.

Frequency range: 0.1 to 4 GHz in two ranges (0.1 to 2 GHz and 2 to 4 GHz).

Frequency accuracy: CW ±10 MHz.

Start endpoint.

±10 MHz +1% of sweep width on fastest sweep.

Stop endpoint.

±10 MHz −2% of sweep width on fastest sweep.

Linearity: ±0.5% of sweep width (except for first 10% of sweep on fastest range).

Frequency stability

Versus temperature: ±200 kHz/°C.

Versus power change from max. leveled power:

(2 to 4 GHz) less than 100 kHz for 10-dB change.

(0.1 to 2 GHz) less than 1.5 MHz for 3-dB change.

(0.1 to 2 GHz) less than 100 kHz for −3 dB to −13 dB.

Versus 10% line voltage: less than 100 kHz.

Less than 500 kHz frequency pulling with change of load impedance.

Harmonics: 0.1 to 2 GHz: more than 25 dB down at rated power.

2 to 4 GHz: more than 20 dB down at rated power. Performance improves with decrease in power level.

Spurious signals (nonharmonics): more than 30 dB down.

Residual FM (in CW): less than 10 kHz peak in 10-kHz bandwidth.

Output range: 0.1 to 2 GHz, +13 dBm; 2 to 4 GHz, +10 dBm.

Flatness

Leveled: 0.1 to 2 GHz, ±1.5 dB using 778D Dual Directional Coupler.

2 to 4 GHz, ±0.3 dB using 787D Directional Detector.

Unleveled: ±7 dB.

Phase-lock: options available to work with 8709A (see next page) available on request.

VSWR: 3:1.

Sweep reference: 0-40 V on 2- to 4-GHz range only.

Construction: all solid-state.

Price: less than $3,000.

STABILIZED OSCILLATOR SYSTEMS
Phase-locked signals, 1 through 40 GHz
Model 8709A, E20 Series 8690A

8709A

Uses:

Narrowband receiver or filter test
Parametric amplifier pump
Doppler system source

Features:

Stabilized at any frequency — 1 to 40 GHz
Stabilized CW or swept, 5×10^{-7}/s, 1×10^{-6}/hr
Positive frequency indication

E20 Series Stabilized Sweep Oscillator Systems

The E20 Series Stabilized Sweep Oscillator Systems satisfy the requirement for high stability in many microwave applications. These systems offer both CW and swept operation in the 1 to 40 GHz range. Phase-lock stabilization is provided by the 8709A Synchronizer.

The 8709A Synchronizer phase-locks the 8690 Series Sweep Oscillators by providing a voltage output that is proportional to the phase difference between the synchronizer input signal and a highly stable internal reference signal. The input signal is derived by mixing the sweep oscillator output with a highly stable external reference oscillator. The lock-points are spaced by the reference oscillator frequency instead of the IF frequency because the synchronizer rejects the lower of two possible lock-points for any given frequency.

The H15-8691-7A/B RF Units include the Shunt Tube BWO Coupler that permits control of the BWO helix voltage by the low voltage output of the 8709A Synchronizer.

Frequency calibration of the RF unit is maintained because the BWO is calibrated with the shunt tube in the circuit. Phase-lock loop gain can be adjusted by changing one resistor so that phase detectors with lower error voltage outputs may be used. The H15-8691-7A/B is compatible with the HP 2650A, HP 2590A, and HP 8709A, and most other commercially available synchronizers.

Major specifications, H15-8691-7A/B Series RF Units

Input voltage: $\leq \pm 20$ V dc, 40 μA dc max.

Modulation sensitivity:
1.0 to 4.0 GHz: 1 MHz/V
4.0 to 12.4 GHz: 2.5 MHz/V
12.4 to 40.0 GHz: 6 MHz/V

Frequency response: dc to 500 kHz.

Price: RF unit plus $230.

Several reference oscillators are available for HP phase-locked systems. Using the 8464A Reference Oscillator provides 5×10^{-7}/s short term stability for CW operation. The 8466 Reference Oscillator provides 5×10^{-7} short term stability with the additional capability of phase-locking while sweeping. For additional stability, the HP 8708A Synchronizer may be used to lock the reference oscillators to satisfy more rigid requirements.

Further information on these systems is available on the E20-8690A Data Sheet and from your local HP sales engineer.

Major specifications, E20 Series 8690A

CW systems:
E20-8690A: 1 to 12.4 GHz
E21-8690A: 12.4 to 40 GHz

CW and swept systems:
E22-8690A: 1 to 12.4 GHz
E23-8690A: 12.4 to 40 GHz

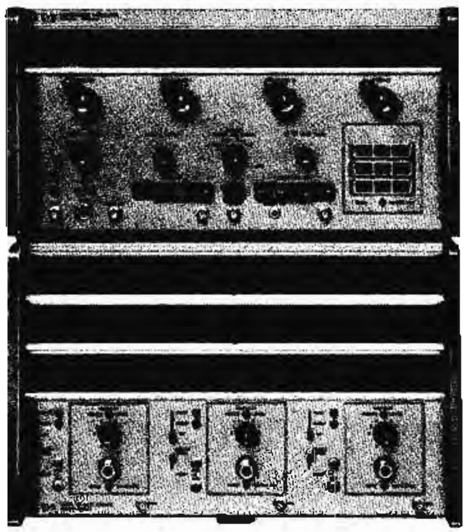
Stabilized frequency stability:
Short term: $\leq 5 \times 10^{-7}$/s
Long term: $\leq 1 \times 10^{-6}$/hr

Residual FM: $\leq 5 \times 10^{-7}$

CONTROL UNIT, RF UNIT HOLDER

Programmable sweeps, 400 kHz through 40 GHz

Models 8706A, 8707A



8706A, 8707A

Inexpensive multiband coverage

A simple and relatively inexpensive solution to the problem of broadband sweep capability is offered by Hewlett-Packard's Model 8706A Control Unit with the Model 8707A RF Unit Holder. When used with the HP Model 8690B Sweep Oscillator and appropriate RF units, a compact, bench-top multiband source is formed.

The Model 8706A Control Unit with its nine band selector buttons replaces the usual RF unit as a plug-in for the sweep oscillator mainframe. It supplies power for and controls as many as three Model 8707A RF Unit Holders, each of which accommodates three RF units. Each 8707A RF Unit Holder provides coverage for three bands; one of these bands extends from 400 kHz to 110 MHz; others are of approximately octave width each and can cover from 1 to 40 GHz.

Operation

Units may be programmed either by front panel control unit pushbutton selection, or sequentially by remote contact closure to ground. The 8706A also can provide voltages for control of remote circuits, relays, etc. By utilizing these voltages to program a coaxial switch, for example, you can channel the output signals of several RF units through a single system output connector. The 8705A Signal Multiplexer (see page 433) is especially designed to accomplish this task efficiently and conveniently through 12.4 GHz. Multi-band tests can then be made quickly and easily; changing RF units *and* cable connections is handled automatically at the touch of a button.

Two separate types of sweep capability are available in each band. If normal sweep is selected for one or more of the RF units in the 8707A RF Unit Holder, the breadth of the RF unit sweep will correspond to the setting of the start/stop cursor on the sweeper mainframe—100% if 0 and 100 are selected, or any proportion as designated on the start/stop dial. A second preset mode is available for one or more RF units by pre-adjusting start-stop frequency settings made on potentiometers adjacent to each RF unit plug-in in the 8707A RF Unit Holder.

Design

Switching time between bands is one second, with no degradation of BWO life. This is an exclusive accomplishment. Unnecessary operation of BWO tubes should be avoided to prolong their life; at the same time, it is desirable to have the output of any RF unit quickly available. The 8707A sweep system maintains the BWO's on standby, removing the high voltage when not in use to extend tube life. When a single band is not to be used over some period of time, for example during a laboratory set-up procedure, an individual RF unit may be easily turned off, minimizing all aging effects.

Specifications 8706A

Compatibility: the 8706A controls up to three 8707A RF Unit Holders. Selection of RF unit is by front-panel pushbutton or remote contact closure (see Remote Control below).

Switching time between RF units: 1 second.

Remote control: connector on rear panel permits selection of RF units from remote location or control of remote circuits or switches from the 8706A. There are nine control pins, each corresponding to a front-panel pushbutton, plus a common ground pin. Mating connector (not supplied), Amphenol 57-30140 (also available from Hewlett-Packard under part number 1251-0142).

- **RF unit selection:** momentary grounding of appropriate control pin.
- **Control pin voltage:** pins are at 0 V (ground) when RF unit is selected, otherwise at −5 V when RF unit is not in use (standby). These voltages can be used to program external devices such as coaxial switches.
- **Minimum external resistance (per control pin) for Unselected RF units:** 50 Ω.
- **Maximum external resistance for positive selection of RF unit:** 2 Ω.
- **Maximum current per control pin:** 100 mA.

Weight: net, 16 lb (7,3 kg); shipping, 22 lb (10 kg).

Price: Model 8706A, $500.

Specifications 8707A

Compatability: accepts up to three 8691D*, 8692-8698 RF units. No modification of the RF units is necessary. Maximum number of BWO tube units is seven, plus one 8698B, for a total of eight.

Frequency range: 400 kHz to 110 MHz, 1 to 40 GHz.

Frequency accuracy: same as RF unit accuracy.

*Caution: Nonshielded 8691A/B's are not compatible with and should not be installed in the 8707A.

SIGNAL MULTIPLEXER

Auto switch ALC, sweep reference and RF to 12.4 GHz

Model 8705A

Maximum leveled power: same as 8691D, 8692-8698 RF units.

Leveling capability: same as 8691D, 8692-8698 RF units.

Output impedance and connector: same as RF units.

Sweep functions

Normal: permits any sweep function available from the 8690B.

Preset: provides start-stop sweep determined by preset adjustments on the 8707A. Sweep end points can be set independently for each RF unit.

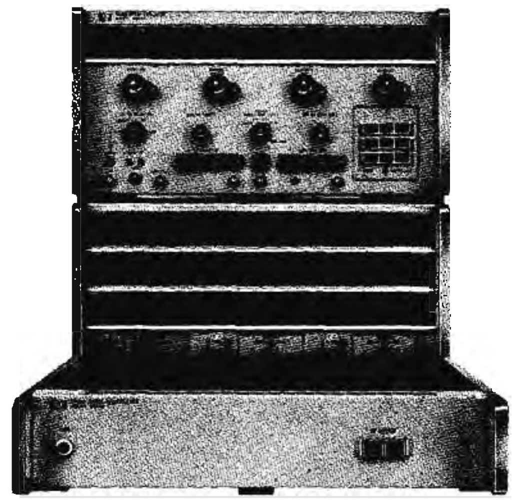
Dimensions: 16¾″ wide, 9″ high, 18⅜″ deep (424 x 229 x 467 mm); hardware furnished for rack mount, 19″ wide, 8-23/32″ high, 16⅜″ deep behind panel (483 x 221 x 416 mm).

Power: approximately 385 W for system with one each 8690B, 8706A, 8707A, and three RF units; approximately 25 W for each additional RF unit.

Weight: net, 28 lb (12,7 kg); shipping, 34 lb (15,4 kg).

Accessory available: K04-8690A Calibrator, $350.

Price: Model 8707A, $1,050.



8705A

Description, 8705A

The 8705A Signal Multiplexer switches RF signals up to 12.4 GHz from three 8690-series RF units to either of two RF ports. The 8705A is designed to complement the ideal wideband signal source combination; an 8690B Sweep Oscillator, an 8707A RF Unit Holder/8706A Control Unit, and 8690-series RF units.

A combination of three input ports and two output ports allows a variety of input-output configurations. Sweep reference signals for each RF unit sweep width are also switched to provide a single Sweep Reference output that corresponds to the spectrum being swept. To provide leveled power at the 8705A RF output ports, a detector operating from a wideband coupler in the 8705A provides an ALC signal for sweep oscillator leveling circuits.

Frequency band selection is controlled by front panel pushbuttons on the 8706A Control Unit or by remote contact closure. Selection of the RF output port may be made by 8705A front panel pushbuttons or by binary logic signals from a computer operating the 8705A logic conversion and switching circuits.

Specifications, 8705A

Switching time between ports: 40 ms.

Frequency range: dc to 12.4 GHz.

Output port reflection coefficient: ≤0.25 (VSWR ≤1.67).

Input port reflection coefficient: ≤0.15 (VSWR ≤1.35).

Insertion loss: 3 dB.

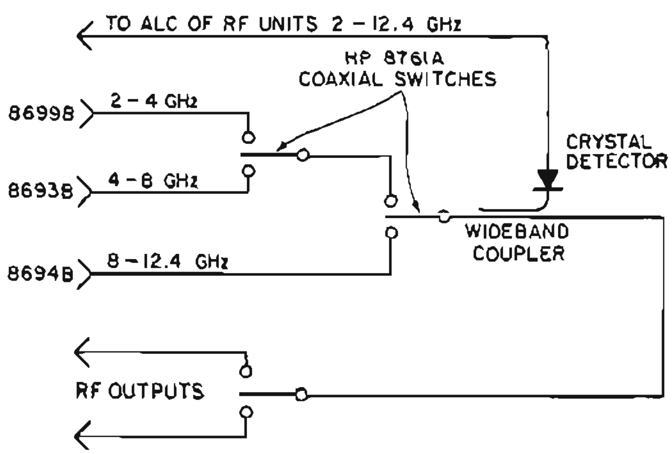
Connectors: type N, stainless steel; other optional.

Power: 115 or 230 V, 8 W.

Weight: approximately 20 lb (9 kg).

Dimensions: 3¼″ high, 16¾″ wide, 18⅜″ deep (8,3 x 42,3 x 46,5 cm).

Price: $1,750.



An example of signal path for 8705A Signal Multiplexer used with Model 8410 Network Analyzer over the full band 0.1 to 12.4 GHz.

DISTORTION ANALYZERS

The goal of audio and communications equipment is to reproduce input signals faithfully at the output. System nonlinearity distorts the waveshape of the signals. Poor reproduction brought about by distortion will appear to the user of audio equipment as a change in the quality or as noise; to the user of communications gear, it appears as channel crosstalk.

Distortion in amplifiers, created by nonlinear circuits, consists of components present in the output that are not contained in the input signal. Distortion in a sine-wave signal source consists of frequency components that exist in the output in addition to the fundamental frequency. An ac signal that appears to be a pure sine wave as viewed on an oscilloscope (Figure 1) may have some harmonic distortion. The total of these frequency components present in the signal in addition to the fundamental frequency can be measured quickly and easily with Hewlett-Packard distortion analyzers.

One type of distortion analyzer contains a narrow-band rejection filter which, when properly tuned, removes the fundamental frequency so that the amplitude of the remaining components can be measured simultaneously. HP distortion analyzers are used for fast quantitative measurements of total harmonic distortion and noise.

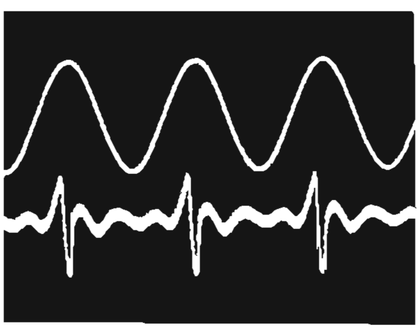


Figure 1. Output signal of nonlinear system, with the fundamental filtered out, is the lower trace on the oscilloscope screen. The residual output shows that a seemingly pure sine wave does in fact contain harmonics.

Total harmonic distortion analysis

This measurement technique compares the amplitude of the harmonics to that of the original signal at the output, where the original signal becomes the fundamental frequency of the harmonics. The defining equation is

(1)

$$\text{total harmonic distortion} = \frac{\sqrt{\Sigma(\text{harmonics})^2}}{\text{fundamental}}$$

A frequency-selective voltmeter is needed to measure the fundamental and either a selective voltmeter with a wide dynamic range or a frequency rejection circuit with a true rms detector to measure the harmonics. The frequency rejection circuit nulls the fundamental and passes its harmonics to the detector with no attenuation, so the ratio between the fundamental and harmonics can be determined.

A less expensive way to measure the total harmonic distortion, however, is to use a rejection filter and a broadband detector. Since the fundamental is not directly measured, the equation becomes

(2)

$$\text{THD} = \frac{\sqrt{\Sigma(\text{harmonics})^2}}{\sqrt{(\text{fundamental})^2 + (\text{harmonics})^2}}$$

If the distortion is less than 10%, the denominator of equation 2 will be within ½% of the denominator in equation 1, which is as accurate as any frequency selective voltmeter.

There are two difficulties in making total harmonic distortion measurements. First, to get a measurement within the desired accuracy, the harmonic content of the test signal must be not more than a third of the distortion expected to be caused by the system. Second, the chore of nulling the fundamental can be time-consuming. Oscillators that meet the distortion requirements and automatic nulling equipment, which has recently become available, can overcome the difficulties.

Automatic null

Since the nulling of the fundamental is normally the time-consuming portion of total harmonic distortion measurement, great savings can be realized, especially in production line testing with an analyzer which automatically rejects the fundamental. The time saved is as much as 25 seconds of a 30-second measurement. With automatic nulling, the accuracy of the null achieved is no longer a function of operator training, manual dexterity or signal source frequency drift.

Automtaic nulling circuitry in Hewlett-Packard distortion analyzers, the H-P 333A and 334A, operates on the principle that the fundamental at either side of a Wien bridge off null follows well-known phase relationships.

In this instrument, (Figure 2) phase-sensitive feedback loops are employed which drive photocells in parallel with the resistances on either side of the bridge. These loops reject the fundamental and are not critical to adjust, since any imbalance on one side of the bridge is automatically compensated for on the other. Imbalances on either side cause phase errors in the fundamental which are in quadrature, so the phase-sensitive feedback loops are independent of each other.

The analyzer will maintain a null even though there is a slow drift in the input frequency. This ability to "pull" the null has

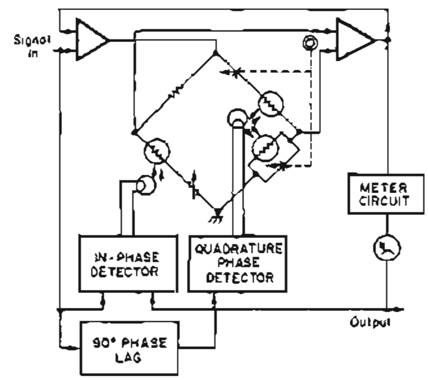


Figure 2. Rejection amplifier with automatic nulling circuitry. Phase detectors sense bridge unbalance and control intensity of lamps to change resistance of photoconductors, thus adjusting bridge to reject fundamental frequency of input signal.

opened the door to a number of applications where the total harmonic distortion measurements were not readily applied in the past. Among them are:

1. Single-frequency production line testing of such components as integrated-circuit amplifiers or transformers. As long as the long-term drift of the signal source is less than ±1%, a good null will be achieved.

2. Optimizing the performance of an oscillator. Here, any variation in the parameters causes the frequency to shift slightly. The automatic nulling of the analyzer allows the oscillator performance to be improved on a continuous basis rather than by relying on a point-to-point check which may or may not find the optimum point.

3. Correcting distortion in signal generators which produce sine waves by mixing or by non-linear shaping. The small frequency shifts would cause the loss of the null if it were not for the automatic null feature.

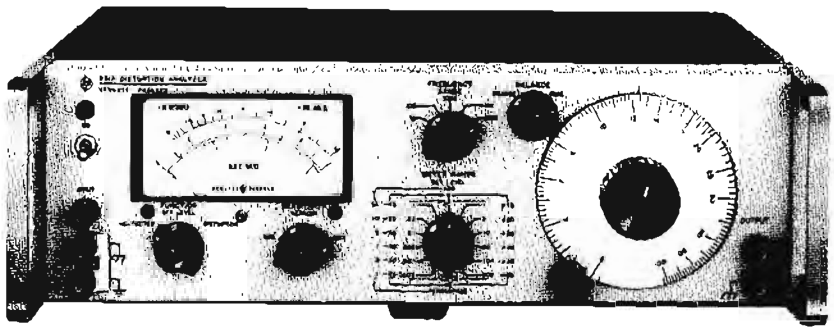
Selecting an analyzer

Distortion Analyzers may be regarded as the inverse of wave analyzers. Distortion analyzers *remove* any signal component to which they are tuned, having the rest of the signal for measurement. In practice, distortion analyzers are tuned to the fundamental frequency and, by measuring the amplitude of the remaining harmonic components all at once, they provide an indication of percentage total harmonic distortion. Distortion analyzers do not provide information about individual distortion products—Wave Analyzers (See page 437) and Spectrum Analyzers (See page 448) do this job, but they do not provide fast readings of the signal's total departure from sine wave purity.

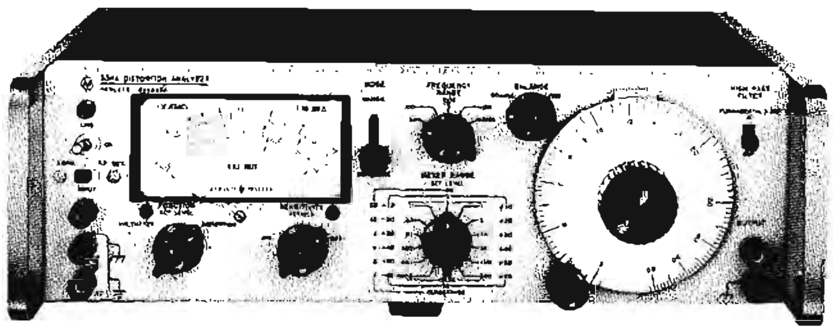
DISTORTION ANALYZERS

Manual or auto tuned; FCC approved

Models 331A, 332A, 333A, 334A



331A



334A

Description

Distortion Analyzers have gone solid-state, offering extended tuning range, greater set-level sensitivity, improved selectivity and greater overall accuracy. The Model 331A, 332A, 333A, 334A Distortion Analyzers measure total distortion down to 0.1% full scale at any frequency between 5 Hz to 600 kHz; harmonics are indicated up to 3 MHz. These instruments measure noise as low as 50 microvolts, and measure voltages over a wide range of level and frequency. All four models may be used as sensitive wide-range transistorized voltmeters for general-purpose voltage and gain measurements. The transistorized ac voltmeter provides 13 ranges from 300 μV to 300 V rms full scale.

Automatic fundamental nulling

Automatic fundamental nulling (available in HP Models 333A and 334A) speeds up the normally time-consuming portion of the measurement. This is done by manually nulling with the coarse tuning and balance controls to less than 10% of the Set-Level Reference. The automatic mode is used to complete rejection of the fundamental on more sensitive ranges without any further manual tuning.

Amplitude modulation detector

The HP Models 332A, H05-332A, 334A and H05-334A Analyzers are provided with an amplitude modulation detector having a frequency range from 550 kHz to greater than 65 MHz.

The high-impedance dc restoring peak detector which utilizes a semiconductor diode measures distortion at carrier levels as low as 1 V. The input to the detector is located on the rear of the instrument. The Model 334A is similar to Model 332A, but is provided with Automatic Fundamental Nulling and a High-Pass Filter.

The H05-332A and H05-334A meet FCC requirements on broadcast distortion levels. Both models measure total distortion down to 0.1% full scale. The Model H05-334A features automatic fundamental nulling. The H05-332A and 334A have a switchable low pass filter to reduce the effect of unwanted high frequencies (noise, etc.) when measuring lower frequency signals with high accuracy.

High-pass filter

In order to reduce the effect of hum components, a high-pass filter is provided which attenuates frequencies below 400 Hz. The filter may be activated by a front-panel switch when measuring distortion of signals greater than 1 kHz in frequency.

Models And Available Features

Model No.	Automatic Fundamental Nulling	Hi-Pass Filter	Lo-Pass Filter	AM Detector	Gear Reduction Tuning
331A					X
332A				X	X
H05-332A			X	X	X
333A	X	X			
334A	X	X		X	
H05-334A	X		X	X	

Optional, for each model, features VU meter characteristics conforming to FCC requirements.

Option 01, for each model, features VU meter characteristics conforming to FCC requirements.

Specifications

Model 331A

Distortion measurement range: any fundamental frequency, 5 Hz to 600 kHz. Distortion levels of 0.1%-100% are measured full scale in 7 ranges.

Distortion measurement accuracy

Harmonic measurement accuracy (full scale)

Fundamental Input Less Than 30 V

Range	±3%	±6%	±12%
100%-0.3%	10 Hz-1 MHz	10 Hz-3 MHz	
0.1%	30 Hz-300 kHz	20 Hz-500 kHz	10 Hz-1.2 MHz

Fundamental Input Greater Than 30 V

Range	±3%	±6%	±12%
100%-0.3%	10 Hz-300 kHz	10 Hz-500 kHz	10 Hz-3 MHz
0.1%	30 Hz-300 kHz	20 Hz-500 kHz	10 Hz-1.2 MHz

Elimination characteristics

Fundamental rejection >80 dB.

Second harmonic accuracy for a fundamental of:
5 to 20 Hz: better than +1 dB.
20 Hz to 20 kHz: better than ±0.6 dB.
20 kHz to 100 kHz: better than −1 dB.
100 kHz to 300 kHz: better than −2 dB.
300 kHz to 600 kHz: better than −3 dB.

Distortion introduced by instrument: <0.03% from 5 Hz to 200 kHz; <0.06% from 200 kHz to 600 kHz.
Meter indication is proportional to the average value of a sine wave.

Frequency calibration accuracy
Better than ±5% from 5 Hz to 300 kHz.
Better than +10% from 300 kHz to 600 kHz.

Input impedance: distortion mode: 1 MΩ ±5% shunted by less than 70 (*90) pF (10 MΩ shunted by <10 pF with HP 10001A 10:1 Divider Probe).

Voltmeter mode: 1 MΩ ±5% shunted by <30 (*50) pF 1 to 300 V rms; 1 MΩ ±5% shunted by <70 (*90) pF, 300 μV to 0.3 V rms.

Input level for distortion measurements: 0.3 V rms for 100% set level or 0.245 V for 0 dB set level. (Up to 300 V may be attenuated to set-level reference.)

DC isolation: signal ground may be ±400 V dc from external chassis.

Voltmeter range: 300 μV to 300 V rms full scale (13 ranges) 10 dB per range.

Voltmeter accuracy: (Using front panel input terminals.)

Range	±2%	±5%
300 μV	30 Hz-300 kHz	20 Hz-500 kHz
1 mV-30 V	10 Hz-1 MHz	5 Hz-3 MHz
100 V-300 V	10 Hz-300 kHz	5 Hz-500 kHz

Noise measurements: voltmeter residual noise on the 300 μV range: <25 μV rms, when terminated in 600 ohms, <30 μV rms terminated with a shielded 100 k ohm resistor.

*With rear input modifications.

Output: 0.1 ±0.01 V rms open circuit and 0.05 ±0.005 V rms into 2 kΩ for full scale meter deflection.

Output impedance: 2 kΩ.

Power supply: 115 or 230 volts ±10%, 50 to 400 Hz, approximately 4 watts. Terminals are provided for external battery supply. Positive and negative voltages between 30 V and 50 V are required. Current drain from each supply is 40 mA.

Model 332A

Same as Model 331A except as indicated below:

AM detector: high impedance dc restoring peak detector with semiconductor diode operates from 550 kHz to greater than 65 MHz. Broadband input, no tuning is required.

Maximum input: 40 V p-p ac or 40 V peak transient.

Distortion introduced by detector: carrier frequency: 550 kHz-1.6 MHz: <50 dB (0.3%) for 3-8 V rms carriers modulated 30%. 1.6 MHz-65 MHz: <40 dB (1%) for 3-8 V rms carriers modulated 30%.

NOTE: distortion introduced at carrier levels as low as 1 V is normally <40 dB (1%) 550 kHz to 65 MHz for carriers modulated 30%.

H05-332A: same as 332A except low-pass filter is added (4 pole, 3 dB down at 30 kHz); meter reads in dBm.

Model 333A

Same as Model 331A except as indicated below:

Automatic nulling mode
Set level: at least 0.2 V rms.
Frequency ranges: X1, manual null tuned to less than 3% of set level; total frequency hold-in ±0.5% about true manual null. X10 through X10 k, manual null tuned to less than 10% of set level; total frequency hold-in ±1% about true manual null.

Automatic null accuracy
5 Hz to 100 Hz; meter reading within 0 to +3 dB of manual null. 100 Hz to 600 kHz; meter reading within 0 to +1.5 dB of manual null.

High-pass filter: 3 dB point at 400 Hz with 18 dB per octave roll off. 60 Hz rejection >40 dB. Normally used only with fundamental frequencies greater than 1 kHz.

Power supply: same as Model 331A except current drain from each supply is 80 mA.

Model 334A

Same as Model 333A except includes AM Detector described under Model 332A.

H05-334A: same as 334A except a low-pass filter is substituted for the high-pass filter; meter reads in dBm.

General

Weight: net 17¾ lbs (8 kg); shipping 26 lbs (11,8 kg).

Dimensions: 16¾" wide, 5" high (without removable feet), 13¼" deep (426 x 126 x 337 mm).

Accessories furnished: rack mounting kit for 19" rack.

Price: HP 331A, $650; HP 332A, $680; HP 333A, $865; HP 334A, $895; H05-332A, $890; H05-334A, $980.

Option 01, indicating meter has VU characteristics conforming to FCC requirements for AM/FM and TV broadcasting; add $15.

What is a wave analyzer?

A wave analyzer can be thought of as a finite bandwidth window filter which can be tuned throughout a particular frequency range.

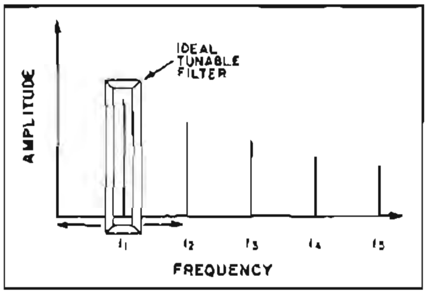


Figure 1. Wave Analyzer Tunable Filter.

Signals located on the frequency spectrum will be selectively measured as they are framed by the window. Thus, for a particular signal, the wave analyzer can indicate its frequency (window position) and amplitude. Amplitude is read on an analog meter; frequency is read on either a mechanical or electronic readout.

Wave analysis measurement techniques were introduced some twenty-five years ago and are used more today than ever before. Continued improvement in sensitivity and dynamic range along with frequency resolution has opened many new application areas.

Today's wave analyzer measurements can be divided into three broad areas:

1. Selective measurements of signals with large differences in level. Examples are distortion analysis, measurements of low level signals very close in frequency to much larger signals, or identification of low level signals obscured by broadband noise.
2. Determination of noise characteristics (noise/$\sqrt{Hz}$) by utilizing the well-defined bandwidth of a wave analyzer. Noise power spectral density can also be measured over the entire frequency range of the instrument.
3. Frequency response testing, using the tracking output as an excitation source to make tests at ultra-low threshold levels. The wave analyzer's high sensitivity eliminates harmonics, spurious responses and ground loop effects.

Each generation of wave analyzers has seen increasingly useful improvements. First, there was the basic tunable filter and broadband voltmeter. Now there are features such as autoranging, automatic frequency control (AFC), electronic sweeping, counter digital readout, selectable bandwidths, and recorder outputs. These convenience and performance features make the instrument easy to use, but they are not the only considerations in selecting a wave analyzer.

The selectivity of a wave analyzer is its greatest asset and a most important specification. Selectivity is defined by the 3 dB bandwidth and the shape factor of the bandpass. The smaller the shape factor number, the more selective the instrument will be. Note the passband (dotted line) in Figure 2. Specifying just the 3 dB bandwidth (bandwidth C) can be misleading—but specifying the ratio of two selected bandwidths (usually −3 or −6 dB and the −60 dB points) provides further definition of the sharpness of the skirt (solid line in the diagram).

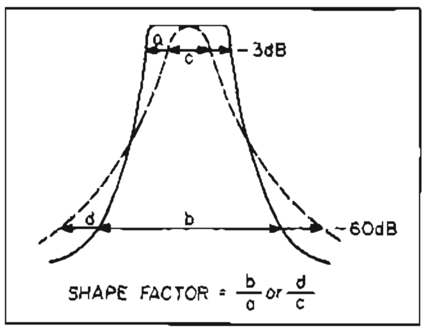


Figure 2. Shape factors for different wave analyzers.

A shape factor so defined gives a true picture of the bandpass. Today's wave analyzers have shape factors as low as 2:1. These are especially useful in making critical frequency measurements where signal density is high.

Dynamic range is an important wave analyzer characteristic. It defines the range of the smallest to the largest signal the instrument can accommodate simultaneously. Some wave analyzers are capable of an 85 dB range. The relationship between dynamic range and attenuator range is shown in Figure 3. The top end of the attenuator range is limited by the amount of attenuation built-in, and the bottom end by the instrument's sensitivity. Dynamic range is limited by nonlinearities and noise.

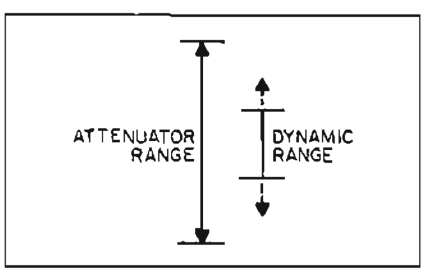


Figure 3. Relationship between attenuation and dynamic range.

Wave analyzers designed with two attenuators allow tracking of the dynamic range of the input. This helps to avoid input overloading that causes measurement inaccuracies. Autoranging further extends the capability of a wave analyzer to track the dynamic range of the input.

To obtain high sensitivity measurements without loading a low-level circuit under test, a wave analyzer with high input impedance is necessary. There is always a trade-off between high sensitivity and high input impedance. Trade-off optimization depends on the application. Input impedances range from 10 kΩ to 1 MΩ while full scale sensitivities range from 3 μV to 50 μV.

Hewlett-Packard wave analyzers cover a broad frequency range from 20 Hz up to 22 MHz. The 3590A covers the audio range plus the RF range to 620 kHz. The 302A covers the audio range and frequencies to 50 kHz. The 310A provides coverage in the video range, 1 kHz to 1.5 MHz. The 312A extends the coverage to 18 MHz in 18 overlapping bands (22 MHz with the H01-312A). This analyzer is useful for testing multiplex communications systems, IF and video amplifiers, filters and attenuators. Each Hewlett-Packard wave analyzer contains special features which adapt it to specific uses. Many features are included for ease of operation, accuracy of readings and ability to compare signals of great variation in amplitude. The selective bandwidths, the shape factor of these bandwidths and the dynamic range (from 72 dB to greater than 85 dB) enhance the use of these wave analyzers. The following individual description of each instrument enlarges upon the features contained by each model.

Model 3590A

The new 3590A Wave Analyzer measures the frequency components of simple or complex signals over an extremely wide amplitude range—more than 85 dB—without manual range switching. Automatic ranging makes successive measurements of all signal components quick and easy. It also gives the instrument ability to make linear dB recordings over the full 85 dB dynamic range. No time is lost making the many up-and-down range changes usually required with wave analyzers when signal components have widely differing amplitudes.

The 3590A also has a wide frequency range; it tunes from 20 Hz to 620 kHz in two overlapping ranges (20 Hz to 62 kHz and 500 Hz to 620 kHz).

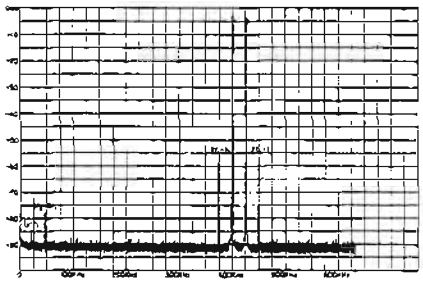


Figure 4. Recording shows the intermodulation distortion products of an amplifier driven by signal f_1 and f_2.

Wide range recorder outputs

Of particular importance, the new Wave Analyzer has both logarithmic and linear dc outputs to drive the X and Y axes of recorders. One Y-axis output is linearly proportional to the measured voltage amplitude and the second output is proportional to the logarithm of the measured amplitude (linear dB). This voltage spans the instrument's more-than-85 dB dynamic range, making this the first wave analyzer to provide a wide-range output suitable for driving all kinds of recorders. With the built-in electronic sweep tuning, a full frequency range plot is easily made of the spectral frequency distribution. Also, frequency response recordings can be made over the entire 85 dB dynamic amplitude range. In addition, the front-panel meter can be switched to read the logarithmic Y-axis voltage, thus displaying amplitude over the full dynamic range on a single, linear, 0 to −90 dB scale. This simplifies reading interpretation when many different amplitude levels are involved.

For driving the X-axis of recorders, another output supplies a voltage proportional to the instrument's tuning. This output can be linearly proportional to frequency, generating X-Y recordings with a linear frequency scale on which harmonic relationships are determined easily. Alternatively, the output can be switched to make the output voltage logarithmically proportional to frequency. With the logarithmic X and Y outputs, wide-range frequency response measurements can be made on the familiar semilog paper (See Figure 5), enabling Bode plots of amplifier or filter frequency response to be made directly. If one wishes, recordings can be made with any combination of linear and logarithmic axes (log-log, lin-log, log-lin, lin-lin).*

*Lin-lin or log-lin plots can also be made with a strip-chart recorder, which supplies a linear X-axis.

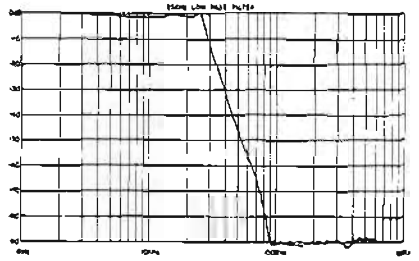


Figure 5. Bode plots can be recorded directly by sweeping and stimulating the device under test with the 3590's internal tracking output (BFO) and using the log-log recorder outputs.

The new generation

The new Hewlett-Packard Model 3590A Wave Analyzer is easier to use than previous instruments. Annunciator lights show overall sensitivity in response to settings of both the interstage range switch and the input attenuator. In the automatic mode, the interstage ranges are switched automatically, with the annunciator lights showing the selected interstage dB range and the overall voltage sensitivity. Meter scales are backlighted to show which scale is in use.

Frequency is likewise easy to read on this new instrument. Frequency readout is in plug-ins, one of which contains a 5-digit electronic counter. The counter measures the tuning frequency with an accuracy of better than 0.001%, with 10 Hz resolution on the 200 Hz-to-620 kHz frequency range and with 1 Hz resolution on the 20 Hz-to-62 kHz range. The counter also supplies instantaneous readings of frequency as the instrument sweeps.

Where 5-digit resolution is not required in frequency measurements, a second plug-in has a mechanical 3-digit-plus-vernier readout. This gives frequency readout with 1% accuracy and with 100 Hz resolution on the high range and 10 Hz resolution on the low range. Should higher resolution and accuracy be desired on some occasion, an external electronic counter can be used to read the "restored frequency" output, an amplified replica of the selected input signal component, available at a front-panel connector.

The instrument tunes easily. It is only necessary to approach the correct tuning, and an automatic frequency control (AFC) circuit then "pulls in" the selected component. The AFC circuit slaves the instrument's tuning to any signal component within the passband, making it possible to use very selective filters without danger of signals drifting out of the tuning "window" before an accurate amplitude measurement can be made. Should the AFC circuit become unlocked, a front panel lamp alerts the operator that his reading may not be valid.

Selectable bandwidths

The instrument has four selectable bandwidths. The 10 Hz bandwidth, for use on the 20 Hz - 62 kHz range, separates closely-spaced frequency components, but requires more careful tuning of the instrument. A 100 Hz bandwidth allows easier tuning where selectivity is not so important, and a 1000 Hz bandwidth permits wide range sweeps at faster rates. The fourth bandwidth is 3100 Hz useful when one wishes to measure a complete multiplexed telephone voice channel or other similar communications channels.

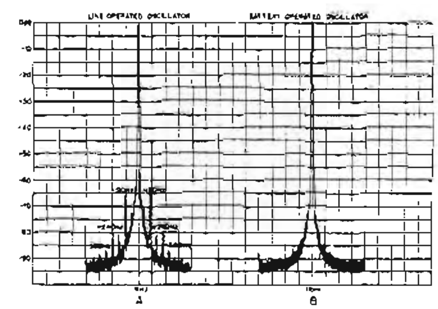


Figure 6. Line-frequency related FM sideband detection is accomplished by using the 3590A's 10 Hz bandwidth. Note that no sidebands are generated by the analyzer.

Bandwidth shape factor (ratio of bandwidth at −60 dB to bandwidth at −3 dB) is a very low 3.5:1, indicating that the analyzer's passband has very steep skirts. Bandwidth shape factor is more important for highly selective measurements than a simple expression of 3 dB bandwidth. Crystal filters, for instance, typically have shape factors of 10:1 or greater, making separation of closely-spaced frequencies more difficult.

Electronic tuning

The instrument is tuned electronically, simplifying frequency sweeping. Five sweep rates (1, 10, 100, 1000, and 3100 Hz/s) are provided, so the operator can select the optimum trade-off between sweep rate and bandwidth. A front-panel indicator lights if the sweep rate is too fast for the bandwidth selected (narrow-band filters do not respond quickly enough if the sweep rate is too fast). The instrument sweeps upward to the top of the range from the start frequency selected by the tuning control.

Programmed tuning by an externally-supplied dc voltage is possible because of the electronic tuning. And where extreme precision is desired, another input allows a frequency synthesizer or other frequency source to serve as the Wave

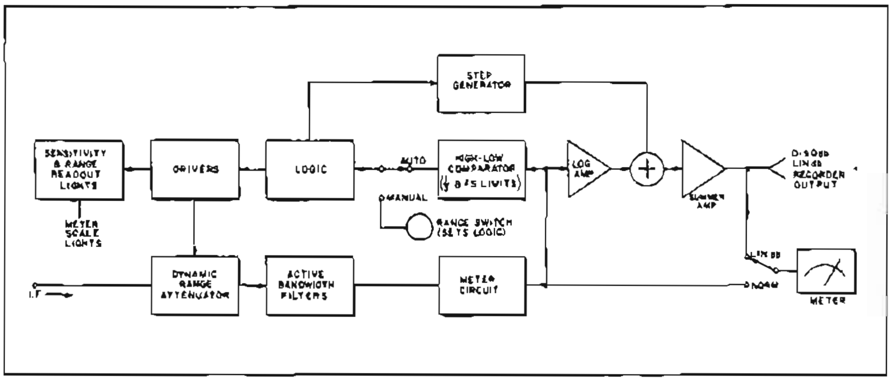


Figure 7. The HP 3590A Wave Analyzer provides automatic ranging of the signal amplitude and allows 0 to −90 dB meter display and recorder output.

Analyzer's local oscillator. (The 3592A, a low-cost plug-in without a local oscillator, is available if the analyzer is to be used only with an external oscillator or as a frequency slave to another analyzer.)

Automatic ranging

The input to the autoranging circuit originates from the output of the meter circuit. When autoranging is turned on, the signal goes to the high-low comparator which samples the signal to determine if its level is between 1/3 and full scale (Figure 7). If the signal is too high or too low, the comparator sends a digital command to the logic circuit which in turn triggers the drivers. The drivers are responsible for switching the dynamic range attenuator reed relays and driving the readout lights on the front panel.

Linear dB output

As a by-product of the autoranging, linear dB outputs to the meter and recorder log output have been made possible. The entire dynamic range can be presented linearly from 0 dB to −90 dB on one scale.

Information in the form of a dc analog signal is taken from the meter circuit output and supplied to the log amplifier. The amplifier logarithmically shapes the linear volts signal into a linear dB signal from 1/3 scale to full scale (10 dB) and −70 dB to −90 dB on the −70 dB range. When autoranging is on, the log amplifier output has ranging discontinuities due to switching of the attenuator reed relays. To avoid the range discontinuities, a step generator, triggered by the autoranging logic circuit, is used to supply a dc step offset to compensate for the range change at the output of the log amplifier.

Special outputs

As in other Hewlett-Packard wave analyzers, the new Model 3590A has a "BFO" output. This is a constant level signal which tracks with and is controlled by the instrument's tuning. The BFO output is useful as a test stimulus, enabling the wave analyzer to serve as both the signal generator and the measuring voltmeter in frequency response measurements on amplifiers, filters, and the like. The advantage of this arrangement is that the narrowband response of the wave analyzer removes any noise and distortion products from the measurement, products which could affect accuracy if a separate broadband voltmeter were used. Furthermore, the "voltmeter" tuning always tracks the "generator" frequency since both are tuned by the same control.

Other modes of operation in the new Wave Analyzer are slanted toward communications usage. There is a carrier reinsertion oscillator to detect either upper sideband (USB) or lower sideband (LSB) single-sideband signals. There is also an AM detector.

Another version of the new Wave Analyzer is identical to the Model 3590A except that the input is designed for communications system test and analysis. The input of this one (Model 3591A) can bridge a communication line or it can terminate it. A front panel switch selects the input impedance, — 75, 135, 150, or 600Ω terminated or 100 kilohms bridged. In addition, the impedance selector switch adjusts the instrument's gain so that amplitude can be read in dBm directly, regardless of the input impedance selected.

Model 302A

The 302A Wave Analyzer is a tunable voltmeter covering the frequency range of 20 Hz to 50 kHz. The frequency scale is linear throughout the band with a constant resolution of a division per 10 Hz. It can be used as a tuned voltmeter which will read absolute or relative levels. The 7 Hz bandwidth permits the separation of closely spaced signals.

The automatic frequency control used in all Hewlett-Packard wave analyzers greatly facilitates wave analysis. With the 7 Hz passband of the 302A, a slightly unstable input signal could easily drift out of the passband during measurement. The automatic frequency control locks the analyzer's tuning to the frequency of the signal component so that measurements are not affected by drift in the source signal.

Semi-automatic plots of amplitude vs frequency can be made with the 302A or 310A in the BFO operation by using the 297A Sweep Drive unit and an X-Y recorder.

Model 310A

The 310A Wave Analyzer is a tunable voltmeter covering the frequency range of 1 kHz to 1.5 MHz. This wave analyzer offers a front panel selection of three bandwidths: 200 Hz for maximum resolution; 1000 Hz to simplify calculations of noise power/Hz measurements; and 3000 Hz for operation of the wave analyzer as a receiver. In this mode, IF bandwidth is sufficient to recover voice modulation from either standard AM or single sideband systems (a carrier reinsertion oscillator is provided to permit detection of either normal or inverted single sideband transmissions).

The 310A Wave Analyzer features a wide dynamic range (−75 dB) over the entire frequency band, automatic frequency control, high sensitivity and a restored frequency output.

Models 312A/313A

The 312A Wave Analyzer is a tuned voltmeter with selectable bandwidths of 200 Hz, 1000 Hz and 3000 Hz. The operating frequency range is 10 kHz to 18 MHz in 18 overlapping bands (to 22 MHz with the H01-312A). Using the narrowest bandwidth, the instrument will function down to 1 kHz. With these bandwidths and frequencies, the 312A can be used for communication system measurements including long haul coaxial cable carriers. The 312A can be used for measurements of harmonics, intermodulation distortion, and crosstalk. It is a sensitive detector for bridge measurements, and with the use of the 313A Tracking Oscillator it will measure frequency vs amplitude for response curves of IF amplifiers, attenuators, and crystal-filter circuits.

In addition the operation of the 312A is simple and is enhanced by logical panel layout. The digital readout indicates the frequency of the center of the passband with 10 Hz resolution.

For maximum flexibility, the 312A input may be operated either balanced or unbalanced. In the terminated mode, the input signal is terminated in a selectable impedance of 50, 60, 75, 124, 135, 150, or 600 ohms. The meter indicates power in dBm absorbed by the selected impedance. In the bridged mode, the input impedance is 20 kΩ balanced and 10 kΩ unbalanced. In the bridging mode, the meter can indicate dBm according to the impedance selected, or it can indicate voltage by selecting the volts calibrated position of the impedance selector switch.

The high impedance 11530A Probe also can be used for bridging measurements to eliminate the loading effects.

The input signal enters the instrument through either the bridged-terminated connector or the probe connector. The probe contains a unity-gain isolation amplifier at the end of a cable. The BAL/UNBAL switch grounds one end of the input terminal in the unbalanced position.

In the heterodyning process of the 312A, the local oscillator uses a synthesis technique stabilized by a 1 MHz crystal timebase oscillator. The output of this local oscillator is mixed with the input frequency to form a 30 MHz intermediate frequency for uniform amplification. The signal is then divided into two channels, shifted in phase and mixed with a 30 MHz crystal oscillator input, resulting in information centered on a zero frequency. Both of these quadrature channels contain three cascaded lowpass filter-amplifiers which produce a flat response within the passband with symmetrical slopes of 72 dB per octave beyond cutoff. These two channels are mixed with two 250 kHz carriers and phased so that the difference frequency is obtained. The resultant is amplified and detected to drive the meter. The AFC circuit keeps the input frequency centered in the passband, and a decade counter is designed to read the center frequency of the passband.

The single sideband detector circuit consists of an upper sideband carrier reinsertion crystal oscillator which operates at 248.2 kHz and a lower sideband oscillator which operates at 251.8 kHz. A product detector and appropriate switching provide for the demodulation of upper and lower sidebands when using the 3 kHz bandwidth for both aural and recorder purposes. The analyzer also detects AM signals.

The 313A Tracking Oscillator complements the 312A Wave Analyzer in making distortion checks, loop gain measurements and analyzing frequency response characteristics. The 313A has two modes of operation, a track 312A mode and a free-running internal mode. In the track 312A mode of operation, the 313A utilizes the 30 MHz crystal oscillator and the local oscillator from the 312A to obtain a beat frequency at the tuned frequency of the 312A. In the internal mode of operation, the 313A uses its own internal local oscillator and 30 MHz crystal oscillator for adjustable frequencies from 10 kHz to 22 MHz in one single band. Any 313A Tracking Oscillator can be used with any 312A Analyzer. Output levels from +10 dBm to −99.9 dBm are available adjustable in 10, 1 and 0.1 dB steps.

An important feature of the 313A Tracking Oscillator is its meter expand function. Any 2 dB range of the 312A meter indication from −7 to +3 dB can be expanded for full-scale coverage. This is accomplished by using the 312A recorder output and placing the 313A meter mode switch to 312A expand position.

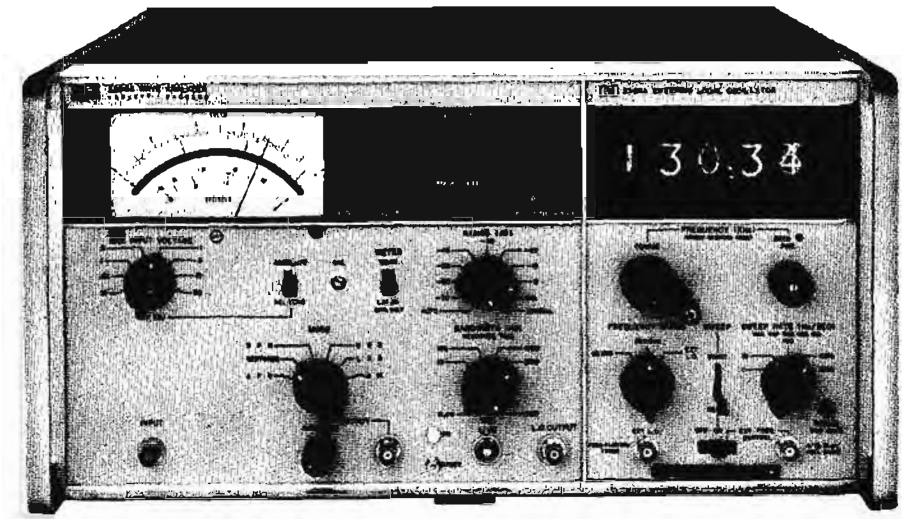
The standard 312A and 313A have a high frequency of 18 MHz while the H01-312A and 313A have a high frequency of 22 MHz. Specifications for special instruments, page 325, give differences in connectors and impedance. Table 1 summarizes the basic specifications of HP wave analyzers.

Table 1. HP wave analyzers.

HP wave analyzers	Frequency range	Selective bandpasses	Dynamic range Absolute	Relative	Freq readouts	Type of inputs	Type of outputs	Modes of operation
302A (p. 444)	20 Hz to 50 kHz	7 Hz	30 μV–300 V full scale	>75 dB	dial	banana jacks	rec: 1 mA dc into 1500Ω full scale BFO: 2 V open circuit, meter at full scale	AFC, normal, BFO
3590A/ 3594A (p. 441)	20 Hz to 620 kHz	10 Hz 100 Hz 1000 Hz 3100 Hz	3 μV–30 V full scale	>85 dB	5-place digital	BNC unbalanced	rec: X and Y axes log and linear. BFO: to 1 V rms. L.O.: (1.28 MHz–1.9 MHz) 0.65 V rms.	AFC, restored, BFO, USB, LSB, AM sweep
310A (p. 445)	1 kHz to 1.5 MHz	200 Hz 1000 Hz 3000 Hz	10 μV–100 V full scale	>75 dB	dial	banana jacks	rec: 1 mA dc into 1500Ω full scale BFO: 0.5 V open circuit, meter at full scale output impedance 135Ω	AFC, normal BFO, USB, LSB AM
312A/ 313* (p. 446)	10 kHz to 18 MHz 18 ranges	200 Hz 1000 Hz 3000 Hz	3 μV–3 V full scale or −97 to +23 dBm −107 to +13 dBm (600Ω only)	>72 dB	7-place decade counter	probe 11530A bridged/ terminated balanced or unbalanced	rec: 1 V dc full scale 1 kΩ source aux: 1 MHz (1 V p-p) 30 MHz (40–60 mV) rms L.O. (30–48 MHz) 60 to 80 mV rms audio: −5 V into 10 kΩ 313A: Track or tuned 75Ω unbalanced, −99.9 to +10 dBm	AFC, AM, beat LSB, USB
3591A/3594A (p. 324)		Same as 3590A/3594A except input bridged/terminated bal. or unbal. and modified input circuitry.						
H01-312A/313A (p. 447)		Same as 312A except 10 kHz to 22 MHz and WE-477B input unbalanced.						
H05-312A/313A (p. 325)		Same as H01-312A except 50Ω unbalanced input with BNC connector.						

*313A Option 01, 50Ω unbalanced output.

PLUG-IN WAVE ANALYZER
85 dB dynamic range; electronic sweeping
Model 3590A



3590A/3594A

Description

The Hewlett-Packard Model 3590A Wave Analyzer offers automatic, state-of-the-art detection of signal amplitude and frequency information. Over a frequency range of 20 Hz to 620 kHz, the analyzer can separate frequency components of an input signal to locate the fundamental, harmonics, intermodulation products, or any other signals present in the spectrum. Selectable bandwidths of 10, 100, 1000 and 3100 Hz permit easy location of signals and separation of closely spaced components. Operation has been greatly simplified by automatic amplitude ranging and electronic sweeping. X-Y recorder outputs permit frequency spectrum recordings to be made covering the entire frequency range with a linear dB amplitude display of 90 dB.

Automatic operation

The 3590A features automatic amplitude ranging and electronic sweeping. During autoranging, the analyzer maintains a meter indication between one-third and full scale, except on the lowest range where the meter can go to zero. Once the input voltage level is adjusted for a proper input level, the autoranging will step through the entire dynamic range in eight 10 dB steps.

Electronic sweeping is simple to use and permits X-Y recordings to be made quickly and easily. Operation involves selecting one of five sweep rates, tuning to a start frequency, and starting the sweep. Maximum sweep time is 620 s, or until the end of the frequency range is reached.

Measurement performance

The key measurement characteristics of the 3590A are 85 dB of dynamic range, 3 μV full-scale sensitivity, 10 Hz to 3.1 kHz bandwidths with a constant factor of 3.5, and 1 Hz frequency resolution. Significant features include warning lights, direct range readout, automatic ranging, electronic sweep, remote tuning, linear 0 to 90 dB meter display, and meter scale lights. High performance combined with maximum operational ease enables the analyzer to make distortion, filter, noise, side band, and spectrum measurements previously unattainable.

Generator-receiver

Besides being a waveform analyzer, the 3590A is also extremely effective as an oscillator-tracking detector combination. By using the BFO output, an operator can stimulate a device under test and detect responses at the analyzer input over a 20 Hz-to-620 kHz range. The BFO output and the analyzer input track together and follow the frequency setting. This feature is particularly useful for measuring transmission and rejection characteristics of systems and filters. Because the analyzer selectively measures only the fundamental of the input signal, distortion products and noise will have negligible effect on the reading accuracy.

Dynamic range

The 3590A's >85 dB of dynamic range can be referenced to 0 dB from 30 V to 10 mV. 86 dB below 10 mV corresponds to .5 μV. Presentation of the dynamic range up to 90 dB can be displayed in linear dB on the third meter scale. Lights behind the meter face indicate the proper scale to be read to help eliminate erroneous scale readings.

Selectable bandwidths

Bandwidths of 10, 100, 1000 and 3100 Hz can be selected from the front panel. Active filtering is used to provide flat passbands with steep skirts. All bandwidths have a 1 Hz rejection notch at midpoint for precise frequency determination. The shape factor is a constant 3.5/1 at −60 dB/−3 dB. Because of the high selectivity and narrow 10 Hz bandwidth, line frequency side bands can be measured as well as other closely spaced signals. Other bandwidths provide useful flexibility for easy location of signals. The 3100 Hz bandwidth is also useful for detection of line communication channels.

85 dB dynamic range; electronic sweeping
Model 3590A

Recorder outputs

Both X and Y recorder outputs are available at the rear panel of the 3590A. These outputs produce either logarithmically or linear varying dc voltages. Any combination of X and Y log or linear outputs (lin-lin, lin-log, log-lin, log-log) can be chosen to provide maximum flexibility. For example, the operator can make recordings with a linear decibel amplitude scale including the full dynamic range. Recordings can also be made on standard semi-log graph paper to produce direct Bode plots.

Y-axis log and linear outputs occur simultaneously, but the X-axis output is switched to choose the output function. When the switch is in Linear (ramp only), the dc offset produced by the start frequency location is blocked out. This permits wide expansion of a narrow sweep segment without having to buck out the offset voltage.

The pen lift operates by dropping the open (contact closure) during the sweep. During retrace and standby, the pen is lifted.

Low frequency spectrum analyzer

All low-frequency sweeping analyzers must sweep slowly to allow their high-resolution, narrow filters time to fully respond to input signals. For this reason, the 3590A employs an X-Y recorder as a display device. Refer to page 448.

Specifications

3590A Wave Analyzer

Frequency range: 20 Hz to 620 kHz.
Amplitude ranges: 3 μV to 30 V full scale in 15 ranges.
Amplitude accuracy (meter switch in normal position)
Overall accuracy: ±0.5 dB or ±5% of reading, including the following:
Frequency response flatness: ±0.2 dB or ±2%.
Meter tracking: ±0.1 dB or ±1% of reading. 0 dB to −10 dB indication.
Amplitude accuracy (meter switch in linear dB position)
Overall accuracy: ±1 dB.
Internal calibrator
Frequency: 100 kHz ±10 Hz.
Amplitude: full scale on 0 dB range in CAL mode.
Amplitude accuracy: ±0.1 dB.
Dynamic range (IM and harmonic distortion products)
>85 dB below zero dB reference level when ABSOLUTE measurements are being made (>70 dB for 20 Hz to 50 Hz).
>80 dB below zero dB reference level when RELATIVE adjustment is used (>70 dB for 20 Hz to 50 Hz).
Dynamic range (residual responses)
>80 dB below zero reference (>70 dB for 20 Hz to 50 Hz).
Noise level

Bandwidths	Input Noise Level (600Ω Source Impedance)
10 Hz and 100 Hz	<0.3 μV or at least 90 dB below zero dB reference
1 kHz and 3.1 kHz	<1.0 μV or at least 80 dB below zero dB reference

Selectivity:

Rejection	Bandwidths 10 Hz	100 Hz	1 kHz	3.1 kHz
3 dB	10 Hz	100 Hz	1 kHz	3.1 kHz
60 dB	35 Hz	320 Hz	3.1 kHz	9.6 kHz

(Frequency accuracy ±10%)

Automatic frequency control
Capture threshold: 75 dB below 0 dB reference.
Dynamic hold-in range: >3 bandwidths.
Tracking rate proportional to bandwidth.
Input impedance
Resistance: 100 kΩ all ranges.
Capacitance: <50 pF for 10 mV, 30 mV, input ranges: <30 pF for 100 mV to 30 V input ranges.
Automatic ranging: 8 ranges, 0 dB to −70 dB. Ranging rate proportional to bandwidth.
Output
Amplitude: adjustable 0 to 1 V rms open circuit.
BFO frequency response flatness: ±0.2 dB or ±2%.
Resistance: 600Ω.
L.O. output:
Frequency: 1.28 MHz to 1.90 MHz (1.28 MHz + tuned frequency).
Amplitude: 0.65 V rms ±20% open circuit.
Resistance: 250Ω.
Recorder outputs

X-Axis (3593A/3594A only)	Plug-in Frequency Ranges 62 kHz	620 kHz
X-axis linear output: (1 kΩ source resistance)	0 to −12.4 V (200 mV/kHz ±5%)	0 to −12.4 V (20 mV/kHz ±5%)
X-axis log output: (1 kΩ source resistance)	5 V/decade ±5% (50 Hz - 62 kHz)	5 V/decade ±5% (500 Hz - 620 kHz)

Y-axis
Linear Y axis output: +10 V dc ±2% for full scale meter indication, 1 kΩ source resistance.
Log Y axis output: +1 V to +10 V dc, proportional to linear dB meter indication (−90 to 0 dB, 0.1 V/dB) ±1 dB, 1 kΩ source resistance.
Pen lift: contact closure during sweep, open during reset (3593A/3594A only).
Power: 115 V or 230 V ±10%, 50 Hz to 400 Hz, <70 W. (includes plug-in).
Dimensions: 16¾" wide, 8¼" high (without removable feet), 16⅜" deep (425 x 210 x 416 mm).
Weight: net 37 lb (16,8 kg); shipping 47 lb (21,3 kg).
Accessories furnished: rack mounting kit for 19" rack.

Available companion X-Y recorders

The HP 7005B has an 11" x 17" recording area giving high resolution and 0.2% accuracy. This recorder is well suited for 3590A applications and features a low price, $1195. See page 139.

The HP 7004A also has an 11" x 17" recording area, but has higher performance specifications. Plug-in capability, greater acceleration and higher sensitivity allow an extremely wide range of applications. The 7004A is recommended where the 3590A will not be the recorder's only application, $1295. See page 143.

The HP 7035B is a compact, lightweight recorder with an 8½" x 11" recording area.* Where transportability and low cost are prime concerns, the 7035A is recommended for use with the 3590A, $985. See page 139.

The HP 7030A is a high performance 8½" x 11" recorder.* Its high sensitivity, acceleration and versatility suggest that the 7030A is a good all-around recorder for many applications besides being a 3590A companion, $1895. See page 142.

Price: HP 3590A, $3200.

HP 3592A Auxiliary Plug-in

The 3592A Auxiliary Plug-in for the 3590A Wave Analyzer was especially designed as a slave unit where the cost was kept to a minimum. The 3592A plug-in must be controlled by an external oscillator. The input filter switch on the front panel charges the 3590A input filter depending upon which frequency range is being used. Any of the three plug-ins for the 3590A Wave Analyzer can be used in a slave unit when the tuning of two or more 3590A's is accomplished by one master unit. However, the 3592A is the most economical.

Specifications

3592A Auxiliary Plug-in

External L.O. input: 0.65 V ±0.2 V rms, 1.28 to 1.90 MHz (1.28 MHz + tuned frequency).
Input impedance: 10 kΩ in parallel with <100 pF.
Weight: net 2 lb (.9 kg); shipping 3 lb (1,4 kg).
Dimensions: 4½" wide, 8" high, 11" deep (11 x 20 x 28 cm).
Price: HP 3592A, $80.

*Special recording paper is available for 8½" x 11" recorders. The paper is specially designed for optimizing display area for linear decibel amplitude and full range sweeping. Order Hewlett-Packard No. 9280-0161, $3.20/100 sheets.

PLUG-INS FOR THE 3590A
Versatility with the choice of three plug-ins
Models 3592A, 3593A, 3594A

3592A 3593A 3594A

3593A Sweeping Local Oscillator

The 3593A Sweeping Local Oscillator Plug-in for the 3590A Wave Analyzer contains a 3 digit mechanical frequency display. Coarse and fine frequency controls are for two selectable frequency ranges: 500 Hz to 620 kHz and a range of 20 Hz to 62 kHz to provide 10 times the resolution and stability for low frequency applications. Remote tuning can be accomplished in the Ext. L.O. position of the Frequency Range switch by applying a 0.65 rms external frequency source from 1.28 MHz to 1.90 MHz.

One of 5 sweep rates can be selected. If the rate is excessive, the Reduce Sweep Rate light will go on indicating that the sweep rate should be lowered or the bandwidth increased. Sweep circuits are placed in standby when the Sweep switch is turned on. DC programming or sweeping can be accomplished by applying a dc voltage to the BNC connect designated when the slide switch is in External position. For internal sweeping the base or start frequency is set by the coarse frequency control and the level switch placed in the start position. The recorder pen is dropped and the sweep begins. At the end of the sweep time the pen will lift and travel to the Y axis zero. During reset, the pen will return to the start position.

Specifications
3593A Sweeping Local Oscillator

	Frequency Ranges	
	20 Hz to 62 kHz	500 Hz to 620 kHz
Frequency accuracy:	±(1% + 20 Hz) of dial setting	±(1% + 200 Hz) of dial setting
Frequency resolution:	10 Hz/minor div.	100 Hz/minor div.
Ext. frequency control:	0 to 15.5 V (250 mV/kHz ±5%)	0 to 15.5 V (25 mV/kHz ±5%)
Bandwidth specified:	10, 100, 1000, 3100 Hz	100, 1000, 3100 Hz

Sweep rates: 1 Hz/s, 10 Hz/s, 100 Hz/s, 1000 Hz/s, 3100 Hz/s.
Sweep linearity: ±1% of final value.
Maximum sweep time: 620 s ±15%.
Start frequency: determine by frequency control setting.
Pen lift: contact closure during sweep, open during reset.
External L.O. input: 0.65 V ±0.2 V rms, 1.28 to 1.90 MHz (1.28 MHz + tuned frequency). Input impedance: 10 kΩ in parallel with <100 pF.
Weight: net 7.5 lb (3,4 kg); shipping 9 lb (4,1 kg).
Dimensions: 8" high, 4½" wide, 11" deep (20 x 11 x 28 cm).
Price: HP 3593A, $1100.

3594A Sweeping Local Oscillator

The 3594A Sweeping Local Oscillator Plug-in for the 3590A Analyzer has all of the features of the 3593A Plug-in with the addition of a 5 digit electronic frequency counter to replace the 3 digit mechanical counter. The 3594A features frequency accuracy and resolution plus the ability to track and display sweeping frequencies.

Specifications
3594A Sweeping Local Oscillator

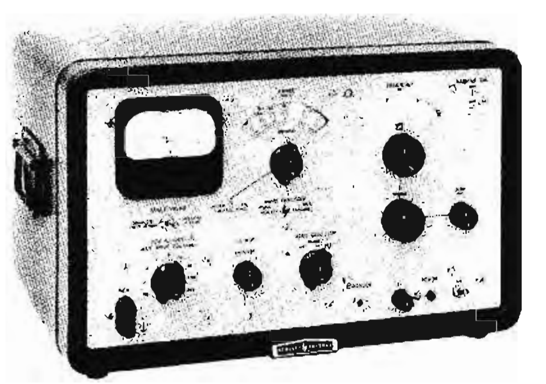
	Frequency Ranges	
	20 Hz to 62 kHz	500 Hz to 620 kHz
Frequency accuracy:	±(1 Hz + time base accuracy)	±(10 Hz + time base accuracy)
Frequency resolution:	1 Hz	10 Hz
Ext. frequency control:	0 to 15.5 V (250 mV/kHz ±2%)	0 to 15.5 V (25 mV/kHz ±2%)
Bandwidth specified:	10, 100, 1000, 3100 Hz	100, 1000, 3100 Hz

Time base accuracy: temperature coefficient: +15° to +35°C ±1 ppm/°C (+25°C ref). Aging rate: ±3 ppm per month.
Sweep rates: 1 Hz/s, 10 Hz/s, 100 Hz/s, 1000 Hz/s, 3100 Hz/s.
Sweep linearity: ±1% of final value.
Mamixum sweep time: 620 s ±15%.
Start frequency: determined by frequency setting.
Pen lift: contact closure during sweep, open during reset.
External L.O. input: 0.65 V ±0.2 V rms, 1.28 to 1.90 MHz (1.28 MHz + tuned frequency). Input impedance: 10 kΩ in parallel with <100 pF.
Weight: net 7.5 lb (3,4 kg); shipping 9 lb (4,1 kg).
Dimensions: 8" high, 4½" wide, 11" deep (20 x 11 x 28 cm).
Price: HP 3594A, $1600.

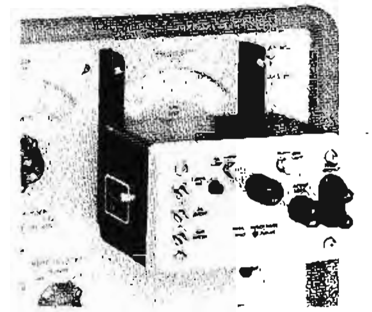
WAVE ANALYZER, SWEEP DRIVE

Measures wave components with narrow B.W.

Models 302A, 297A



302A



297A mounted on 302A

Description

The HP Model 302A Wave Analyzer is a tunable voltmeter of high selectivity and high sensitivity covering the frequency range of 20 Hz to 50 kHz. The frequency scale is linear throughout the band with a constant resolution of one division per 10 Hz.

The instrument separates an input signal into its individual frequency components so that fundamental harmonic and intermodulation products may be separately measured and evaluated. It may also be used as a narrow-band selective voltmeter which will read absolute or relative levels.

An automatic frequency control (AFC) circuit locks the measuring system to the frequency of the incoming signal, eliminating any need for frequency tracking while making a measurement.

Besides its primary function as a waveform analyzer, the 302A can be operated as an oscillator-selective voltmeter combination. In BFO operation, an oscillator and the tuned voltmeter track together over the entire frequency range (20 Hz to 50 kHz) of the Model 302A. One control tunes both the oscillator and the voltmeter simultaneously, making filter and amplifier response measurements easy.

Specifications, 302A

Frequency range: 20 Hz to 50 kHz.

Frequency scale: 1 division per 10 Hz.

Dial accuracy: ±(1% +5 Hz).

Amplitude range: 30 μV to 300 V full scale, 15 ranges in 10 dB steps. An absolute-relative switch, in conjunction with a variable 10 dB control, is provided for adjustment for intermediate values.

Voltage accuracy: ±5% of full-scale value.

Residual modulation products and hum voltage: >75 dB down.

Intermediate frequency rejection: intermediate frequency present in input signal rejected by at least 75 dB.

Single fixed bandwidth: 7 Hz.

Bandpass shape

Rejection	Bandwidth
≥3dB	7Hz
≥50dB	50Hz
≥80dB	140Hz

Input impedance: determined by setting of input attenuator. 100 kΩ (<100 pF shunt) on 4 most sensitive ranges; 1 MΩ (<20 pF shunt) on remaining ranges.

Restored frequency output: 1 V across 600 Ω at output terminals for full-scale meter deflection; output voltage proportional to meter reading; output level control provided; frequency response ±2%, 20 Hz to 50 kHz; output impedance approximately 600 Ω.

Oscillator output: 1 V across 600 Ω at output terminals (mode selector in BFO); output level control provided; frequency response ±2%, 20 Hz to 50 kHz; output impedance approximately 600 Ω.

Recorder output: 1 mA dc into 1500 Ω or less at full-scale meter indication for grounded or ungrounded recorders.

Automatic frequency control: range of frequency hold-in is ±100 Hz minimum.

Power: 115 or 230 V ±10%, 50 to 400 Hz, approx. 3 W; terminals are provided for powering instrument from external battery source; battery supply range, 28 V to 18 V.

Dimensions: cabinet 12½" high, 20¾" wide, 14½" deep behind panel (318 x 527 x 368 mm).

Weight: cabinet net 43 lbs (19,5 kg), shipping 53 lbs (23,9 kg); rack mount net 35 lbs (16 kg), shipping 49 lbs (22,1 kg).

Price: HP 302A, $1900 (cabinet); HP 302AR, $1885 (rack mount).

297A Sweep Drive

The 297A is a motor-drive unit designed to enhance the usefulness of the HP 302A, 310A or 312A Wave Analyzers. With the 297A you may sweep through all or any part of the 302A range. Because the 297A produces an X-axis output, you may easily make semi-automatic plots of harmonics, intermodulation products and response characteristics with an X-Y recorder such as Model 7035A.

The 297A may also be used to drive other tunable devices through their ranges. A stand (HP 11505A) allows the shaft height to be adjusted from 4 to 12 inches (102 to 305 mm).

Specifications, 297A

Sweep limits: any interval from 64 revolutions to 10 degrees.

Sweep speed with 302A: 170 and 17 Hz/s.

Shaft speed: 10 rpm, 1 rpm, and neutral; other shaft speeds available on special order; neutral permits manual operation.

Sweep voltage output: at least 12 V maximum; full output is obtained with either 2.1 or 50 revolutions of the shaft.

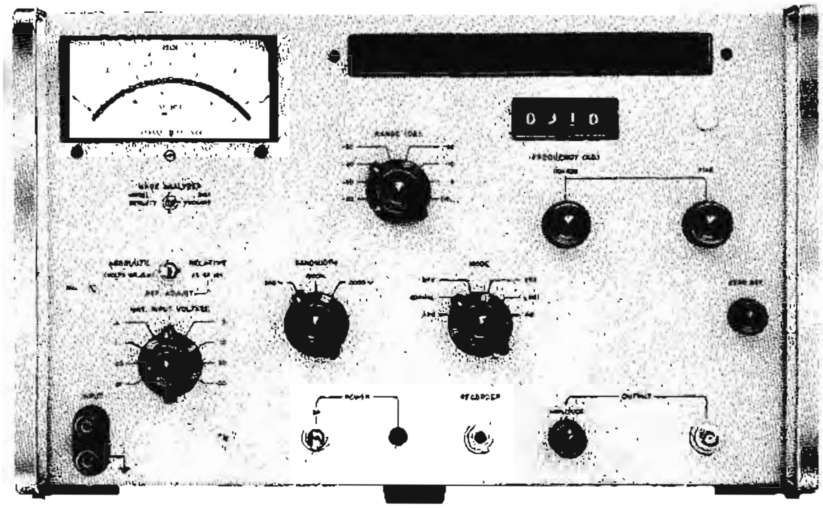
Torque: 9 in/oz at 10 rpm (approx. 22 in/oz max. at 1 rpm).

Power: 115 V ±10%, 60 Hz, 12 W running or stalled.

Weight: net 4¼ lbs (1,9 kg); shipping 7 lbs (3,2 kg).

Price: HP 297A, $375.
HP H03-297A (230 V, 50 Hz), $400.

WAVE ANALYZER
Measure harmonics, intermodulation products
Model 310A


310A

Description

The HP 310A High-Frequency Wave Analyzer is a narrow-band selective voltmeter. Selectivity allows analysis of closely spaced fundamental signals, harmonics, and intermodulation products. Signal components between 1 kHz and 1.5 MHz may be measured in both relative and absolute terms. Absolute read-outs in volts and dBm, and relative readings in percent and dB are easily made. BFO operation allows use of the 310A as a signal generator and response meter suitable for measuring both amplifier and passive element characteristics. Also, provisions have been made for detecting and monitoring single side-band and AM signals.

Specifications

Frequency range: 1 kHz to 1.5 MHz (200 Hz bandwidth); 5 kHz to 1.5 MHz (1000 Hz bandwidth); 10 kHz to 1.5 MHz (3000 Hz bandwidth).
Frequency accuracy: ±(1% + 300 Hz).
Frequency scale: linear graduation, 1 div per 200 Hz.
Selectivity: 3 IF bandwidths, 200 Hz, 1000 Hz and 3000 Hz; mid-point of the passband (f_o) is readily distinguished by a rejection region 1 Hz wide between the 3 dB points.

	200 Hz bandwidth	1000 Hz bandwidth	3000 Hz bandwidth
Rejection*	frequency (Hz)	frequency (Hz)	frequency (Hz)
≥3 dB	$f_0 \pm 108$	$f_0 \pm 540$	$f_0 \pm 1550$
≥60 dB	$f_0 \pm 630$	$f_0 \pm 3130$	$f_0 \pm 9633$
≥75 dB	$f_0 \pm 1000$	$f_0 \pm 5000$	$f_0 \pm 17000$

*Rejection increases smoothly beyond the -75 dB points.

Voltage range: 10 µV to 100 V full scale, ranges provided by input attenuator and meter range switch in steps of 1:3 or 10 dB.
Voltage accuracy: ±7% of full scale.
Internal calibrator stability: ±1% of full scale.
Dynamic range: >75 dB.
Noise and spurious response: at least 75 dB below a full-scale reference set on the 0 dB position of Range switch.
Input resistance: determined by input attenuator; 10 kΩ on most sensitive range, 30 kΩ on next range, 100 kΩ on other ranges; shunt capacitance <100 pF on three most sensitive ranges, <50 pF on other ranges.
Automatic frequency control: dynamic hold-in range is ±3 kHz minimum at 100 kHz; tracking speed is approximately 100 Hz/s; locks on signal as low as 70 dB below a full-scale reference set on the 0 dB position of the Range switch.
Restored-frequency output: restored signal frequency maximum output is at least 0.25 V (meter at full scale) across 135Ω, with approximately 30 dB of level control provided; output impedance approximately 135Ω.
BFO output: 0.5 V across 135Ω with approx. 30 dB of level control provided; output impedance approx. 135Ω.
Recorder output: 1 V dc into an open circuit from 1000Ω source impedance for single-ended recorders; output of 1 mA dc into 1500Ω or less available on special order.
Receiver function (Aural or Recording provision): internal carrier reinsertion oscillator is provided for demodulation of either normal or inverted single sideband signals; AM signal also can be detected.
RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D.
Power: 115 or 230 V ±10%, 50 to 400 Hz; 20.5 W max.
Dimensions: 16¾" wide, 10¾" high, 18⅜" deep (426 x 274 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 10-15/32" high, 16⅜" deep behind panel (483 x 266 x 416 mm).
Weight: net 45 lbs (20,3 kg); shipping 52 lbs (23,4 kg).
Accessories available: 11001A Cable Assembly, $6; 10503A Cable Assembly, $7; 10111A Adapter, $7; 297A Sweep Drive, $350; 11505A Bench Stand for 297A, $25; K02-310A Bracket for mounting the 297A when the 310A is rack-mounted, $35.
Price: HP 310A, $2500.

Options

01: internal frequency calibrator providing check points every 100 kHz; interpolation accuracy (between check points): ±2 kHz up to 1.4 MHz, ±3 kHz between 1.4 and 1.5 MHz; add $105.
02: dB scale uppermost on meter face and extended to −25 dB, add $25.

WAVE ANALYZER; OSCILLATOR

Signal analysis to 22 MHz; tracking oscillator

Models 312A; 313A

312A Waveform analyzer

Model 312A permits analysis of complex wave forms whose spectra extend to 18 MHz. The Wave Analyzer utilizes the tuned-voltmeter technique to separate the various components of an input signal so that the fundamental, harmonics, and intermodulation products can be located and measured. The instrument is particularly well suited for measurement in communications systems accommodating basebands to 18 MHz. The high selectivity, wide dynamic range, and high sensitivity of the 312A greatly simplify measurements such as distortion, attenuation, cross talk, frequency response, etc. Versatility is enhanced by three selectable bandwidths: 200 Hz for maximum resolution, 1,000 Hz for simple calculations of noise power per Hz, and 3,000 Hz for easy location of signals or operation as a receiver.

For maximum flexibility, the 312A input may be operated either balanced or unbalanced. In the Terminated mode, the input signal is terminated in a selectable impedance of 50, 60, 75, 124, 135, 150, or 600 ohms. The meter indicates power in dBm absorbed by the selected impedance; in the 50 ohms position, the meter also indicates voltage. In the Bridged mode, the input impedance is 20 kilohms balanced and 10 kilohms unbalanced. When bridging an externally terminated transmission line of the same impedance selected on the 312A, the meter indicates dBm. In this mode the 312A can also indicate voltage by selecting the Volts Calibrated position of the Impedance Selector. The high impedance 11530A Probe can also be used for bridging measurements to eliminate the loading effect of the input cable on the circuit under test.

The 312A has two signal attenuators. One, at the input, prevents the applied signal from overdriving the input amplifier. The second attenuator provides up to 60 dB attenuation in the IF channel and permits measurement of signals which are at least 65 dB below a full-scale reference set on the 0-dB position. Thus, low level distortion products may be readily measured.

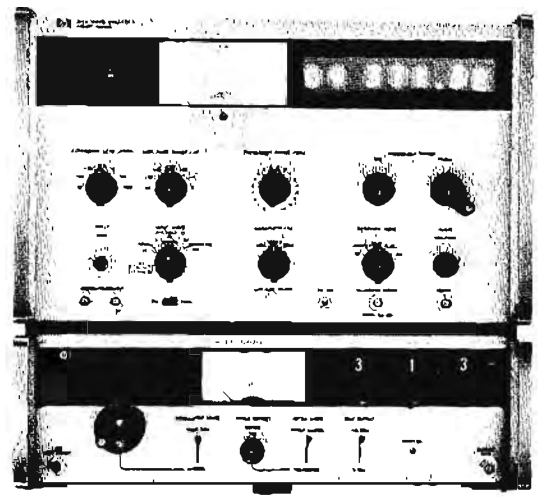
Tuning is accomplished in 18 overlapping bands. The frequency to which the analyzer is tuned is indicated by an in-line digital readout with 10-Hz resolution.

For use with equipment requiring only 75-ohm unbalanced measurements, the HP H01-312A provides wave analysis capability to 22 MHz.

313A Tracking oscillator

HP 313A Tracking Oscillator provides a tracking output to complement the 312A Wave Analyzer. The frequency of this output signal automatically tracks the center of the 312A passband, so the 312A and 313A are excellent for analyzing the frequency response characteristics of amplifiers, filters, etc.

The output of the 313A is extremely flat over the entire frequency range and is calibrated in dBm. A precision 100-dB attenuator, calibrated in 0.1 dB steps, adds to the versatility. Together with the wide dynamic range of the 312A, the output flexibility of the 313A permits high values of gain and attenuation to be checked easily and accurately.



312A; 313A

The 313A can also be used to provide increased amplitude resolution by expanding selectable 2-dB ranges of the 312A meter to full scale on the 313A meter. Any 2-dB range between −7 and +3 dB on the 312A meter may be selected for display. Amplitude variations as small as 0.01 dB can be resolved. Thus, minute variations in filter passbands or long-term gain variations in a communications channel can be analyzed easily.

The 313A can be operated as a signal source independent of the 312A Wave Analyzer. As such, the 313A has a frequency range from 10 kHz to 22 MHz in a single band. The output is extremely flat over the entire range and is adjustable from +10 to −99.9 dBm.

Specifications, 312A

Tuning characteristics

Frequency range: 10 kHz to 18 MHz in 18 overlapping bands, 200 kHz overlap between bands. Usable to 1 kHz with 200 Hz bandwidth.

Frequency accuracy: ±(10 Hz + time-base accuracy). Frequency indicated on in-line digital readout with ±10 Hz resolution.

Time-base stability

Aging rate: less than ±2 ppm per week.

As a function of ambient temperature: +15° to +35°C, less than ±20 ppm; 0° to +55°C, less than ±100 ppm.

As a function of line voltage: less than ±0.1 ppm for changes of ±10%.

Selectivity

Rejection	200 Hz bandwidth	1000 Hz bandwidth	3000 Hz bandwidth
3 dB	200 Hz ±10%	1 kHz ±10%	3 kHz ±10%
60 dB	<470 Hz	<2350 Hz	<6680 Hz

(Midpoint of the band is marked by rejection notch 3Hz wide.)

Automatic frequency control

Dynamic hold-in range: ±3 kHz at 3 kHz bandwidth (0 dB ref.).

Tracking speed: 100 Hz/s; locks on to signals as low as 60 dB below zero reference. Zero reference level set with Amplitude Range switch set to 0 dB.

Amplitude characteristics

Amplitude range: 50 to 150Ω, −97 dBm to +23 dBm full scale: 600Ω, −107 to +13 dBm.

Voltage: 3 μV to 3 V full scale (50Ω reference).

Amplitude accuracy

Amplitude range: attenuator: ±0.1 dB (1% of reading).

Reference level attenuator: at 1 MHz, ±0.2 dB.

Frequency response (bridging input with external termination of 50Ω ±1%): 10 kHz to 10 MHz, ±0.2 dB (2% of reading) 10 MHz to 18 MHz, ±0.5 dB (5% of reading).

Meter tracking: ±0.1 dB to −10 dBm (1% of reading).

Internal calibrator output

Frequency: 1 MHz square wave (derived from time base).

Amplitude: −40 dBm into 75Ω termination.

Amplitude stability: ±0.1 dB.

Output connector: BNC female.

Matching impedance: 50, 60, 75, 124, 135, 150 or 600Ω, balanced or unbalanced.

Bridging impedance: 20 kΩ ±3% shunted by <30 pF (balanced); 10 kΩ ±3% shunted by <60 pF, reference level attenuator at −40 dB (unbalanced).

Common-mode rejection (balanced input): 10 kHz to 5 MHz, >40 dB; 5 MHz to 18 MHz, >30 dB.

Input connector: BNC female (2).

Harmonic distortion: 10 kHz to 1 MHz, >55 dB below zero reference with Amplitude Range switch set at 0 dB; 1 MHz to 18 MHz, >65 dB below zero reference with Amplitude Range switch set at 0 dB.

Residual responses: 72 dB below zero reference with no input and reference level in any position.

Noise level, referred to input: 50 to 150Ω, −120 dBm (200 Hz bandwidth); 600Ω, −130 dBm (200 Hz bandwidth).

Receiver characteristics

Receiver mode outputs:

AM and AM/AFC: diode-demodulated audio.

Beat: beat frequency audio center at f_o.

LSB: product-demodulated audio, carrier reinserted at f_o −1.8 kHz.

USB: product-demodulated audio, carrier reinserted at f_o −1.8 kHz.

Output connector: BNC female.

Audio output level (into at least 10 kΩ): 0.5 V rms with full-scale meter deflection.

General

Recorder output level: 1 V ±0.1 V with full-scale meter deflection across open circuit. Output connector, BNC female. Tracking accuracy, better than ±0.1 dB to 20 dB below full-scale reference on 0 dB position of Amplitude Range switch; better than ±0.2 dB to 30 dB below full-scale reference. Output resistance, 1 kΩ.

Auxiliary outputs

1 MHz: 1 V p-p sine wave into 1 kΩ; output connector, BNC female.

30 MHz: 40 mV to 70 mV rms into 50Ω; output connector, BNC female.

Local oscillator (30 to 48 MHz): 60 mV to 90 mV rms into 50Ω; output connector, BNC female.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 90 W.

Dimensions: 16¾" wide, 10¾" high, 18⅜" deep (426 x 274 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 10 15/32" high, 16⅜" deep behind panel (483 x 266 x 416 mm).

Weight: net 46 lbs (20,7 kg); shipping 59 lbs (26,6 kg).

Accessory available: 11530A Probe provides amplitude accuracy (probe and divider only) of ±0.5 dB; $200.

Probe input impedance (at 1 MHz)

Probe divider	Input Impedance	
	Unbalanced	Balanced
1:1 (0 dB)	20 kΩ shunted by <20 pF	40 kΩ shunted by <10 pF
10:1 (20 dB)	20 kΩ shunted by <12 pF	40 kΩ shunted by < 6 pF
100:1 (40 dB)	20 kΩ shunted by < 7 pF	40 kΩ shunted by < 4 pF

5060-0216 Joining Bracket Kit for joining two full-module instruments, $25.

Price: HP 312A, $3900.

HP 312A option 01 (carrier noise measurement) add $100.

HP C01-312A, furnished with WE-465C coaxial input connector and WE-477B coaxial connector for the internal calibrator output, $3975.

Specifications, H01-312A*

(Same as 312A with following exceptions)

Frequency range: 10 kHz to 22 MHz in 22 overlapping bands.

Amplitude accuracy: reference level (matched 75Ω input); ±0.2 dB (+15° to +40°C), ±0.3 dB (0 to +55°C).

Meter calibration: dBm only (75Ω reference).

Input impedance: 75Ω or bridging (10 kΩ) shunted by <35 pF, unbalanced, selectable at front panel. Input connector equivalent to WE-477B.

Receiver output connector: accepts WE-289B twin plug or single two-conductor telephone plug.

Internal calibrator output connector: equivalent to WE-477B.

Price: HP H01-312A, $3850.

Specifications, 313A

Frequency range

As tracking oscillator: same as 312A (18 MHz) or H01-312A, H05-312A and H10-312A (22 MHz). Refer to page 325.

As signal source: 10 kHz to 22 MHz in one band, continuous tuning.

Frequency accuracy

As tracking oscillator: 35 Hz ±4 Hz above 312A tuning.

As signal source: ±1% of maximum dial setting from 10 kHz to 2 MHz; ±3% of maximum dial setting from 2 to 8 MHz; ±5% of maximum dial setting from 8 to 22 MHz.

Frequency stability

As tracking oscillator: same as 312A time base ±100 Hz/°C.,

As signal source: short term (5 min) drift <1 kHz in stable environment after warmup.

Frequency response: ±0.1 dB, 10 kHz to 22 MHz.

Amplitude stability: ±0.1 dB for 90 days (0 to +55°C).

Meter mode

312A Expand: meter expands any 2 dB range of 312A meter indication from −7 to +3 dB using 312A recorder output. Meter range, −1 to +1 dB; tracking error, ±0.05 dB over full 2 dB range (operates with any 1 V, 1 kΩ recorder output).

Output monitor: meter indicates voltage level at the input of the attenuator and can be calibrated from the front panel.

Maximum output: 0 or +10 dBm ±0.1 dB, selectable at front panel.

Output attenuator: 3-section attenuator provides 0 to 99.9 dB attenuation in 0.1 dB steps.

Attenuator accuracy: 0.9 dB section (0.1 dB steps), ±0.02 dB; 9 dB section (1 dB steps), ±0.1 dB; 90 dB section (10 dB steps), ±0.1 dB to 50 dB, ±0.2 dB to 90 dB.

Output impedance: 75Ω unbalanced (50Ω optional, see Option 01 below).

Output connector: BNC female (also see C01-313A below).

Harmonic distortion: more than 34 dB below fundamental.

Non-harmonic distortion

As tracking oscillator: more than 40 dB below fundamental.

As signal source: more than 50 dB below fundamental.

Recorder output: +0.3 V for full-scale deflection. Output impedance 1 kΩ, BNC female connector.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 30 W maximum.

Dimensions: 16¾" wide, 5½" high, 18⅜" deep (426 x 141 x 467 mm).

Weight: net 25 lbs (11,3 kg); shipping 29 lbs (13,1 kg).

Accessories furnished: 11086A interconnecting cables for use with HP 312A, each cable 2 ft (610 mm) long with BNC male connectors (3).

Price: HP 313A, $1300.

C01-313A, furnished with output connector equivalent to WE-477B; $1355.

Option 01: output impedance 50Ω unbalanced; no additional charge.

*For other special 312A's, refer to page 325.

FREQUENCY DOMAIN MEASUREMENT

Signal analysis in the frequency domain is basic to engineering measurements. Evaluation of the relative amplitudes and frequencies of the discrete components of RF signals yields information on bandwidths, distortion, modulation characteristics, spurious signal generation and other valuable data impossible or impractical to obtain by any other means. This analytic capability makes the spectrum analyzer an exceptionally versatile instrument for general laboratory use — an "oscilloscope in the frequency domain."

Every electrical signal is a function of both frequency and time. The familiar time domain oscilloscope displays the instantaneous amplitude of the signal as a function of time. All frequency components of the signal are combined in a single trace to display the time-varying properties of the composite signal.

Analysis in the frequency domain separates these individual frequency components and displays the amplitude of each as a function of frequency. Thus the spectrum analyzer provides a visual display of the Fourier transform for the complex signal. In the frequency domain, signals which contain many frequencies of widely different amplitudes can be separated for easy, accurate analysis. Figure 1 shows a three dimensional representation of the time/frequency domains.

Hewlett-Packard spectrum analyzers provide frequency coverage from 1 kHz to 40 GHz. The model 8553L/8552A covers the 1-kHz to 110-MHz frequency range with an extremely flat frequency response of ±0.5 dB. Major features of this analyzer include absolute vertical calibration in both dBm and voltage, and high resolution (minimum bandwidth of 50 Hz). Only fundamental mixing is used, eliminating image, multiple, and harmonic responses.

The basic frequency range of the Model 851B/8551B Spectrum Analyzer is 10 MHz to 12 GHz with 1-kHz resolution. The addition of external waveguide mixers provides coverage from 8.2 GHz to 40 GHz.

Broadband applications

Radio frequency interference (RFI) testing, spectrum surveillance, and gathering of spectrum signatures are important fields being revolutionized by spectrum analyzers. The far-ranging sidebands of radar transmitters, intermodulation products of multiple transmissions, and spurious signals generated by electronic and electrical devices can be quickly detected and measured with a spectrum analyzer.

The HP Model 8441A Preselector is a valuable tool to aid RFI and spectrum surveillance measurements when using the 851B/8551B analyzer. The 8441A is a voltage-tuneable bandpass filter using an yttrium-iron-garnet (YIG) current-tuneable filter to pass a desired signal and reject others. By automatically tracking with the desired spectrum analyzer tuning response, it virtually eliminates multiple, image, and spurious responses in the 1.8 to 12.4 GHz range. The preselector also extends the dynamic range of the 851B/8551B analyzer for distortion measurements as much as an additional 35 dB, permitting distortion measurements as low as 0.01%.

The extreme flatness, absolute amplitude calibration, and high sensitivity (to −130 dBm) ideally suit the 8553L/8552A analyzer to RFI/EMI measurements below 110 MHz.

Fast rising, short duration pulse waveforms in the nanosecond region can be generated by semiconductor diodes driving a shorted transmission line. With the broad frequency display (Figure 2) and flat amplitude response of the 851B/8551B, it is a simple task to measure narrow, fast-rising pulse spectra and make adjustments for discontinuities in the generating system. The adjustment of parametric amplifiers and varactor-tuned multiplier strings is also greatly simplified since the wide 2-GHz spectrum width of the 851B/8551B allows all frequencies to be observed simultaneously.

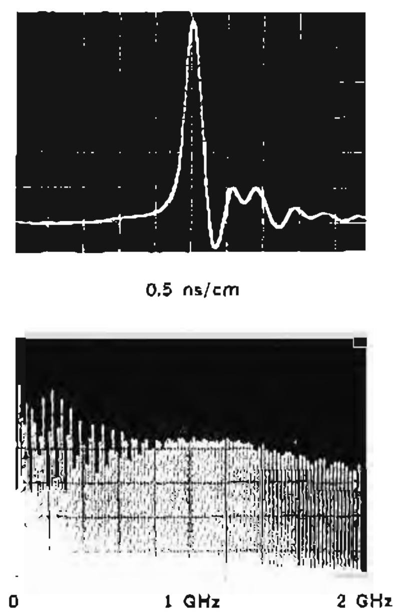


Figure 2. Nanosecond pulse and spectrum resulting.

Variable persistence

Display sections with variable persistence/storage CRT's are available for both the 851B/8551B Microwave Spectrum Analyzer and the 8553L/8552A RF Spectrum Analyzer. Variable persistence is virtually indispensable in providing a bright, steady trace without flicker for the slow sweeps required in achieving the maximum sensitivity and resolution of the analyzer, as well as analyzing low-repetition-rate phenomena such as radar pulses and modulation spectra (Figure 3).

Figure 3. A low modulation level such as this (2% AM) would be difficult to measure in the time domain. In the frequency domain, however, the measurement can still be made easily and accurately. Sidebands as low as 70 dB below the carrier could be measured (0.06% AM).

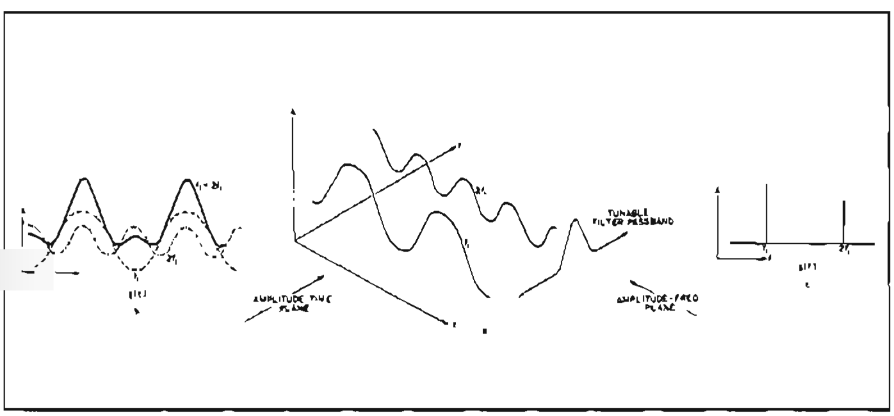


Figure 1. The Frequency/Time Domains. a. Three-dimensional coordinates showing time, frequency, and amplitude. The addition of a fundamental and its second harmonic is shown as an example. b. View seen in the t-A plane. On an oscilloscope, only the composite $f_1 + 2f_1$ would be seen. c. View seen in the f-A plane. Note how the components of the composite signal are clearly seen here.

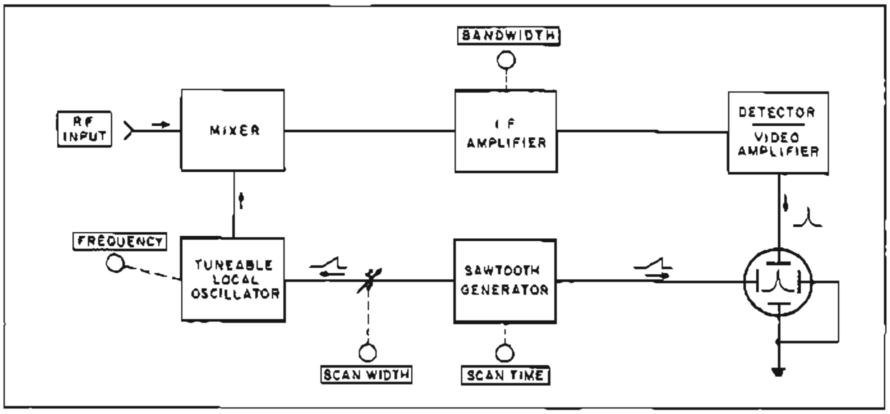


Figure 4. Simplified Spectrum Analyzer of the Swept-Receiver Design.

General analyzer requirements

The basic functions of a spectrum analyzer are to translate electrical functions into their various frequency components and present their amplitudes on a visual display. To be versatile and effective, the spectrum analyzer should have: 1) the ability to locate and identify signals over a wide frequency spectrum, 2) the ability to magnify portions of the spectrum for detailed analysis with stable, calibrated sweeps and resolution, 3) minimum display clutter from spurious responses in the analyzer, and 4) wide dynamic range and flat frequency response.

The usual method of obtaining a visual amplitude-vs-frequency display is to apply the output of a "swept receiver" to a CRT. The receiver is electronically tuned by a linear ramp voltage. This tuning voltage is also applied to the horizontal deflection plates of the CRT so that the horizontal position of the spot is proportional to frequency.

The detected output of the receiver is applied to the vertical deflection plates. When a signal is received, a vertical deflection proportional to the amplitude of the signal is produced, thus displaying a plot of amplitude versus frequency on the CRT. If the analyzer sweeps through a CW signal slowly, the resulting response on the CRT is a plot of the passband of the analyzer's IF amplifier.

Either the first or second local oscillator (LO) of the receiver can be swept. Sweeping the first LO (Figure 5a) has the advantages of providing very good frequency response flatness, wide spectrum widths, and generally lower distortion.

In the swept-second-LO type of analyzer (Figure 5b) a portion of the spectrum is heterodyned to a broadband first IF where it is scanned by the swept second LO. Thus in this type of analyzer, maximum spectrum width is limited by the bandpass of the first IF, typically 100 MHz. Frequency response flatness and distortion characteristics of the analyzer now depend on the first IF and second mixer as well as the first mixer.

Frequently, the two types of analyzers are combined, as in the 8553L/8552A. Here the first LO is swept for the wide scans, and the third LO is swept for the narrower scans. This approach combines the wide sweep capabilities of swept-first-LO analyzers with excellent stability in the narrow scans since the first LO is phase-locked to a stable crystal oscillator when the third LO is being swept.

Many spectrum analyzers use harmonic mixing to extend the frequency range of the analyzer economically; the RF input signal is mixed with a harmonic of the first local oscillator to heterodyne it to the first IF. The HP 8551B is a typical example; harmonics as high as $n = 10$ are used to extend the frequency range to 40 GHz.

Spurious responses

If the amplitude of the RF input signals is small (compared to the amplitude of the local oscillator), the mixer does not generate harmonics (distortion products) of the input signal. The input attenuators of HP spectrum analyzers allow the analyzer to operate over a wide range of input levels without overloading the input mixer, thus minimizing the generation of spurious responses. Reduction of spurious responses is essential to achieving a wide dynamic range such as the 70-dB dynamic range of the Model 8553L/8552A.

Resolution

Resolution is the ability of the analyzer to separate signals closely spaced in frequency. Since the response of the analyzer to a CW signal is a plot of the passband of the analyzers IF amplifier, the width and shape of this response are the major limitations on resolution. Two CW signals with a frequency separation less than the IF bandwidth would both be in the passband at the same time, thus they could not be separated.

Two other factors are also important: the sweep rate and the stability of the analyzer. If the analyzer is swept through a signal too fast, the apparent bandwidth displayed on the CRT will be wider than the actual bandwidth. Sensitivity is also reduced under these conditions since the signal does not remain in the IF passband long enough for the amplifier to fully respond. The Auto Bandwidth Select mode of the 851B/8551B automatically chooses the minimum IF bandwidth useable without this limitation. A special logic circuit in the 8553L/8552A identifies the condition and lights a front-panel warning lamp to alert the operator.

If frequency modulation is present on the local oscillator (other than the linear sweep voltage), the effect is equivalent to having a signal that is frequency-modulated. As a result the analyzer will present an FM spectrum rather than a single response. Both the FM deviation and the modulating rate of any residual FM in the analyzer must be less than its minimum IF bandwidth.

Series 63 application notes

A series of application notes containing detailed information concerning spectrum analysis are available on request through your Hewlett-Packard Sales Office.

Application Note 63 contains an introduction to spectrum analysis which explains the basic principles of frequency domain measurements. Illustrations of spectral displays and examples of their interpretation form a considerable portion of the text. An appendix provides a rigorous treatment of Fourier analysis as applied to spectrum analyzer displays.

AN63A through AN63D detail measurement techniques with Hewlett-Packard spectrum analyzers. For example, AN63B discusses the use of the 8441A Preselector, AN63C describes the measurement of white noise power density, and AN63D describes accurate frequency calibration (typically to 0.01%) of spectrum analyzers using the HP 8406A Frequency Comb Generator.

A manual, "EMI Measurement Procedure," describes RFI/EMI measurements with the 851B/8551B to satisfy requirements of MIL-STD-826A, including details of test setups and procedures. A slide rule for simplifying calibration of the analyzer is included with the manual.

Low-frequency, narrow-band analyzer

Wave Analyzers offer another method of measuring both the amplitude and frequency of an input signal's components.

The electronic sweeping and amplitude autoranging of the new HP 3590A wave analyzer permit X-Y and strip chart plots of amplitude versus frequency over a frequency range of 20 Hz to 620 kHz and a dynamic range of more than 85 dB. For additional information, see pages 437 to 443.

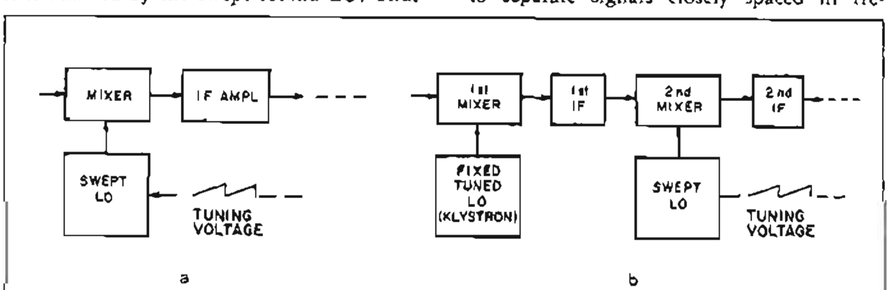
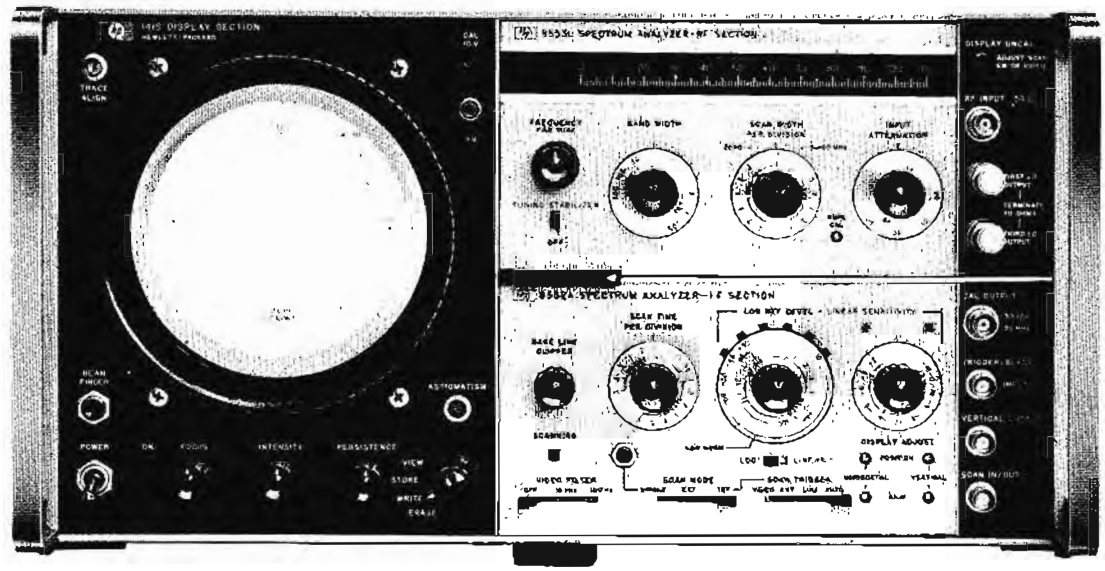


Figure 5. Two Methods of Obtaining Swept-Frequency Capability. a. Spectrum Analyzer using swept first LO. b. Spectrum Analyzer using swept second LO.

1 kHz-110 MHz
Absolute amplitude calibration to −130 dBm
Model 8553L/8552A



141S/8553L/8552A

The Model 8553L/8552A Spectrum Analyzer provides frequency domain analysis from 1 kHz to 110 MHz - audio to VHF. The traditional capabilities of low-frequency, highly selective wave analyzers are combined with wide dynamic range and sweep capabilities to produce a new advance in spectrum analysis. New features such as absolute amplitude calibration in voltage and power greatly simplify many otherwise tedious measurements in linear circuit design and systems analysis. Instrument controls are easy to operate and the display is easy to interpret.

The analyzer consists of an 8553L RF Section and an 8552A IF Section combined in a 140S or 141S Display Section. The 140S has a fixed-persistence, non-storage CRT; the 141S has a variable-persistence/storage CRT. Both display sections have an internal graticule for parallax-free measurements on the CRT. The graticules are specially calibrated with log (dB) and linear (voltage) scales for spectrum analyzer use. With the 141S you can adjust the trace persistence from 0.2 second to more than a minute to achieve a bright, steady trace that does not flicker even on slow sweeps. The long persistence also permits intermittent signals occurring over a period as long as a minute to be captured and displayed; because of their short duration, such signals are nearly impossible to measure using conventional techniques. The 141S also provides storage for side-by-side comparison of changing signals—and normal persistence as well.

All HP 1400-series oscilloscope plug-ins will fit these display sections for complete flexibility in both the frequency and time domains. The spectrum analyzer RF and IF plug-ins will also operate with the standard 140A, 141A, and 143A Oscilloscope display sections. However, these units do not have the additional shielding and filtering for low-level use (such as RFI) or the special spectrum analyzer graticule. A set of overlays is available for the 140A and 141A to provide the log and linear calibrations.

Wide frequency range

The 8553L/8552A Spectrum Analyzer has fully calibrated swept coverage from 1 kHz to 110 MHz with a spurious-free display. The frequency response is exceptionally flat (±0.5 dB over the entire frequency range) for precision swept measurements from audio to VHF.

Calibrated scan widths 0 - 100 MHz

Calibrated symmetrical scan widths are selectable from 0.2 kHz/div to 10 MHz/div around the center frequency. For fast broadband analysis, the preset 0-100 MHz scan can be selected, with the 300-kHz IF bandwidth selected automatically. In preset scan a unique inverted marker identifies the center frequency of the display for ZERO scan or PER DIVISION scan. Figure 1 shows a 10-MHz comb display with marker tuned to the sixth harmonic. Switching the SCAN WIDTH to PER DIVISION, Figure 2, expands the sweep symmetrically about the 60-MHz component identified by the marker. In ZERO scan, the analyzer is a fixed-frequency, selectable bandwidth receiver, manually tuned by the FREQUENCY control.

Stability

An automatic stabilization system phase-locks the first local oscillator to a stable crystal when the scan width is less than 50 kHz/div, reducing the residual FM of the analyzer to less than 20 Hz peak-to-peak. This high order of stability makes it easy to check signal generators for residual FM or

70-dB Dynamic Range

Model 8553L/8552A

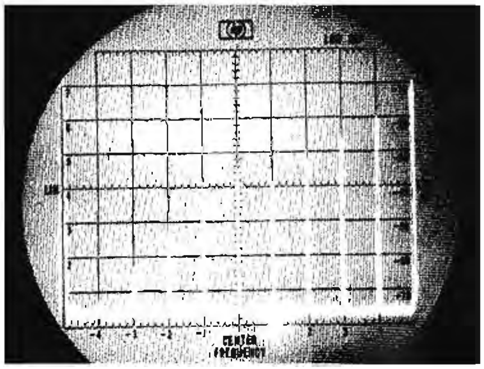


Figure 1. Preset 0-100 MHz SCAN displays output (fundamental through 10th harmonic) of 10-MHz comb generator. Highly linear scan makes it simple to measure the frequency of any component accurately. Note inverted scan marker beneath 6th harmonic (60 MHz); switching to SCAN WIDTH PER DIVISION expands the spectral display symmetrically about the frequency the marker identifies.

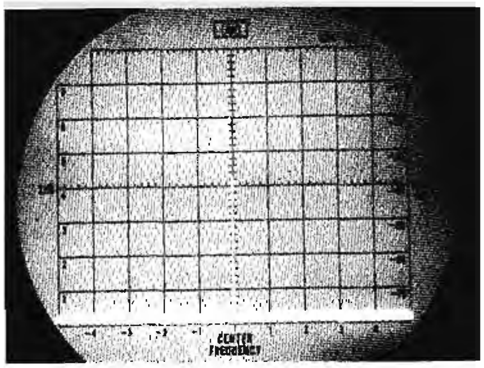


Figure 2. 60 MHz signal selected by the marker from the comb of Figure 1. SCAN WIDTH is 1 MHz/division; IF BANDWIDTH is 10 kHz. Signal amplitude is 4.2 divisions, and the display is LINEAR (voltage). The LINEAR SENSITIVITY is 0.2 mV/div, therefore the signal amplitude is 0.84 mV rms.

frequency drift, measure phase noise in phase-lock systems, evaluate oscillator spectral purity, and to use the Bessel null technique for precise calibration of FM deviation meters.

Resolution

The IF bandwidth of a spectrum analyzer determines its resolution (ability to separate closely spaced signals). The 8552A/8553L has a minimum 3-dB bandwidth of 50 Hz with a shape factor (60 dB to 3 dB bandwidth ratio) better than 25:1. Figure 4 shows the spectrum of a carrier with 30% AM at 400 Hz. The sidebands are 16 dB below the carrier but could be resolved as far as 50-60 dB below the carrier. A choice of nine bandwidths from 50 Hz to 300 kHz allows selection of the optimum bandwidth for the sensitivity, resolution, and scan width required.

Absolute amplitude calibration — high sensitivity

One of the most important features of the 8553L/8552A is its absolute vertical calibration; signal amplitudes are measured directly in microvolts or dBm. The LOG display

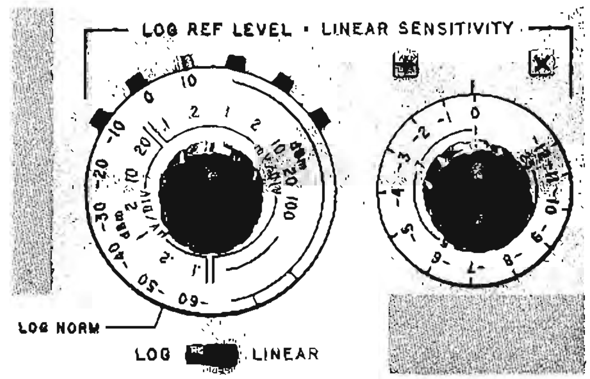


Figure 3. Settings of INPUT attenuator and LINEAR SENSITIVITY analyzer controls determine scale factor for absolute voltage calibration. The "X" lamp indicates that the scale factor is the product of the LINEAR SENSITIVITY dial readings (blue color-coded): 0.2 mV/div x 1 = 0.2 mV/div.

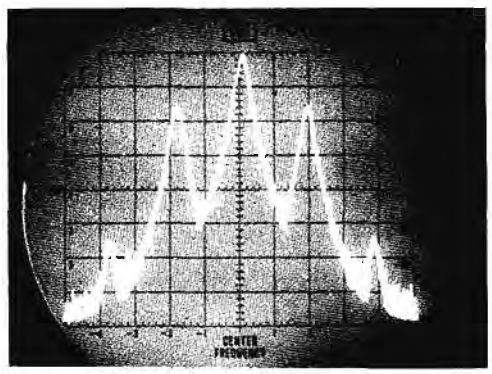


Figure 4. LOG Display of Amplitude Modulated Carrier. SCAN WIDTH is 200 Hz/div; IF BANDWIDTH is 50 Hz. The modulation frequency is measured directly from the display as 400 Hz (2 division spacing of carrier and sidebands). The modulation percentage is measured from the 16 dB amplitude ratio of the carrier and sidebands . . . modulation percentage is 30%. The 800-Hz second harmonic distortion components are 40 dB below the fundamental, indicating 1% distortion. The calibrated LOG display also shows the carrier level to be —31 dBm (see Figure 5).

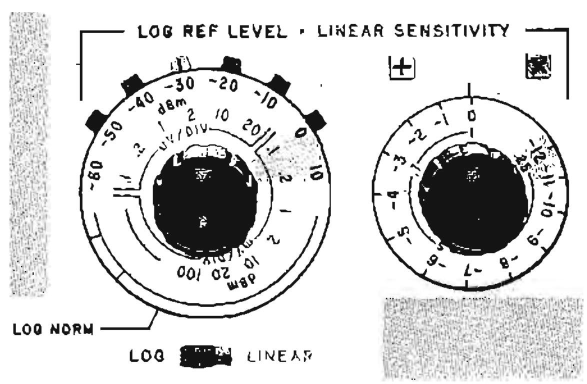


Figure 5. Settings of the INPUT ATTENUATOR and LOG REFERENCE LEVEL controls determine the scale factor for absolute amplitude calibration. LOG is selected and "+" lamp lights to indicate that LOG REFERENCE LEVEL is the sum of the black color-coded dial readings; i.e., LOG REF = —30 dBm +0 dBm = —30 dBm. Carrier signal level in Figure 4 is 1 dB (0.1 div) below LOG REF graticule line, so signal amplitude is (—30 dBm —1 dB) = (—31 dBm). The level of the other signal components can be measured as easily; for example, the 400-Hz sidebands are each —47 dBm and the 800-Hz sidebands are —85 dBm.

(Fig. 4 and 5) reads directly in dBm; the LINEAR display (Fig. 2 and 3) is calibrated in voltage. The high sensitivity of the analyzer permits its use as an RF voltmeter or power meter to levels as low as 0.07 microvolts (—130 dBm). You can also measure distortion in an amplifier or oscillator as a function of output level and check output levels of oscillators and signal generators. In EMI studies field strength can be measured with a calibrated antenna.

The absolute calibration of the analyzer can be verified easily with a built-in calibrator (—30 dBm at 30 MHz). In addition, a red front-panel lamp warns when the displayed amplitude is uncalibrated because the scan rate is too fast for the IF bandwidth selected.

70 dB display range

The full 70 dB displayed dynamic range of the 8553L/8552A is free of distortion products generated by the analyzer itself. An RF Input Attenuator (0 to 50 dB) prevents overloading of the input mixer to keep analyzer distortion products more than 70 dB below any signal input level up to +10 dBm. With this extremely clean display you can measure distortion levels as low as 0.03% or monitor signals of widely varying amplitudes, such as in EMC, RFI, and surveillance work. Another application is displaying the frequency response characteristics of amplifiers and filters for measurement or alignment (Figure 6).

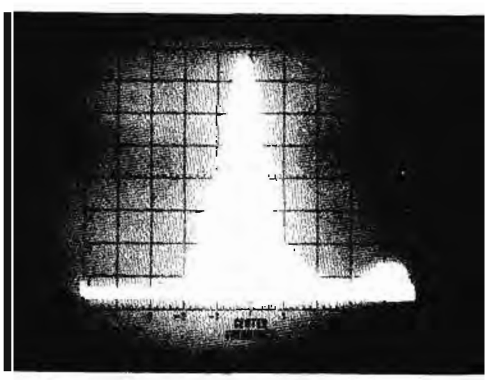


Figure 6. LOG Display of swept filter test. 70 dB dynamic range of analyzer easily displays spurious filter response 63 dB below principal filter response. BASE LINE CLIPPER is adjusted to blank lower portion of display, useful in photography so the bright base line will not overexpose the film. Center frequency is 50 MHz, SCAN WIDTH is 10 MHz/div. The 141S Variable Persistence/Storage Display Section is used here to hold the display for comparison as the filter is adjusted.

Video filter

The video filter smooths the detected signal before it is displayed on the CRT, adding additional convenience to the analyzer. This is especially useful in averaging noise or other broadband signals, e.g., measuring noise power density. Very small signals near the residual noise level are also easier to see with the noise components averaged by the video filter.

Specifications for RF and IF sections

RF input and tuning characteristics

Frequency range: 1 kHz to 110 MHz.

Frequency response: ±0.5 dB, 1 kHz to 110 MHz (for attenuator settings ≥10 dB). Typical fine grain flatness, ≤0.1 dB per MHz.

Input impedance: 50Ω nominal.

Reflection coefficient ≤0.13 (1.3 SWR, 18 dB return loss) for input attenuator settings ≥10 dB.

Maximum input level: peak or average power to input mixer < +13 dBm (1.4 V ac peak; ±50 V dc).

Sensitivity: $\frac{\text{Signal Power} + \text{Noise Power}}{\text{Noise Power}} = 2$

IF Bandwidth (kHz)	Sensitivity (dBm)	Frequency Range* (MHz)
1	—120	1 - 110
10	—110	1 - 110
100	—100	1 - 110

*Typical sensitivity versus input frequency curves for frequencies from 1 kHz to 110 MHz are shown in Fig. 7.

Tuning dial accuracy: display center frequency is within ±1 MHz of indicated dial frequency.

Center frequency identifier: marker in 0-100 MHz SCAN WIDTH mode identifies display center frequency of SCAN WIDTH/DIVISION and ZERO SCAN modes.

Scan characteristics

Scan width: 15 calibrated scan widths from 200 Hz/div to 10 MHz/div in a 1, 2, 5, 10 sequence plus ZERO and preset 0-100 MHz SCAN. Scan is displayed on a 10-division horizontal span of display section CRT.

Scan width accuracy: scan widths 10 MHz/div to 2 MHz/div and 20 kHz/div to 200 Hz/div: frequency error between two points on the display is less than ±3% of the indicated frequency separation between the two points. Scan widths 1 MHz/div to 50 kHz/div: frequency error between two points on the display is <10% of the indicated frequency separation, typically 5%.

Scan time: 16 rates from 0.1 ms/div to 10 s/div in a 1, 2, 5, 10 sequence, INTERNAL and SINGLE SCAN modes only.

Scan time accuracy: 0.1 ms/div to 20 ms/div, ±10%. 50 ms/div to 10 s/div, ±20%.

Scan mode

Internal: analyzer repetitively scanned by internally generated ramp; synchronization selected by SCAN TRIGGER. SCANNING lamp indicates duration of scan.

Single: single scan actuated by front panel pushbutton. SCANNING lamp indicates duration of scan.

External: scan determined by 0 to +8 volt external signal; analyzer input impedance >10 kΩ. Blanking: —1.5 V external blanking signal required.

Scan trigger: required only when INTERNAL SCAN MODE selected.

Auto: scan free-runs.

Flat Response, ±0.5 dB
Model 8553L/8552A

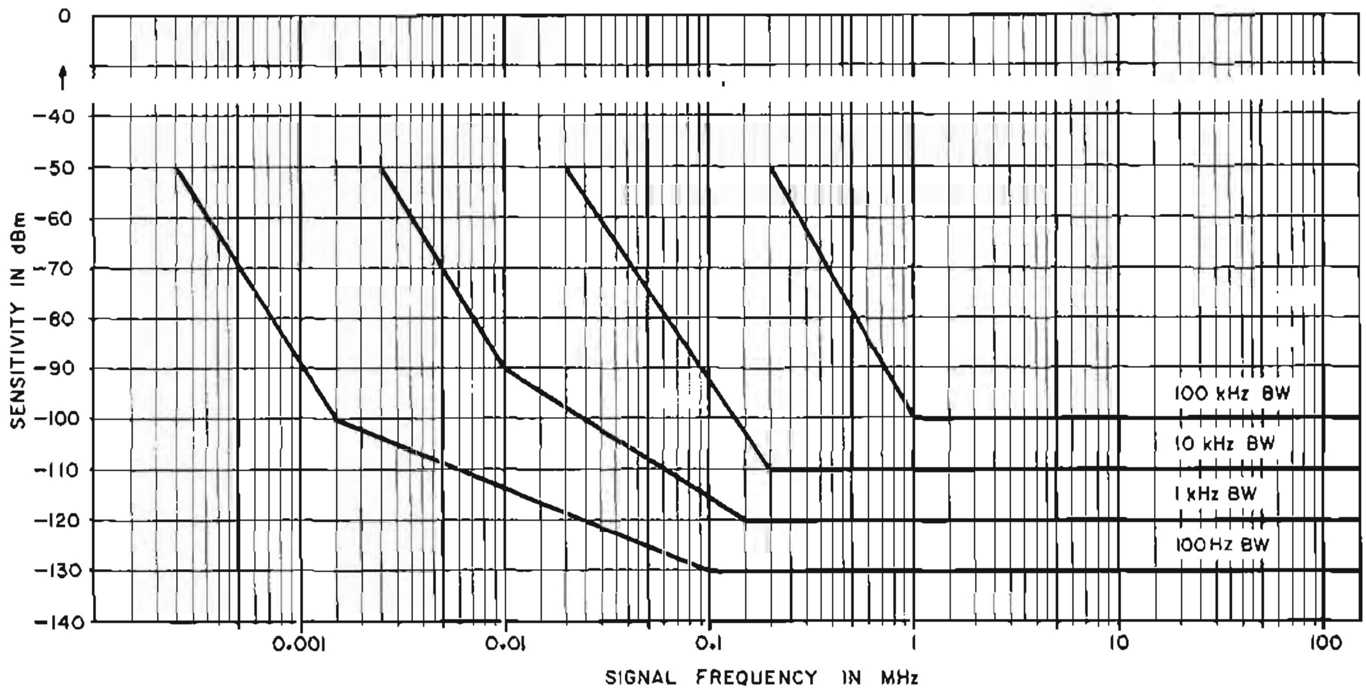


Figure 7. Typical Sensitivity vs. Input Frequency.

Line: scan synchronized with power line frequency.

External: scan synchronized with external 2- to 20-volt signal (polarity selected by internally located switch of Model 8552A IF Section).

Video: scan internally synchronized to envelope of RF input signal (signal amplitude of 1.5 major divisions peak-to-peak required on display section CRT).

Spectral resolution

IF bandwidth: 3-dB bandwidths of 50, 100, 300 Hz, and 1, 3, 10, 30, 100, and 300 kHz can be selected.

IF bandwidth accuracy: individual bandwidths calibrated within ±20%, 10-kHz IF bandwidth calibrated within ±5%.

IF bandwidth selectivity: 60 dB/3 dB bandwidth ratio less than 20:1 for IF bandwidths from 1 kHz to 300 kHz. 60 dB/3 dB bandwidth ratio less than 25:1 for IF bandwidths from 50 Hz to 300 Hz.

Video filter bandwidth: two post-detection bandwidths: 10 kHz and 100 Hz.

Video filter bandwidth accuracy: individual video bandwidths calibrated within ±20%.

Amplitude characteristics

Vertical display calibration (8 divisions full scale deflection)

Logarithmic: calibrated directly in dBm over 140-dB range from −130 dBm to +10 dBm, 10 dB/div on 0 to −70 dB CRT display. LOG REFERENCE LEVEL control and log reference vernier establish absolute power reference level in dBm for CRT display.

Linear: calibrated directly in V/div from 0.1 μV/div to 100 mV/div in a 1, 2, 10 sequence. LINEAR SENSITIVITY and vernier controls establish absolute voltage calibration (deflection factor).

Calibrator: 30-MHz signal provided as operating standard for absolute vertical calibration of display: −30 dBm ±0.3 dB.

Vertical display accuracy:

	Logarithmic dBm	Linear volts
Calibrator	±0.3 dB	±3.5%
Log Reference Level (Linear Sensitivity)	±0.2 dB	±2.3%
Log Reference Vernier (Linear Sensitivity Vernier)	±0.1 dB*	±1.2%*
RF Input Attenuator Accuracy (excluding flatness)	±0.2 dB	±2.3%
Analyzer Frequency Response (flatness)	±0.5 dB	±5.8%
Switching between bandwidths (at 20°C)	±0.5 dB	±5.8%
Amplitude Stability: 100 Hz-300 kHz bandwidth	±0.05 dB/°C	±0.6%/°C
50 Hz bandwidth	±0.1 dB/°C	±1.2%/°C
CRT Display	±0.25 dB/dB but not more than ±1.5 dB over the full 70 dB display range.	±2.8% of full 8 div deflection

*Vernier accuracy at 0, 6, and 12 dB; otherwise ±0.25 dB (±2.8%).

Absolute amplitude calibration to —130 dBm

Model 8553L/8552A

Display uncalibrated light: panel lamp warns operator of uncalibrated amplitude display if selected IF bandwidth or video bandwidth is too narrow for combination of scan width and scan time selected.

Spectral purity

Automatic stabilization: first local oscillator automatically stabilized (phase-locked) to internal reference for scans of 20 kHz/div or less.

Long term stability (after approximately one hour warmup):

Stabilized: 100 Hz/min; 500 Hz/10 min.

Unstabilized: 5 kHz/min; 20 kHz/10 min.

Residual FM:

Stabilized: less than 20 Hz peak-to-peak.

Unstabilized: less than 1 kHz peak-to-peak.

Noise sidebands: more than 70 dB below CW signal 50 kHz or more away from signal, with a 1-kHz IF BANDWIDTH setting.

Spurious responses: for —40 dBm signal level to input mixer: image responses, out-of-band mixing responses, harmonic and intermodulation distortion products, and IF feedthrough responses all more than 70 dB below the input signal level.

Residual responses: 200 kHz to 110 MHz: <—110 dBm. 20 kHz to 200 kHz: <—95 dBm.

Display Section Specifications

Model 140S Specifications (for additional information, see Model 140A, page 512).

Plug-ins: accepts Model 8553L/8552A Spectrum Analyzer plug-ins and Model 1400-series time domain plug-ins.

Cathode-ray tube:

Type: post-accelerator, 7300 volt accelerating potential; etched safety glass face plate reduces glare; transparent coating reduces RFI. P7, long persistence phosphor; light blue filter supplied.

Graticule: 8 x 10 divisions (approximately 7,2 x 9,0 cm) parallax-free internal graticule; five subdivisions per major division on horizontal and vertical axes.

Model 141S Specifications (for additional information, see Model 141A, page 513).

Plug-ins: same as 140S.

Cathrode-ray tube:

Type: post accelerator storage tube, 7300 volt accelerating potential; aluminized P31 phosphor; etched safety glass face plate reduces glare.

Graticule: 8 x 10 divisions (approximately 6,6 x 8,2 cm) parallax-free internal graticule; five subdivisions per major division on horizontal and vertical axes.

Presistence:

Normal: natural persistence of P31 phosphor (approximately 0.1 second).

Variable:

Normal writing rate mode: continuously variable from less than 0.2 second to more than one minute (typically to two or three minutes).

Max. writing rate mode: typically variable from 0.2 second to 15 seconds.

Erase: manual; erasure takes approximately 100 ms.

General Specifications

CRT base line clipper: front panel control adjusts blanking of CRT trace base line to allow more detailed analysis of low-repetition-rate signals and improved photographic records to be made.

Vertical display output: approximately 0 to —0.8 V for 8 div deflection on CRT; 2 kΩ output impedance.

Scan output: approximately —5 to +5 volts for 10 div CRT deflection; 5 kΩ output impedance.

RFI: conducted and radiated leakage limits are below requirements of MIL-I-16910C and MIL-I-6181D from 150 kHz to 110 MHz and below MIL-I-16910A from 14 kHz 150 kHz when 8553L and 8552A are combined in a 140S Display Section.

Temperature range: operating, 0° to +55°C; storage, —40° to +75°C.

Power requirements: 115 or 230 volts ±10%, 50 to 60 Hz, normally less than 225 watts (varies with plug-in units used).

Weight: Model 8552A IF Section: Net, 9 lb (4,1 kg). Shipping, 14 lb (6,4 kg).

Model 8553L RF Section: Net, 12 lb (5,5 kg). Shipping, 17 lb (7,8 kg).

Model 140S Display Section: Net, 37 lb (16,8 kg). Shipping, 45 lb (20 kg).

Model 141S Display Section: Net, 40 lb (18 kg). Shipping, 51 lb (23 kg).

Dimensions: 9-1/16" high (including height of feet) x 16¾" wide x 18⅜" deep (229 x 425 x 467 mm).

Accessory equipment furnished: two 50Ω BNC terminations for front panel 1st LO OUTPUT and 3rd LO OUTPUT (Model 8553L).

Accessory required for service: 11592A Service Kit, $185. Includes extender cables, connector adapters, etc.

Accessories available: Model 8406A Frequency Comb Generator: provides frequency markers spaced 1, 10, and 100 MHz for precise frequency calibration of analyzer. Frequency accuracy is ±0.01%.

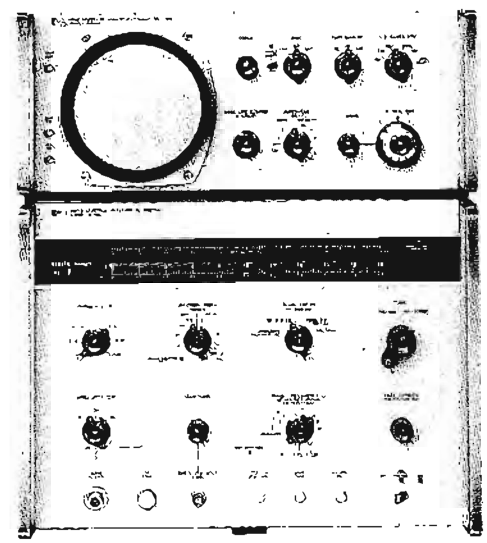
Price: Model 8552A IF Section, $1,900.

Model 8553L RF Section, $1,800.

Model 140S Display Section, $725.

Model 141S Variable Persistence Display Section, $1,525.

10 MHz—40 GHz
Fully calibrated, 2 GHz spectrum width
Model 8551B


8551B

Description

The Hewlett-Packard 8551B Spectrum Analyzer System is a fully calibrated, highly versatile analyzer which covers the range from 10.1 MHz to 40 GHz. The accuracy and flexibility of the instrument make it suitable for many applications beyond the capability of other spectrum analyzers. These include wideband yet rapid RFI measurements, spectrum surveillance and spectrum signature work, and semiconductor evaluations embracing such tests as fast pulsing viewed in the frequency domain.

The analyzer consists of two units, the 8551B RF Section and either the 851B or the 852A Display Section, comprising a triple-conversion superheterodyne receiver with swept first local oscillator and oscilloscope readout. The 8551B RF Section includes the mixers, local oscillators, and two of the three IF amplifiers. The 851B or 852A Display Section includes the final IF amplifier, IF attenuator and bandpass filters, and video detector plus the cathode-ray tube, sweep generator, and display controls.

Maximum RF input flexibility

The extremely wideband coaxial input system will accept signals from 10.1 MHz to 12 GHz. Use of the broadband, untuned first mixer permits simultaneous observation of widely spaced signals; testing of parametric amplifiers is an application in which this feature is useful, for you can observe the signal, pump, and idler frequencies on a single display and immediately note the effects of adjustments. When it becomes desirable or necessary to limit the input frequency range, this can be done easily by adding appropriate preselectors (such as filters, isolators, tuned amplifiers, etc.). The user has complete latitude in the choice of preselectors, for the analyzer imposes no arbitrary frequency band limitations.

Additional input system flexibility and convenience are afforded by the inclusion of a high performance RF attenuator for use with the coaxial inputs when higher level signals are to be examined. Signal levels as high as 1 watt can be viewed without jeopardizing the input mixer. The attenuator has 60-dB range in 10-dB steps, and because its residual attenuation is very small (less than 2 dB at 10 GHz), it can remain an integral part of the input system, thereby eliminating any need for cable patching. In addition, the attenuator provides a well-matched input for the analyzer. The match on the straight-through or 0-dB position of the attenuator is also good with a maximum reflection coefficient of 0.5 (SWR of 3).

Flat response, high sensitivity

The HP-developed input mixer provides the analyzer with extremely flat frequency response. Over full 2-GHz spectrum widths, response is ±2 dB on fundamental mixing, ±2 to ±3.5 dB on harmonic mixing to 12 GHz. Over spectrum widths of 100 MHz, frequency response is correspondingly better. Response over the 4- to 6-GHz range is shown in Figure 1. Such flat frequency response permits reliable quantitative measurements where amplitude comparisons of signals at different frequencies can be made (such as in measuring the harmonic content of signals). Very low-level harmonic and intermodulation products are generated within the mixer. For example, with a −30 dBm input level to the mixer, harmonic and intermodulation products are typically >50 dB below the signal level when fundamental mixing is employed. An additional feature of the input mixer is that the diode is a standard, readily available item easily replaceable from the front panel.

The 8551B has high sensitivity as well as flat frequency response. Sensitivity (10 kHz BW) ranges from −100 dBm in the lower coaxial ranges (where fundamental mixing is employed) to −65 dBm in the highest waveguide band (using harmonic mixing). This sensitivity plus the 60 dB range of the input attenuator enables the analyzer to handle an extremely broad range of signal levels.

The discussion above deals primarily with the coaxial input system of the analyzer. Analysis of signals at higher frequencies where waveguide systems are employed can also be performed. External waveguide mixers covering 8.2 to 40 GHz are used, with a simple coaxial cable serving as the link between the mixer and the 8551B. The single cable delivers local oscillator power to the mixer and returns the mixing products to the analyzer. Thus there is no need to use cumbersome flexguide or resort to awkward handling merely to observe signals in waveguide systems. External waveguide attenuators, such as the HP 382 series, can be used to control the input signal level.

2-GHz spectrum width with clutter-free display

A fresh approach to spectrum analyzer design has resulted in an 8551B offering up to 2 GHz of calibrated spectrum width with a display that is free from the spurious responses and images which historically have made interpretation of spectral displays very difficult. This is achieved through use of the 2-4 GHz backward-wave oscillator as the first swept

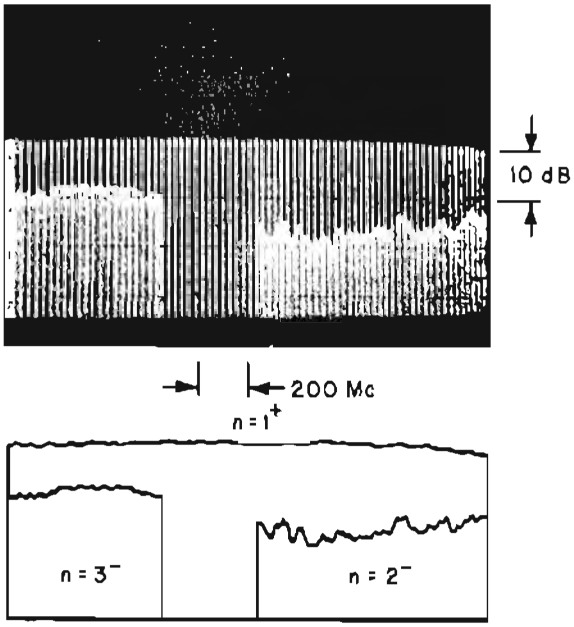


Figure 1. Frequency response, 4 to 6 GHz. Fundamental mixing is shown across the entire 2-GHz range, and third- and second-harmonic mixing are also shown over the ranges in which they occur. (Since odd-harmonic mixing is selected, the mixer bias is not optimized for even-harmonic mixing.)

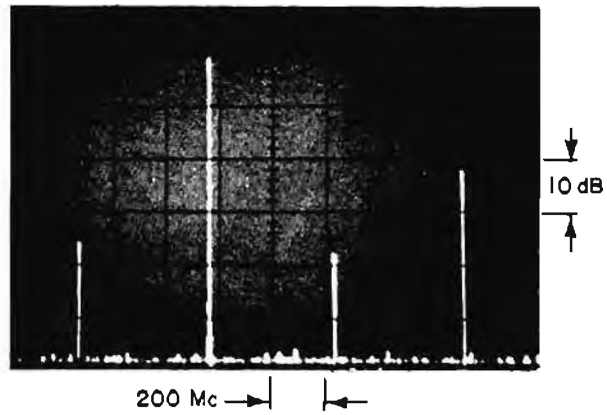


Figure 2. Broad spectrum-width capability permits simultaneous observation of first, second, third, and fourth harmonic output of an HP 10515A Frequency Doubler with a 1-volt input at about 500 MHz.

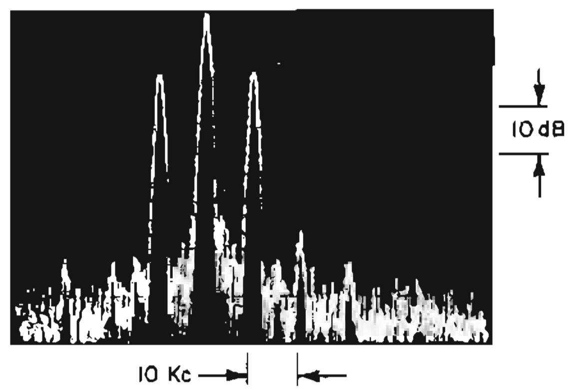


Figure 3. Narrow-band capability permits examination of VHF signal amplitude-modulated 40%. (HP 8442A 20-MHz Crystal Filter used here for optimum resolution.)

local oscillator (LO) followed by a 2-GHz first IF amplifier. Sweeping the first local oscillator allows use of fixed tuned, narrow-band IF amplifiers throughout the analyzer, eliminating the sources of spurious signals found in other spectrum analyzers. The high frequency first IF spaces images 4 GHz apart and therefore image signals do not clutter the display. The combination of a 2-4 GHz swept LO and a 2-GHz first IF provides low frequency coverage down to 10.1 MHz. When the LO is set to 2 GHz, the LO feeds directly through the IF and can serve as a signal source to perform self-checks on the analyzer's performance and calibration. Figure 2 illustrates the use of the 2-GHz spectrum width in the evaluation of a frequency doubler.

When viewing signals very close to 2 GHz in frequency, a separate first IF of 200 MHz can be switch-selected. The 200-MHz first IF mode can be used to observe signals from 1.8 to 4.2 GHz; sensitivity exceeds −100 dBm and images are 400 MHz apart. Flatness of response and freedom from internally generated spurious signals are also characteristic of this mode.

In addition to its wide sweep capability, the 8551B Spectrum Analyzer also excels in the presentation of narrow frequency sweeps. Spectrum widths as narrow as 100 kHz can be selected for detailed examination of individual signals, distortion products, etc. Figure 3 is the spectrum of an amplitude-modulated signal in the VHF region. The narrow sweep capability of the analyzer is made possible by a self-contained phase-lock system which reduces residual FM in the first local oscillator to less than 1 kHz. Stabilization of the local oscillator by means of phase-lock is possible for spectrum widths up to (10 n) MHz (where n is the harmonic number of the LO); this is well beyond the point where residual FM of the unstabilized LO could be detected on the display. For operator convenience, a front panel warning light indicates spectrum width too great for use of phase-lock stabilization.

The 8551B provides simplicity of tuning, particularly when the unit is operated with the LO stabilized. The phase-lock system itself tracks with tuning so the LO remains stabilized while it is sweeping and also when its center frequency is changed. Thus, there is no need to re-establish phase-lock with every change of frequency, so the operator can continue to tune the analyzer with a single knob.

Two tuning speeds are available. The shift between coarse and fine tuning is accomplished by a pull-push selector on the tuning control. An ultra-fine vernier is also available during stabilized operation for precise positioning of the display.

Positive signal identification

Measurements with the 8551B are simplified by the fact that all displayed signals are easily and positively identifiable. Factors contributing to the ease of signal identification are the 4-GHz image separation and almost total absence of spurious signals which otherwise clutter the display and mask real signals. Actual identification is straightforward. A front-panel control permits rapid determination of the LO mixing harmonic and identification of the signal as an upper or lower mixing product.

Specifications
8551B RF section
(When connected to display section)

Coaxial input characteristics

Frequency range: 10.1 MHz to 12 GHz. Input connector, Type N female.

Sensitivity

$\left(\frac{\text{signal power} + \text{noise power}}{\text{noise power}} = 2;\ \text{10-kHz IF bandwidth}\right)$:

10.1 MHz to 100 MHz, −98 dBm, fundamental mixing
100 MHz to 1.8 GHz, −100 dBm, fundamental mixing
1.8 to 4.2 GHz, −100 dBm, fundamental mixing (using 200 MHz 1st IF)
2.4 to 4.1 GHz, −90 dBm, second harmonic mixing
4.1 to 6 GHz, −100 dBm, fundamental mixing
6 to 8 GHz, −88 dBm, third harmonic mixing
8 to 10 GHz, −91 dBm, second harmonic mixing
10 to 12.0 GHz, −85 dBm, third harmonic mixing
With source stability better than 1 kHz, greater sensitivity can be achieved using narrower IF bandwidth.

Image separation: 4 GHz, (2 GHz First IF); 400 MHz separation when using 200 MHz IF.

Maximum input power (for 1 dB signal compression):

Input Atten Setting	Typical Max Input (peak or average)
0 dB	−10 dBm
10 dB	0 dBm
20 dB	+10 dBm
30 dB	+20 dBm
40 - 60 dB	+30 dBm

Mixer diode: standard 1N4603 replaceable from the front panel.

Residual responses (no input signal): less than −90 dBm referred to signal input on fundamental mixing (−85 dBm when LO is within 60 MHz of 2 or 4 GHz).

RF input attenuator: 0 to 60 dB in 10-dB steps (attenuator residual loss and flatness characteristics included in sensitivity and frequency response specifications). Input ac-coupled; maximum dc voltage: 50 V on 0 - dB setting, 7 V on all others.

Waveguide input characteristics

Frequency range: 8.2 to 40 GHz (accessory mixers and adapters required).

Sensitivity

$\left(\frac{\text{signal power} + \text{noise power}}{\text{noise power}} = 2;\ \text{10-kHz IF bandwidth}\right)$:

8.2 to 18 GHz, −80 dBm
18 to 26.5 GHz, −75 dBm
26.5 to 40 GHz, −65 dBm

Maximum input power (for 1 dB signal compression):
8.2 to 12.4 GHz (using 11521A Mixer) typically −15 dBm peak or average.
12.4 to 40 GHz (using 11517A Mixer) typically −15 dBm peak or average.

External mixer input connector: BNC female; LO power to mixer and 2-GHz IF signal from mixer use this connector.

RF sweep, first local oscillator (LO), and RF tuning characteristics

Spectrum width: 10 calibrated spectrum widths from 100 kHz to 2 GHz in a 1, 3, 10 sequence to 1 GHz. Vernier allows continuous adjustment between calibrated ranges and can be used to reduce width to 0. Displayed over 10-cm horizontal span on display section CRT.

Swept frequency linearity: spectrum widths 200 MHz/div to 3 MHz/div: Frequency error between two points on the display is less than ±10% ±3 MHz of the indicated frequency separation between the two points.
Spectrum widths 1 MHz/div to 10 kHz/div (stabilized tuning mode): Frequency error between two points on the display is less than ±5% of the indicated frequency separation between the two points.

First local oscillator: 2 to 4 GHz backward-wave oscillator.

Tuning accuracy: ±1% of first LO fundamental or harmonic.

Tuning modes: selectable continuous coarse, fine, and stabilized (phase-locked) tuning determines center frequency about which first local oscillator (LO) is swept. Tuning accomplished with single front panel TUNE control (with FREQUENCY VERNIER control for increased settability when in stabilized tuning mode; vernier tuning range 100 kHz).
Frequency change of LO fundamental is 200 MHz per revolution of TUNE control for COARSE, 10 MHz per revolution for FINE.

LO stabilization range: first LO can be phase-locked to internal voltage-tuned reference oscillator. LO sweep tracks reference oscillator sweep for spectrum widths up to (n) x (10 MHz); (n = harmonic number).

Stabilized tuning: internal reference oscillator automatically tracks with TUNE control over full LO range to retain stabilization at any LO frequency. Frequency change of LO fundamental is 10 MHz per revolution of the TUNE control. FREQUENCY VERNIER control (100 kHz tuning range) permits precise settability.

LO characteristics

Residual FM: less than 1 kHz (p-p) when first LO stabilized; typically less than 40 kHz (p-p) when LO not stabilized.

Noise sidebands: more than 60 dB below CW signal level 90 kHz or more away from signal, using fundamental mixing.

Auxiliary RF output: approximately 20 mW available at rear panel Type N female connector for use with other equipment (e.g. frequency counter, wavemeter). Requires nominal 50-ohm load impedance; HP 908A termination furnished.

Frequency response, Coaxial input

(Includes mixer and RF attenuator response with attenuator setting ≥10 dB):

Frequency range	Mixing mode n*	Mixing mode IF (GHz)	Relative gain** (dB)	Flatness, full range (dB)	Flatness, 100 MHz (dB)
10.1 to 1.8 GHz	1−	2	0	±2.0	±2.0
(100 MHz to 1.8 GHz)	1−	2	0	±1.5	±1.0
1.8 to 4.2 GHz	1±	0.2	0	±3.5	±2.0
2.4 to 4.1 GHz	2−	2	−7	±2.5	±2.0
4.1 to 6 GHz	1+	2	0	±1.5	±1.0
6 to 8 GHz	3−	2	−11	±2.0	±1.5
8 to 10 GHz	2+	2	−7	±2.0	±1.5
10 to 12.0 GHz	3+	2	−12	±3.5	±2.0

* n = LO harmonic. Normal operating range specified; full range approximately same performance.
** The approximate relative displayed amplitudes of equal-amplitude input signals for the various harmonic mixing modes.

851B, 852A display section

Signal identification and self-check characteristics

Signal Identifier: front panel switch introduces precise frequency offsets to permit exact determination of LO harmonic number used for mixing. Direction of display shift indicates whether signal frequency is higher or lower than LO harmonic. Concentric push button switch permits reestablishment of reference position to facilitate identification of drifting signals.

Self-check: first IF of 2 GHz permits use of swept LO (tuned to 2 GHz) for calibration, alignment, and general performance checks. Stabilized LO provides swept RF signal with very high linearity over 10-MHz range for IF bandwidth calibrations.

General

IF output center frequency: 20 MHz (at rear panel BNC female connector for use with 851B or 852A Display Section).

RFI: conducted and radiated leakage are below requirements of MIL-I-16910C when the RF and display sections are fastened together with the bracket kit supplied.

Power: 115 or 230 V ±10%, 50 to 60 Hz, less than 275 W (less than 330 W, total, when display section power supplied through 8551B rear panel switched line output).

Weight: net 88 lb (39,6 kg); shipping 134 lb (60,3 kg).

Dimensions: 16¾" wide, 12-7/32" high, 18⅜" deep (425 x 310 x 467 mm).

Accessory items furnished: 7½ ft (2290 mm) power cable; rack mounting kit; cables to connect 8551B RF section to display section; 908A Termination for rear panel auxiliary LO output.

Price: Model 8551B, $7550.

851B display section

Display characteristics

Vertical display (7 cm full scale deflection):

Cathode-ray tube: 7.5 kV post-accelerator tube with P2 medium persistence phosphor (other optional) and internal graticule; light blue filter supplied; light-proof CRT bezel provides firm mount for oscilloscope camera.

CRT internal graticule: parallax-free 7 x 10 cm, marked in centimeter squares with 2-mm subdivisions on major horizontal and vertical axes.

CRT base line clipper: front panel control permits blanking of CRT trace base line, to allow more detailed analysis of low repetition rate signals.

Power: 115 or 230 V ±10%, 50 to 400 Hz, <55 W.

Weight: net 34 lb (15,2 kg); shipping 38 lb (17,1 kg).

Price: Model 851B, $2400.

Options: 07;P7 phosphor in lieu of P2 (amber filter supplied) no additional charge. 31;P31 phosphor in lieu of P2 (green filter supplied) no additional charge.

852A display section

Display characteristics

Cathode-ray tube:

Type: post-accelerator storage tube, 7300-volt accelerating potential; aluminized P31 phosphor; etched safety glass face plate reduces glare.

Graticule: 7 x 10 divisions (approximately 8.5 x 5.9 cm) parallax-free internal graticule; 5 subdivisions per major division on major horizontal and vertical axes.

Warranty: CRT specifications (persistence, brightness, storage time) warranted for one year.

Persistence:

Short: natural persistence of P31 phosphor (approximately 0 1 second).

Variable: (typically to 2 or 3 min).

Normal writing rate mode: continuously variable from less than 0.2 sec to more than 1 min).

Max. writing rate mode: typically variable from 0.2 to 15 s.

Erase: manual; erasure takes approximately 0.5 s; CRT ready to record immediately after erasure.

Brightness: greater than 100 footlamberts in NORMAL or VIEW; typically 5 footlamberts in STORE.

Vertical display (7 div full scale deflection):

Mode	Scale Factor	Accuracy**
LINEAR	Relative voltage/div	±3% full scale
SQUARE	Relative power/div	±5% full scale*
LOGARITHMIC	10 dB/div calibrated over 0 to 60 dB on CRT display	<±0.2 dB/ but not more than ±2 dB over full calibrated 60 dB CRT display range*

*Except pulse spectra on 1 MHz IF bandwidth.
**0 to 40°C.

CRT base line clipper: front panel control permits blanking of CRT trace base line to allow more detailed analysis of low repetition rate signals.

Power: 115 or 230 volts ±10%, 50 to 400 Hz, 75 W.

Weight: net 36 lb (16,1 kg); shipping 40 lb (18 kg).

Price: Model 852A, $3,400.

851B, 852A display section

IF characteristics

IF input center frequency: 20 MHz (accepts 20-MHz output from 8551B RF Section).

IF bandwidth: manual: bandwidths of 1, 3, 10, 100 kHz, and 1 MHz can be selected; AUTO SELECT: one of the above bandwidths automatically selected for best resolution of a CW signal for each combination of Spectrum Width and Sweep Time; Bandwidth Accuracy: individual bandwidths are calibrated within ±20%, bandwidth repeatability and stability typically better than ±3%.

IF gain set: 2-section attenuator provides 0 to 80 dB attenuation in 1-dB steps; one section provides 0 to 70 dB attenuation in 10-dB steps; the other 0 to 10 dB in 1-dB steps; IF Vernier provides continuous adjustment between 1-dB steps.

IF gain set accuracy: 70-db section, ±0.5 dB; 10-dB section, ±0.1 dB.

Sweep characteristics

Sweep time: six calibrated rates from 3 ms/div to 1 s/div in a 1, 3, 10 sequence; Vernier provides continuous adjustment between calibrated rates and extends slowest rate to at least 3 s/div.

Sweep time accuracy: ±3%.

Sweep synchronization: INTERNAL: sweep free-runs; LINE: sweep synchronized with power-line frequency; EXTERNAL: sweep synchronized with externally applied signal of +3 to +15 volts peak amplitude; BNC female input connector on rear panel; SINGLE SWEEP: sweep actuated by front panel pushbutton; panel light signifies duration of single sweep.

External sweep: input: 0 to +15 volt external signal (from 10 k ohm source impedance) results in full horizontal trace; BNC female connector on rear panel, direct-coupled; blanking: −5 volt external blanking signal required to blank retrace; BNC female connector on rear panel.

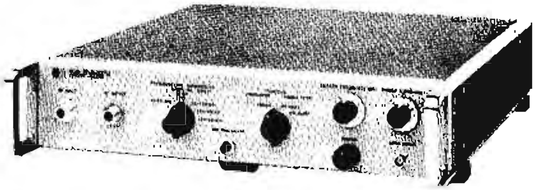
General

Output signals: vertical and horizontal signals applied to CRT are available for external applications; rear panel BNC female connectors: vertical: 0 to approximately −4 volts, open circuit, 4700 ohms source impedance; horizontal: 10 volts p-p ±0.3 volt, open circuit, sweep approximately symmetrical about 0 volts, source impedance 4700 ohms, IF test point (20 MHz) also provided, rear panel BNC female connector.

RFI: conducted and radiated leakage are below the requirements of MIL-I-16910C when the RF and display section are fastened together with the bracket kit supplied.

Dimensions: 16¾" wide, 6-21/32" high, 16⅜" deep behind panel (425 x 177 x 416 mm).

Accessory items available: 8442A 20-MHz Crystal Filter for increased resolution on 1-kHz IF bandwidth $225. 197A Oscilloscope Camera, $540.



8441A

The HP 8441A Preselector is a voltage-tunable bandpass filter designed primarily as an accessory instrument for the HP 8551B Spectrum Analyzer. The 8441A uses an yttrium-iron-garnet (YIG) filter as the tunable element. The YIG sphere is tuned by a current-controlled magnetic field. Passband of the filter is about 30 MHz; frequency range is from 1.8 to 12.4 GHz. When used with the 8551B, the preselector tracks the RF input frequency of the analyzer to reject all signals other than those desired. By automatically tracking the analyzer front end, the 8441A Preselector virtually eliminates multiple responses, image responses and spurious responses. The display on the CRT is greatly simplified as only the band of frequencies desired is present on the display. The center frequency of the display may be read directly on the 8551B tuning dial, eliminating the need for signal identification.

The 8441A can be used as a manually tuned narrow-band microwave filter anywhere in the 1.8 to 12.4 GHz frequency range. Continuous tuning is controlled by one dial on the front panel. Also, the filter may be tuned across its range by an internal sweep oscillator. Center frequency and sweep limits are front panel selected. When internally swept, the 8441A plus a broadband crystal detector and a sensitive oscilloscope form a simple spectrum analyzer.

Specifications, as preselector for 8551B

Frequency range: 1.8 to 12.4 GHz. Input connector, Type N female.

Insertion loss: insertion loss in the passband is less than 5 dB; minimum VSWR in the passband is less than 2:1. The filter reflects applied signals at frequencies other than the passband, so the VSWR is very high outside the passband.

Undesired response reduction: (reduction of responses of the 8551 to harmonic mixing modes other than the one preselected) At least 35 dB.

Contribution to 8551B frequency response:

Preselector Harmonic Mixing Mode	Addition to 8551B Variation
1±; 200 MHz IF	±2.5 dB over 2 GHz range
1+; 2 GHz IF	±2.5 dB over 2 GHz range
2±; 2 GHz IF	±3.5 dB over 2 GHz range
3±; 2 GHz IF	±4.5 dB over 2 GHz range

Limiting level: (maximum input level for <2 dB signal compression).
−20 dBm, 1.8 GHz to 2 GHz.
+10 dBm, 2 GHz to 12.4 GHz.

Absolute maximum input level: +30 dBm; 8551B Input Attenuator must be set to keep power to analyzer input mixer below 0 dBm to prevent damage to the mixer.

Reduction in 8551B local oscillator emission: (LO emission is 2 GHz to 4 GHz; level is typically 0 dBm).

2 GHz IF input: 50 dB (except when preselecting 2⁻harmonic mixing mode from 2 GHz to 4 GHz).

200 MHz IF input: 33 dB (1⁻harmonic mixing mode).
40 dB (1⁺harmonic mixing mode).

Dimensions: 16¾" wide, 3¼" high, 19" deep (425 x 83 x 483 mm).

Maximum 851 or 852 sweep rate: 10 milliseconds/div.

Connections to 8551B:
851B/852A Horizontal Output, BNC female.
8551B Preselector Drive Output, BNC female.
8551B RF Input, Type N female.

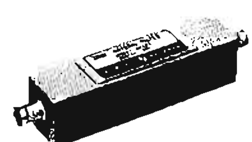
RFI: conducted and radiated leakage are below those specified in MIL-I-6181D and MIL-I-16910C.

Power: 115 or 230 volts ±10%, 50 to 400 Hz.

Weight: net 19 lb (8,6 kg); shipping 23 lb (10,5 kg).

Accessory items furnished: 7½-foot power cable, rack mounting kit; cables to connect preselector to 8551B.

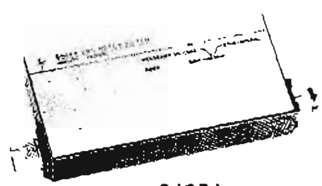
Price: Model 8441A, $2,950.



8442A

The HP 8442A 20-MHz Crystal Filter is a bandpass filter with a 20-MHz center frequency for use with the HP 8551B Spectrum Analyzer. The filter, which has a 2-kHz passband, improves the skirt characteristics of the 851/852 display section of the analyzer for greater resolution of closely spaced signals. Filter bandwidth at the 60-dB points is less than 10 kHz. Small in size, the filter is easily connected in the 20-MHz line between the 8551B and the display sections of the analyzer.

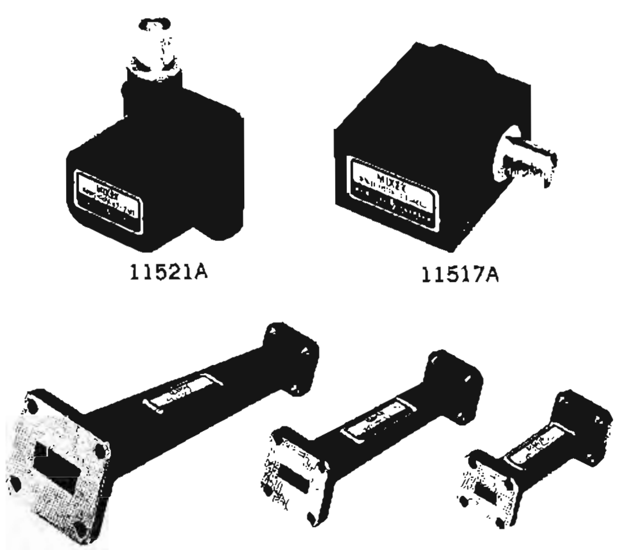
Price: HP 8442A, $225.



8439A

8439A 2-GHz notch filter

Model 8439A has an extremely narrow rejection notch (2 MHz at 60 dB down) at 2 GHz, thereby permitting observation of broadband signals without interference from signals at the 2-GHz IF (evidenced by the raising of the entire base line on the CRT). Price: HP 8439A, $240.



11521A 11517A

11518A 11519A 11520A

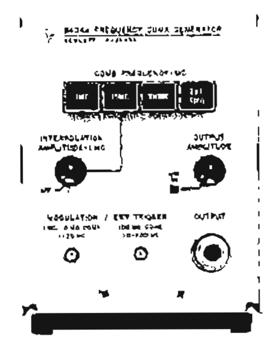
External waveguide mixers, adapters

External waveguide mixers 11517A and 11521A permit direct observation of signals in waveguide systems. The 11517A covers 12.4 to 40 GHz and requires adapters 11518A, 11519A, 11520A as transitions to P-, K-, R-band waveguide respectively. The 11521A Mixer covers X-band (8.2 to 12.4 GHz). Price: HP 11517A Mixer (12.4-40 GHz), $160, 11518A Adapter (12.4-18 GHz), $75; HP 11519A Adapter (18-26.5 GHz), $75; HP 11520A Adapter (26.5-40 GHz), $75; HP 11521A Mixer (8.2-12.4 GHz), $75.

K15-8551B

K15-8551B up-converter

The K15-8551B extends the lower frequency limit of the 8551B spectrum Analyzer from 10 MHz to 10 kHz. With a sensitivity of about −107 dBm (1 μV) throughout this range, the Up-converter/Spectrum Analyzer combination is equally well suited to the laboratory and the field. For example, the combination can be used in the design of low-level transistor oscillators; it can also serve as a spectrum-surveillance monitor for control of interference in radio communication. For maximum flexibility, the up-converter includes an input attentuator which provides up to 120 dB of attenuation in 10-dB steps plus an amplifier with 20 or 40 dB of gain. Price: HP K15-8551B, $1555.



8406A

8406A frequency comb generator

Model 8406A provides frequency markers spaced 1, 10, and 100 MHz apart for frequency calibration of the spectrum analyzer. Because the markers are harmonics derived from 0.01% crystal oscillators, accurate determination of absolute as well as relative frequencies is possible. An external oscillator can be used to produce a comb with different spacing; or each of the output combs can be phase-modulated with external oscillators to produce sidebands about each comb signal, thereby facilitating interpolation measurements. The combs are useable from the fundamental to beyond 5 GHz. Price: HP 8406A, $575.

MEASURING TRANSMISSION AND REFLECTION MAGNITUDE AND PHASE

Microwave measurements, of necessity, are becoming more and more complex. Engineers today want full characterization of components, devices, and combinations of these components and devices. Amplitude measurement is no longer adequate in many cases. Full characterization of a microwave system can be obtained only by measuring the total amount of signal change caused when each component of the system is subjected to the conditions under which it will be used. Any device may be characterized using the simple flow graph of Figure 1. If each component

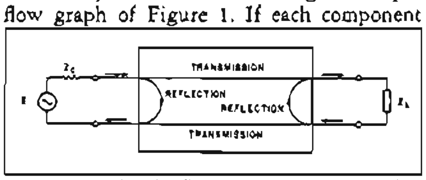


Figure 1. Simple flow graph representation of a microwave device.

in a system can be characterized in this form for both magnitude and *phase*, the flow graphs for each component may be combined into the final system configuration and an accurate prediction of the interaction of these components may be made. Without the phase relationships of the transmission and reflection parameters, only a gross approximation of the system response would be possible.

Consider, as in Figure 2a, a set of electronically tuned phase shifters for a phased-array radar system. If one antenna signal leads that of the second antenna by 90°, then the pattern of Figure 2b will be produced. The pattern of Figure 2c will be produced if the signal lagged by 90°. Correct phase characterization of the system allows the response to be predicted. Phase calibration of the phase shifters would allow the radiation pattern of the array to be aimed without physically moving the antennas.

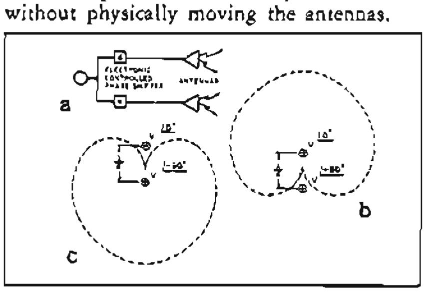


Figure 2. Phase-shift allows prediction of pattern direction, hence electronically steered antennas.

For assurance of maximum power transfer from transmission line to transmitting antennas, the input impedance of the antenna and output impedance of the cable must be complex conjugates. Determination of magnitude and phase relationships of the reflected signals at the ports in question allows a matching network to be inserted to accomplish this match. The amplitude and phase response of the matching network must also be known.

If the resonant frequency of a crystal must be known accurately, Figure 3, its phase response versus frequency provides a much more accurate readout than would a direct impedance readout. The phase shift of a reflected signal from the crystal will pass through 0° at its series resonant and then its parallel resonant frequencies. The impedance of the crystal slowly becomes small as it approaches series resonance and then peaks at a very large value for parallel resonance. The phase response, as in Figure 3, displays a very precise characteristic curve which changes sharply at the frequencies of interest.

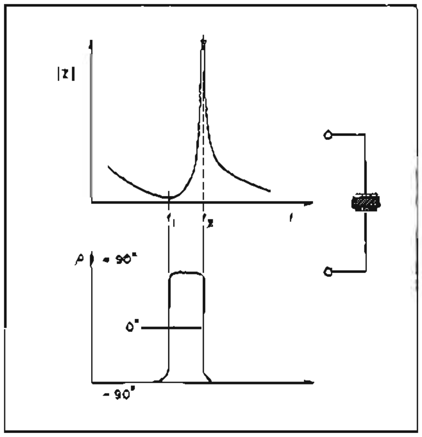


Figure 3. Phase response of crystal and selective tuning of readout device allows crystal response to be measured quickly and accurately.

Tracking detector

A new phase and amplitude tracking detector (HP 676A) combined with the Hewlett-Packard 675A Sweeping Signal Generator is the first of its kind to provide swept phase and amplitude information over the 10-kHz to 32-MHz frequency range. The dual channel approach provides 360° of phase measurements with continuous phase shift over the entire range. Because the swept frequency can be chosen anywhere in the 10-kHz to 32-MHz range, this technique is ideal for both narrow and broadband frequency sweeps of both amplitude and phase.

Transfer characteristics, impedance plots, dynamic input and output impedance, system flatness, return loss, time delay, small signal analysis, and open- and closed-loop response are some of many practical applications made possible by using the HP 675A/676A. A great advantage of the HP 676A tracking detector over most broadband detectors used in sweeping signal generators is that the 676A detects only the fundamental swept output of the sweeper, thus eliminating unwanted signals and noise often only 30 dB down from the desired signal. The 675A/676A dynamic range (80 dB) offers innumerable advantages. High-Q filters often attenuate signals as much as 80 dB, and low level signals are lost in the noise levels of most detectors. The ability of the 675A/676A to compare a device under test against a known standard, its capability to display amplitude and phase simultaneously on an oscilloscope, and its overall flexibility make the 675A/676A Network Analyzer a significant instrument for making phase and amplitude measurements. Refer to pages 466 and 411-419 for additional information.

Vector voltmeter

The Model 8405A Vector Voltmeter is a dual-channel RF millivolt meter and phase meter. It reads the absolute voltages on either of two channels and simultaneously determines the phase relationship between them. Its frequency range is 1 to 1000 MHz. The vector voltmeter is shown in Figure 4.

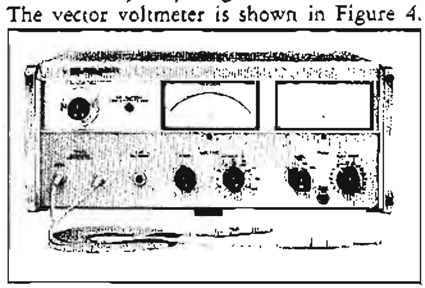


Figure 4. HP 8405A Vector Voltmeter.

CW measurements over this frequency range are made by means of sampling circuitry which converts the RF frequency to a 20-kHz IF frequency for processing. The conversion process is achieved by harmonic frequency conversion in which an oscillator is automatically tuned to sampling frequency such that the RF frequency minus a harmonic number times the VTO frequency is always equal to 20 kHz. This sampling technique provides a dynamic range greater than 90 dB. This large dynamic range is achieved by allowing a maximum voltage of 1 volt on each of the two RF probes with a residual system noise level of less than 10 microvolts.

To measure the transmission characteristics of a device fully, the A channel probe on the 8405A must be sampling an unchanging reference signal. By sampling this same signal with the B channel probe, an amplitude and phase reference calibration may be obtained. A 10°/step phase offset and continuous vernier allow the phase calibration between A and B to be conveniently set at zero on the phase meter on the ±6° range. A range switch allows full scale ranges of ±6, ±18, ±60, ±180 degrees. The amplitude meter range begins at 1 volt full scale and ranges in 10-dB steps down to 100 microvolts full scale.

Figure 5 shows a typical setup for measuring the transmission characteristics of an unknown device. Note the inclusion of the power splitter to provide A and B channels, the probe tees to provide isolation of the probe from the measurement and the 50-ohm terminations to eliminate reflections in the system.

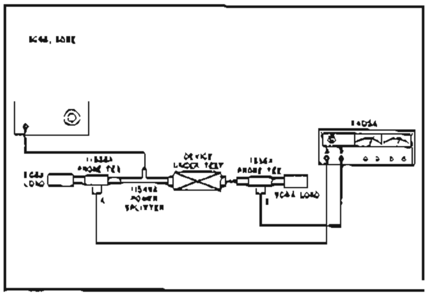


Figure 5. Transmission tests for phase and amplitude response (attenuation or gain) of a test device can be made over a dynamic range greater than 90 dB.

The vector voltmeter does not need a highly stable source because any drift in frequency is compensated by the automatic tuning circuitry. As frequency changes slightly, the phase-lock circuitry tunes the voltage-tuned oscillator until the IF frequency equals 20 kHz. The signal source may have harmonics present which will be converted, through the sampling process, to harmonics of the IF frequency. A 1-kHz pass band in the IF stage eliminates these harmonics and the voltage and phase of the fundamental are read out.

Circuits may be probed in much the same manner as is done with oscilloscopes. The absolute voltages at the points of contact of both probes with the circuit and the phase difference of the signals at those points may be read without loading the circuit because of the high impedance of the probes. However, as frequency increases, even the small shunt capacitance of the probes becomes a factor and the probe tees must be used.

The input impedance or, more precisely, the complex reflection coefficient at the input of the test device, can be measured as shown in Figure 6. This technique, called a "$1 + \rho$ technique," is useful over the full frequency range of the vector voltmeter. The vector

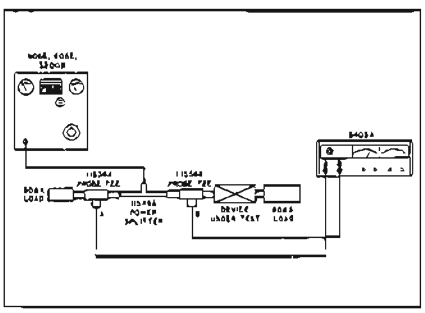


Figure 6. Equipment setup for measuring the reflection coefficient of a device with the $1 + \rho$ technique.

voltmeter is set up without the test device in place for calibration. A reading of unity (1 mV is generally a good figure) full scale is obtained. The device is then inserted and the incident plus the reflected signal is read giving a $1 + \rho$ reading on the vector voltmeter. If the phase shift is referenced to zero during calibration, the phase of the reflected signal can also be read by this method. Details on setup and use of the 8405A can be found in Application Note 77-3.

For frequencies above 100 MHz, reflectometer systems may be used to determine the reflection coefficient of a device. Figure 7 shows a reflectometer setup using the vector voltmeter. The system is calibrated with

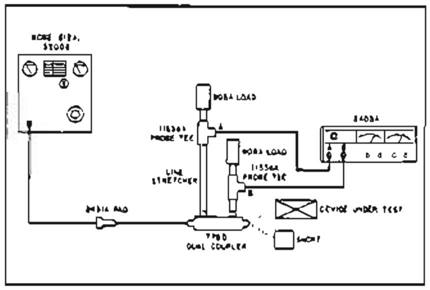


Figure 7. Amplitude and phase of reflected signal from test device can be measured directly using dual directional coupler as shown.

respect to a short circuit at the test port of the coupler which gives a reflection coefficient of $1\underline{/180^\circ}$. This is referenced on the meters of the 8405A and the device is then connected. The reflection coefficient is the ratio of the reflected voltage read with the device connected to the reflected voltage read with the short connected. The phase may be read directly if the phase meter is referenced correctly.

Network analyzers

The HP Model 8410A Network Analyzer (Figure 8) is a unique instrument which covers the frequency range of 100 MHz through 18 GHz. It is capable of measuring the amplitude and phase relationships between two signals in both coaxial and waveguide transmission line. The network analyzer is capable of sweeping octave bands throughout its full frequency range. Here, as in the case of the 8405A Vector Voltmeter, harmonic frequency conversion from RF to IF is used. For swept-frequency measurements, this frequency conversion is accomplished in the 8411A harmonic frequency converter by means of an automatic phase-lock loop between the 8410A and the 8411A. The harmonic sampling technique allows the IF frequency to be held constant. Any deviation from this constant IF is then detected and a signal proportional to the difference is used to tune a voltage-tuned oscillator so that a constant IF frequency is preserved.

The network analyzer must have some means by which the power can be split into reference and test channels. There are a variety of methods for splitting power. The simplest is the power splitter (Figure 9a) used with the vector voltmeter. The path lengths of the two channels are approximately equal. The critical factors with such a power splitter are frequency response and relative tracking of the two channels. The power splitter can be used for transmission gain/attenuation tests.

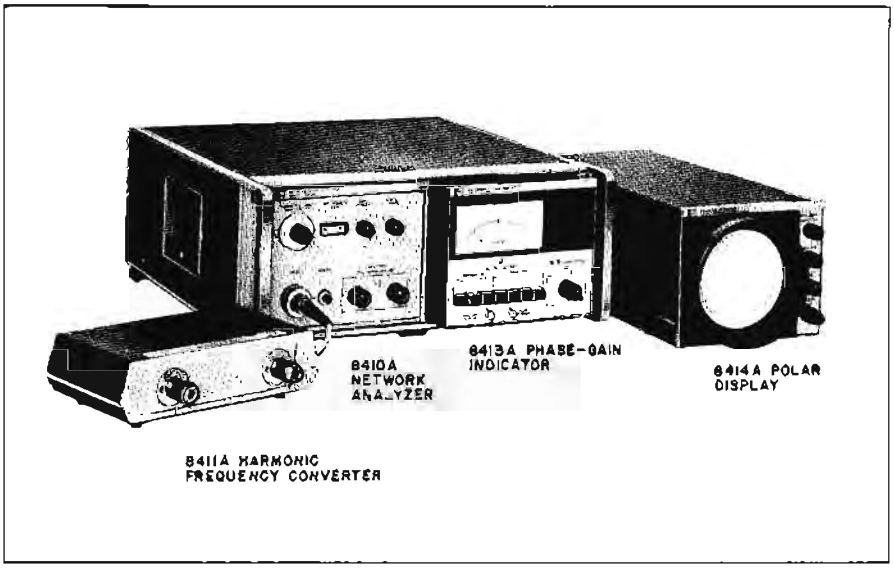


Figure 8. Hewlett-Packard Model 8410A Network Analyzer.

A second method for splitting power is to use a 3-dB coupler (Figure 9b). The path lengths will not necessarily be equal and allowance must be made for the coupling curves of the output ports of the coupler. Meaningful display for swept-frequency would be difficult due to the ratio readout of the network analyzer.

Still another method of splitting RF power for the network analyzer is two directional couplers as in Figure 9c. The first coupler

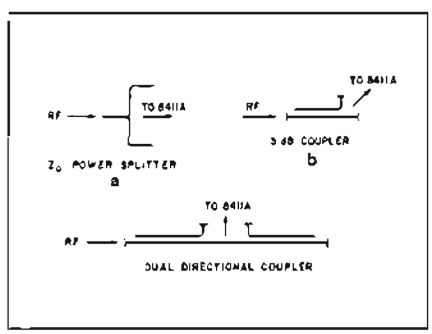


Figure 9. Reference and test channels for the network analyzer may be obtained using various methods such as a) power splitters, b) 3-dB couplers, c) dual directional or back-to-back couplers. The second coupler in c would be turned around for transmission measurements.

obtains incident power for the reference channel, the second obtains power for the test channel. Orientation of the second coupler for reflection tests or transmission tests would be chosen by the user. The path lengths of the two channels are unequal, the coupler outputs must track with frequency, and the couplers must be wide band with high directivity. The coupling coefficient of the two couplers should be the same.

Assuming good tracking, wide band frequency coverage, and reasonable frequency response characteristics, it is still necessary to equalize the lengths of the two channels to allow swept phase measurements. By adding a line stretcher in one of the channels, it is possible to equalize the lengths and, in some cases, measure the actual length of devices by observing the swept phase shift as the line stretcher is adjusted. No linear phase shift as a function of frequency is indicative of equal path lengths between reference and test channels.

Once this power split is accomplished, all measurements can be made using the network analyzer in terms of a set reference in the reference channel. The reference channel is also used to regulate any common-mode variations in power. An AGC amplifier in the reference channel, in conjunction with its feedback circuitry, compensates for as much as 20 dB variation in the input power. The correction signal is also fed to a matched AGC amplifier in the test channel. Any common-mode variations will thus be compensated and a leveled signal source is unnecessary.

With the common-mode variations in RF power compensated by the AGC amplifiers in the network analyzer, it is now possible to measure the ratio of the test channel signal to the reference channel signal directly. Any deviation in the test channel can now be read directly from one of the plug-in modules which plugs directly into the 8410A main frame.

The 8413A Phase Gain Indicator has a meter readout for CW measurements or analog outputs at 50 millivolts/dB and 10 millivolts/degree for swept-frequency readout on an oscilloscope or an X-Y recorder. The 8413A also has a rear-panel output which is linear 0-1 volt proportional to the ratio between the reference and test channels. The data can also be read on a linear polar readout, the 8414A Polar Display Unit, with linear radial scale for ratio of test to reference channel at the input ports of the 8411A. This display is a CRT display capable of making either swept-frequency or CW measurements. The use of the 8413A plug-in module allows direct linear readout of both amplitude in dB and phase in degrees as a function of frequency. This type of readout is useful for the conventional method of displaying the amplitude and phase response of such devices as filters, amplifiers, and attenuators. The 8414A lends itself more readily to the measurement of amplitude and phase of reflected signals when measuring impedance. This becomes useful for direct impedance readout when a Smith Chart overlay is placed on the CRT face.

The network analyzer can be tuned very simply for swept-frequency measurement. A front panel dial indicates the proper position of the coarse frequency control for bracketing the range of frequencies to be swept. Once the frequency range to be swept has been bracketed on the dial, a sweep stability control is adjusted to maintain phase lock across the full range of frequencies. This tuning is done simply and quickly by watching the trace of amplitude or phase on an oscilloscope. A swept-frequency display of the response of an unknown device allows tuning of the device under test to get the proper response at a particular frequency and still allows the effect of that tuning to be observed at other frequencies in the band of interest. Swept-frequency measurements also allow rapid viewing of amplitude and phase response of devices over wide frequency ranges.

With the broad frequency range of the 8410A Network Analyzer, it is possible to observe several octave bands in minutes by merely switching the coarse frequency control knob on the system. This eliminates changing the transducer unit every time an octave band is changed.

Transmission measurements

When measuring the characteristic amplitude and phase response of a device to be inserted in a transmission line there are generally two important types of measurements. The first type is that of viewing the wide dynamic response of the device under test and the second is viewing the wide scale blowup of some particular part of that wide dynamic range, even at an attenuation level of 50 dB or at a gain of 40 dB.

Wide dynamic range

The 8410A Network Analyzer will measure more than 60 dB of attenuation or 40 dB of gain in a single measurement. The swept-frequency measurement of a bandpass filter with at least 60 dB of rejection may be viewed with completely flicker-free display as in Figure 10. Due to the harmonic sampling technique and the fast response time of the AGC circuitry and phase-lock circuitry, the sweep oscillator can sweep at least 150 GHz/s and remain phase-locked. A sweep reference connection from the rear of an HP 8690B sweeper to the rear of the 8410A allows phase-lock at sweep speeds exceeding 600 GHz/s.

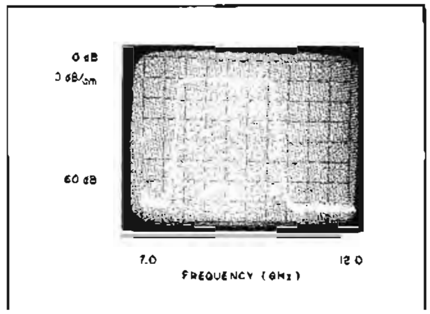


Figure 10. Swept-frequency display of an 8-10 GHz bandpass filter. Scale: 10 dB/cm vertical; 500 MHz/cm horizontal. Sweep speed: 0.01 second.

A typical transmission test setup is shown in Figure 11. The 8740A Transmission Test Unit (Figure 12) is a combination power splitter and line stretcher which operates from dc through 12.4 GHz and is usable to 18 GHz. The line stretcher allows electrical length adjustments between channels of up to 30 cm for phase-balancing the two channels. A 10-cm mechanical extension allows compensation for the physical length of a device. Additional sections of rigid 10- or 20-cm air line may be added to the reference channel to compensate for any extra physical length. Hence, the response of a test device with more than 60 dB of insertion attenuation may be viewed. The test channel gain on the network analyzer mainframe may be adjusted to allow increased resolution about any point in the 60-dB "window" of the system. A device having 60 dB of attenuation may be viewed about the 0-dB reference line.

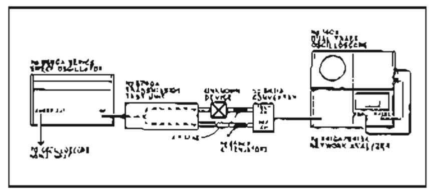


Figure 11. Typical test setup for measuring swept or CW phase shift and attenuation (gain) through a device.

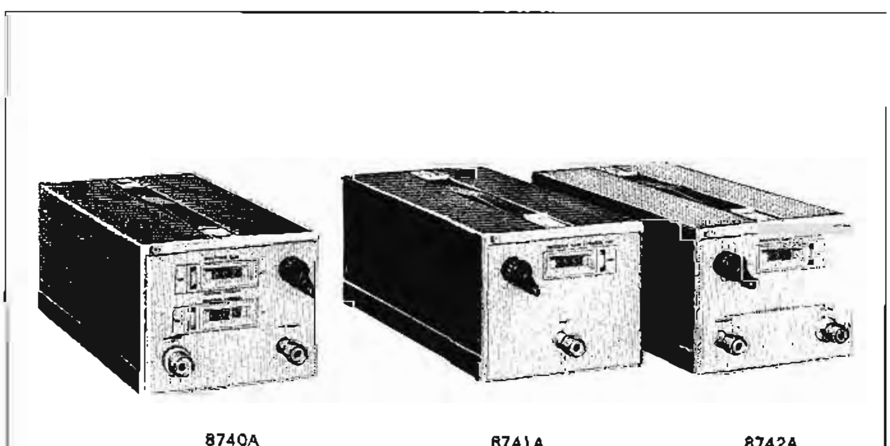
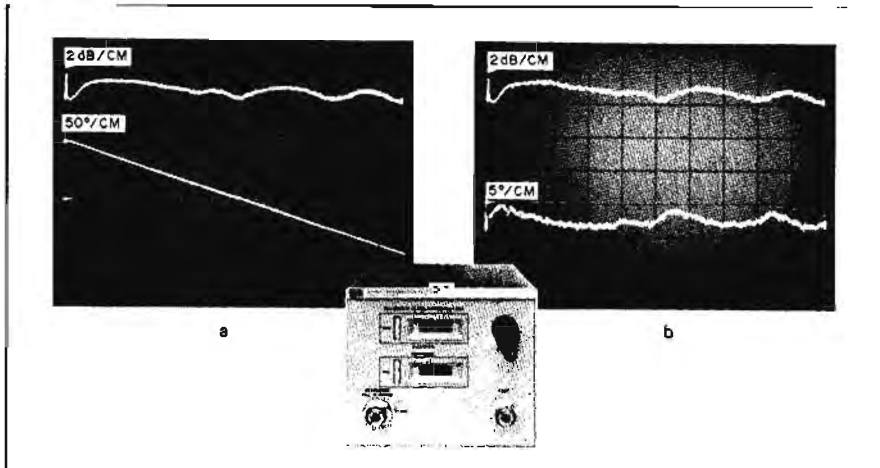


Figure 12. Hewlett-Packard transducer units. 8740A transmission test unit, dc - 12.4 GHz; 8741A reflection test unit, 100 MHz - 2.0 GHz; 8742A reflection test unit, 2.0 GHz - 12.4 GHz.

High resolution measurements

For a device such as the filter of Figure 10, the wide variation in response due to signal rejection is very important. Equally important, however, is the small insertion loss (residual attenuation) present in the passband. The high resolution readout of nonlinear phase shift as a function of frequency is also important. Figure 13a shows the insertion phase and attenuation of a PIN modulator. Figure 13b shows the same response with the linear phase shift compensated by the calibrated line stretcher allowing a scale change of 10:1 for high resolution.

Direct phase and amplitude comparison between a standard device and several other devices can be achieved by placing the standard in the reference channel and the device to be compared in the test channel. The swept response will then be the actual deviation of the test device from the standard as a function of frequency. This technique is useful in matching cables, amplifiers, modulators, etc. An X-Y recording of the response of each test device with respect to the standard allows rapid accept/reject tests for production lines.



gure 13a. Insertion phase and attenuation of a PIN modulator showing both amplitude frequency response and the linear phase shift due to excess electrical length.

Figure 13b. The excess electrical length of the PIN modulator of Figure 13a has been compensated by the transmission unit line stretcher. The phase display now shows the "nonlinear" portion of the phase transmission. Note the phase scale change to 5°/cm. The excess electrical length over coaxial air line is read from the transmission unit directly as 6.0 cm.

Reflection measurements

All methods for measuring the mismatch of a device when it is placed in a perfect transmission line must, in some manner, detect the signal reflected from the device with respect to the signal incident upon the device. Detecting probes or point contact diodes can detect the amplitude of such a signal but they do not respond to phase information. By using a high directivity reflectometer system, such as the HP 8741A (.11 to 2.0 GHz) or HP 8742A (2.0 to 12.4 GHz) (Figure 12), in conjunction with the 8410A Network Analyzer, the phase and amplitude of that reflected signal can be measured. Figure 14 shows a reflection test setup for measuring the reflection coefficient magnitude and phase by means of wideband reflectometers. A line stretcher allows for phase-balancing of the reference and test channels. The line stretcher compensates for as much as 15 cm of reference plane extension from the plane of connection on the reflection unit test port.

If one were interested only in the amplitude of the reflected signal, the 8413A Phase-Gain Indicator and an oscilloscope would allow swept or CW readout of return loss in dB. The phase information is also available if desired. A reflectometer calculator is available from Hewlett-Packard for making rapid conversions between return loss, VSWR, and reflection coefficient magnitudes.

By measuring the reflection coefficient of a device, its impedance may be read as the reflection is plotted on a Smith Chart. If only the magnitude of the reflection is known, the plot of reflection coefficie . would be a circle on the Smith Chart centered at unity with a radius proportional to the magnitude of the reflection coefficient (see Figure 15). By referring the measurement to a short circuit with a reflection coefficient $\rho = 1 \underline{/180°}$, and measuring the magnitude and phase shift of the reflected signal, impedance can be read as a single value because the reflection coefficient is now a point as shown in Figure 16.

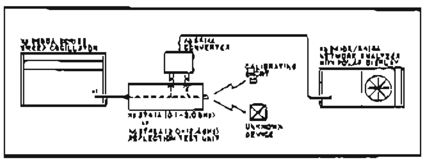
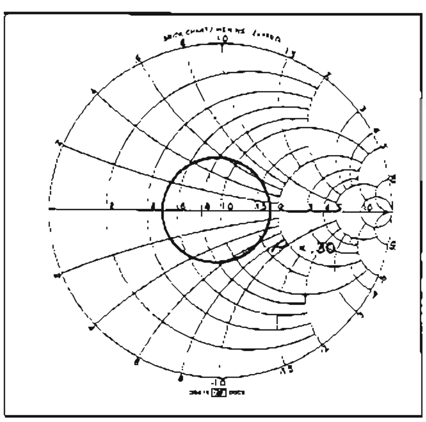


Figure 14. Reflectometer setup for Smith Chart impedance measurements. Readout of both the reflection coefficient magnitude and angle can also be made directly from polar display unit.



gure 15. Plot of the possible impedances r a reflection coefficient of $\rho = 0.30$ when only the magnitude is known.

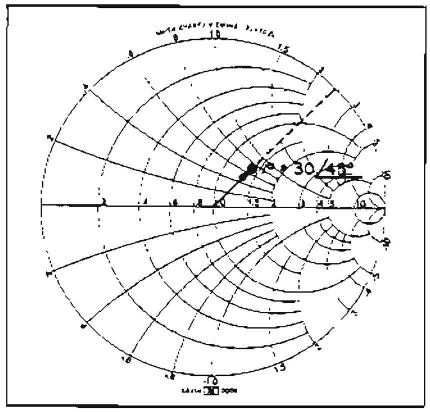


Figure 16. Plot of the impedance for a reflection coefficient of known magnitude and phase $\rho = 0.30 \underline{/45°}$.

Using reflectometer systems 8741A and 8742A, the reflection coefficient (magnitude *and* phase), can be measured and read out in polar coordinates on the 8414A Polar Display Unit. A Smith Chart overlay can then be placed on the CRT face and normalized impedance can be read directly as a function of frequency. Using the 8741A and 8742A broadband reflectometers, which cover frequency ranges of .100 GHz through 2.0 GHz and 2.0 GHz through 12.4 GHz respectively, it is possible to characterize a device through 7 octaves with only one minor change of equipment.

The step attenuator on the 8410A mainframe allows the test channel gain to be varied for high resolution readout of low reflection coefficients. By decreasing the test channel gain, the output reflection of an active device, such as a tunnel diode (Figure 17), can be measured. The compressed Smith Chart overlay used in Figure 17 provides for direct readout of negative impedance.

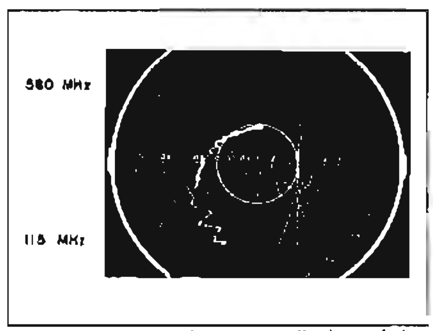


Figure 17. Swept-frequency display of impedance of a tunnel diode when it is biased in the negative impedance region.

Reflection and transmission measurements

The introduction of reliable, high quality, wide-band coaxial switches, such as the HP 8761A, brought about an arrangement of wide-band directional couplers such as the HP 778D and 779D, which allows reflection *and* transmission tests of an unknown device. The ability to measure both the input impedance and the transmission properties of a device using the same transducer saves time and money for the user. If the transmission and reflection characteristics can be measured with only one instrument setup, measurement accuracy will also be improved. A new measurement capability is achieved in determining the transmission and reflection characteristics of a two-port device at both ports with only one setup. The Hewlett-Packard Model 8743A Reflection/Transmission Test Unit in Figure 18 is capable of measuring the input impedance of a device and, by simply pushing a button, the transmission coefficient of that device from input to output. The Model 8745A S-Parameter Test Set in Figure 19 measures the input and output impedance and the forward and reverse transmission coefficients of a device with push-button ease.

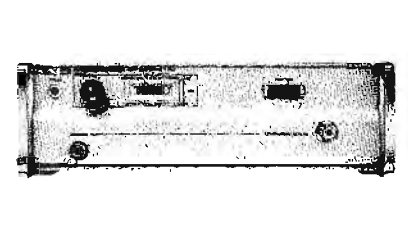


Figure 18. Hewlett-Packard Model 8743A Reflection/Transmission Test Unit.

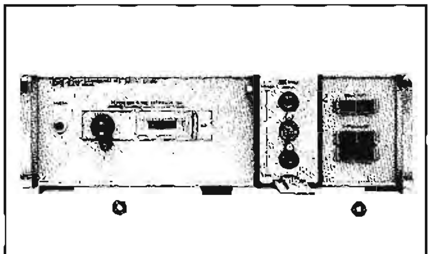


Figure 19. Hewlett-Packard Model 8745A S-Parameter Test Set.

To speed the overall measurement-design process, it is necessary to define components in terms of some universally accepted language. Networks have been characterized for many years in terms of z, y, and h parameters. At frequencies above 100 MHz, currents and a defined reference plane for an open circuit are difficult to measure. For these reasons, the microwave industry has found it necessary to define a set of descriptive network parameters which could be measured at very high frequencies.

Transmission and reflection coefficients of devices in terms of incident and reflected voltages are parameters measured by all microwave engineers. If these coefficients are defined in general terms and are measured in a system with a known characteristic impedance, they are given the title "scattering parameters." In Figure 20 (compare with Figure 1) the s parameters of a two-port device are named. They are like h, y, and z parameters because they describe the inputs and outputs of a black box. S-parameters have the inherent advantage of being measured while the device is terminated in its characteristic impedance or, more correctly, the characteristic impedance of the measuring system (50 ohms).

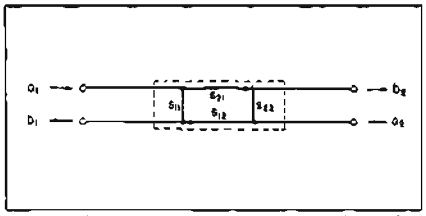


Figure 20. S-parameter representation of a two-port microwave device.

The outputs in Figure 20 can be related to the inputs by the equations:

$$b_1 = s_{11}a_1 + s_{12}a_2$$

$$b_2 = s_{21}a_1 + s_{22}a_2$$

When $a_2 = 0$, $s_{11} = \frac{b_1}{a_1}$, $s_{21} = \frac{b_2}{a_1}$.

And when $a_1 = 0$, $s_{12} = \frac{b_1}{a_2}$ and $s_{22} = \frac{b_2}{a_2}$

where a_1 and a_2 are the square-root of the incident power and b_1 and b_2 are the square root of the reflected power at ports 1 and 2 respectively. (For more details see "Two-Port Power Flow Analysis Using Generalized Scattering Parameters" by George Bodway, *Microwave Journal*, May 1967.)

To measure the scattering parameters of a device, the above condition for input power equal to zero must be satisfied. When measuring the input reflection, s_{11}, and the forward transmission, s_{21}, the incident power at port 2 must be zero. When measuring the output reflection, s_{22}, and the reverse transmission, s_{12}, the incident power at port 1 must be zero. This is accomplished by driving one port with a Z_0 source and terminating the other port in Z_0 characteristic impedance. (See Figure 21.)

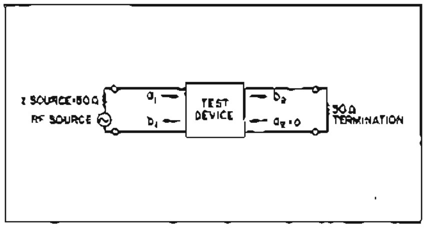


Figure 21. Measurement of s_{11} and s_{21} is accomplished by making $a_2 = 0$ with a Z_0 termination at port 2.

The characteristic impedance termination has the following advantages:

1. The termination is accurate at high frequencies.

2. No tuning is required to terminate a device in the characteristic impedance.

3. Broadband swept-frequency measurements are possible because the device will remain terminated in the characteristic impedance as frequency changes.

4. The termination enhances stability providing a resistive termination that stabilizes many negative resistance devices, which might otherwise tend to oscillate.

An advantage due to the inherent nature of s parameters is:

5. Different devices can be measured with one setup because probes do not have to be located right at the test device.

A typical display of s_{11} for a transistor is shown in Figure 22. The Smith Chart overlay allows direct impedance readout for the input of the transistor.

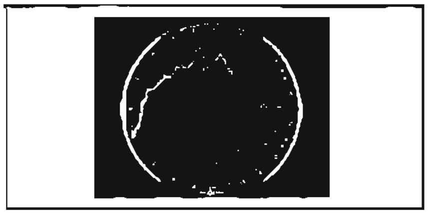


Figure 22. Swept-frequency display of s_{11} of a transistor with Smith Chart overlay for direct impedance readout. Frequency range :300 MHz to 700 MHz.

The ability of a tunnel diode to sustain oscillations, its negative impedance region, can be displayed using the 8745A. The photo display shown in Figure 17 shows the response of a tunnel diode biased for maximum tunneling (tuned while watching a swept-frequency display) over a frequency range of 115 MHz to 560 MHz. The network analyzer allows the full scale of the display to be adjusted for direct readout on a compressed Smith Chart. Fixtures which are capable of accepting various lengths of leads make characterization of transistors and diodes for any lead length relatively simple. The Hewlett-Packard transistor fixtures allow s parameter measurement on transistors, diodes, and FET's at frequencies up to 2.0 GHz.

If the rate of change of the phase of s_{21} or s_{12} is constant with respect to frequency for a given device, the ability of that device to pass a pulsed signal undistorted can be predicted. A linear phase shift as a function of frequency denotes constant "group delay." Group delay is defined as:

$$t_d = \frac{d\theta}{d\omega} = \frac{1}{2\pi} \cdot \frac{d\theta}{df}$$

where θ is the phase shift and ω is the radian frequency. A low-value, constant group delay is important in communication systems where several channels are carried on one link. If the group delay is not constant for all frequencies of interest, distorted information at the receiving end of the link is obtained. This is especially true of any pulse-coded communication system. Group delay can be read quickly and accurately from the swept display of phase when a test device is connected to the 8743A or 8745A. A typical display is shown in Figure 23.

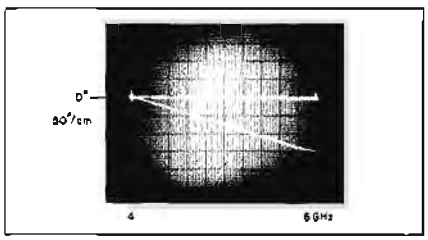
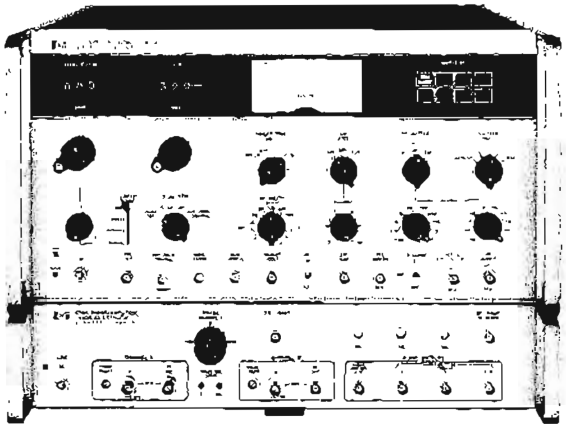


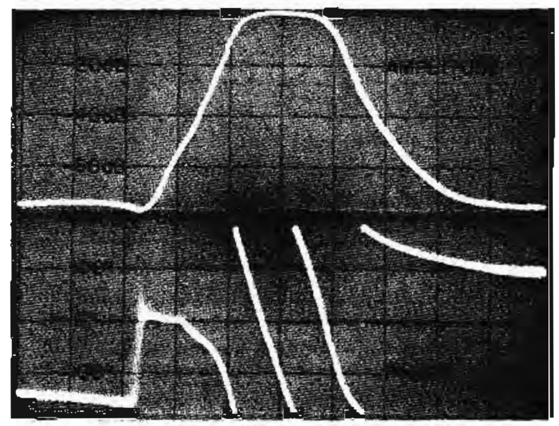
Figure 23. Linear phase shift indicates constant group delay for frequencies between 4 and 6 GHz. 150° phase shift in 2 GHz gives group delay of 11.9 nanoseconds.

A further advantage of a unit which allows pushbutton reflection and transmission measurements presents itself for antenna measurements. It is important to know the input impedance of an antenna as well as its transmission pattern as a function of azimuth and frequency. The Hewlett-Packard network analyzer system is a very effective instrument for making many necessary microwave measurements.

NETWORK ANALYZER
80 dB amplitude response/360° phase
Models 675A & 676A



Network Analyzer (675A/676A)



Phase and amplitude response of an LC filter displayed on a scope using 675A and 676A.

Description

Network Analyzer (675A and 676A). This is the first of its kind to provide swept phase and amplitude information over the 10 kHz to 32 MHz range. Both laboratory and production oriented, the 675A Sweeping Signal Generator and 676A Phase/Amplitude Tracking Detector system provides an amplitude response with 80 dB dynamic range, accompanied by 360° (or multiples of) phase measurement capability. Because the swept frequency can be chosen anywhere in the prescribed range, this technique is amendable to both narrow and broadband frequency sweeps for both amplitude and phase.

Transfer characteristics, impedance plots, dynamic input and output impedance, system flatness, return loss, time delay, small signal analysis, open and closed loop response are some of the applications that are made practical by amplitude and phase information obtained through a swept technique.

Start-stop, center and manual frequency sweep

The frequency can be manually positioned or automatically swept between two preset limits, or swept about a center frequency in calibrated increments. A frequency calibrated display with calibrated amplitude and phase is possible using a low frequency oscilloscope or x-y recorder. Along with the low residual FM (<70 Hz peak) low spurious and low noise (−85 dB) these capabilities permit accurate measurements of devices with ultra steep responses. A wide range of sweep times insures display accuracy regardless of the bandwidth of the circuit under test.

A bypass marker system superimposes markers on all phase and amplitude channels for easy frequency identification and calibration. 100 kHz and 1 MHz comb markers, and up to five individual single frequency markers can be made available in the 100 kHz to 32 MHz range. An external marker can also be used to further extend frequency identity. Markers may also be horizontally oriented.

Amplitude and phase

Four scope outputs (A, B, A-B, PHASE A-B) are provided at the front panel of the 676A Tracking Detector. A and B represent 80 dB of log amplitude dynamic range (50 mV/dB) for each channel. A-B is the log difference of the two channels. All are represented in linear dB. The PHASE A-B is a dc voltage linearly proportional (10 mV/degree) to phase from 0° to 360°.

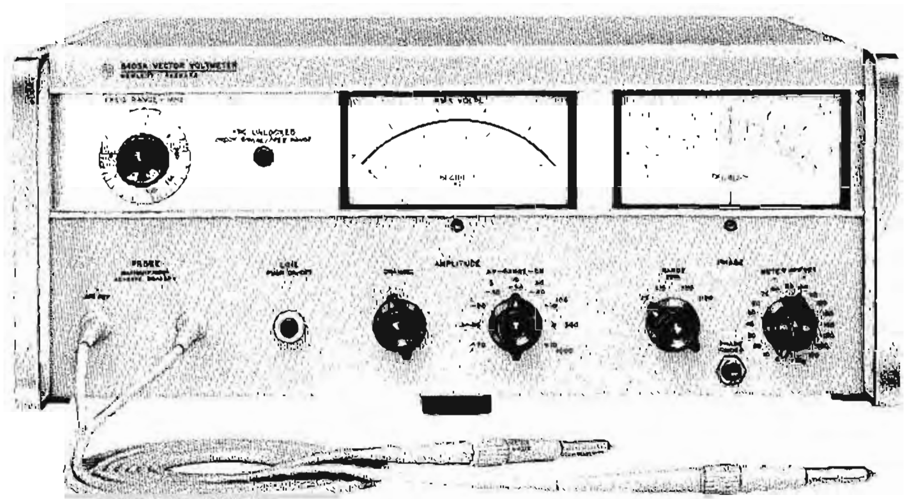
The RF power output of the 675A is divided in the 676A Tracking Detector so that an equal and in-phase voltage appears at the "RF OUT" connectors of both channel A and B (+2 dBm max into 50Ω). Typically the device under test is connected between "RF OUT" and "IN" connectors of one channel and a short jumper placed across the other channel. The amplitude of both channels are simultaneously adjusted over a 99 dB range in 10 dB and 1 dB steps plus vernier. To make using an oscilloscope or recorder more convenient a "CAL" is provided for the scope outputs to allow fine adjustment of the display. Phase is also conveniently calibrated using the 5° or 100° "PHASE CAL CHECK" buttons. Either pushbutton supplies a calibrated dc offset to the Y input of the oscilloscope allowing a quick check of phase calibration of the display. With the "PHASE CHANNEL A" control continuous 0° to 360° phase shift is provided in channel A.

For more phase resolution the sensitivity of the scope can be increased to provide 1°/cm with the PHASE CHANNEL.

Specifications

For complete specifications of the 675A Sweeping Signal Generator and 676A Phase/Amplitude Tracking Detector see pages 417-419.

VECTOR VOLTMETER
Accurate voltage and phase measurements, 1-1000 MHz — Model 8405A



8405A

The HP 8405A Vector Voltmeter measures the magnitude of and the phase difference between two voltage vectors from 1 to 1000 MHz. Since RF voltages have both magnitude and phase, simple voltage measurements tell only half the story. Much circuit design is virtually impossible without phase information; both magnitude and phase data are required to optimize circuit design.

The HP 8405A provides high accuracy and resolution; direct readout, and operating convenience, features which enable you to make RF voltage and phase measurements more easily than ever before. It reduces costs by minimizing equipment requirements, saves time by simplifying measurements, and increases effectiveness by extending capability in the RF range.

1-1000 MHz frequency range

The instrument uses phase-locked coherent sampling to translate 1- to 1000-MHz RF signals to 20-kHz IF signals. The IF signals retain the same wave shapes and the same amplitude and phase relationships as the original RF. Thus, the vector voltmeter's performance is related to what you might expect from a precision laboratory receiver.

Automatic tuning over an octave

You simply rotate a front-panel switch to select any of the 21 overlapping octave ranges which include the input signal frequency, and the automatic phase-locked tuning does the rest. To eliminate guesswork, a front-panel light tells you when the voltmeter is properly tuned. It can then follow slowly drifting signals automatically.

100 μV sensitivity, >90 dB dynamic range

Voltages from less than 100 microvolts to 1 volt can be measured on channel B of the 8405A, from less than 300 microvolts to 1 volt on channel A. (Channel A requires the higher input to operate the automatic tuning). External 10:1 dividers extend channel A and B measurements to 10 volts. Thus, readings can be taken over a 90- to 100-dB range. Either channel A or B voltages are read on a single front-panel meter by simply setting a switch. Both voltage and phase meters have rugged, reliable taut-band suspensions with mirror-backed scales individually calibrated to the meter movement.

The input signals are applied through convenient ac-coupled probes that are permanently attached to the instrument. These probes present a high input impedance (0.1 megohm shunted by 2.5 picofarads) for minimum loading effects when probing. The 10:1 dividers increase input impedance to 1 megohm shunted by 2 picofarads. The ac-coupling in the probes permits you to measure signals as much as 50 volts off ground. Output signals include the 20-kHz signals from each channel plus recorder outputs proportional to phase and amplitude.

360° phase range, 0.1° resolution

Phase is read on a zero-center meter with end-scale ranges of ±180°, ±60°, ±18°, and ±6°. The ±6° scale provides 0.1° resolution, and a meter offset selectable in precise 10° increments permits this resolution to be realized anywhere in the 360° range. Phase accuracy is ±1.5° at fixed frequencies and equal signal levels in channels A and B.

High selectivity, 1-kHz bandwidth

Although the sampling system employed in the 8405A results in wide frequency coverage, the actual measurement bandwidth in the 20-kHz IF preceding the voltage and phase measuring sections is only about 1 kHz, affording high selectivity. As a result, measurements are free from errors that might be encountered with a wideband system if signal harmonics or other spurious outputs were present.

VECTOR VOLTMETER

360° phase range, 100 μV sensitivity

8405A Vector Voltmeter

Specifications

Instrument type: two-channel sampling RF millivoltmeter-phase-meter, which measures voltage of two signals and simultaneously displays the phase angle between the two signals.

Frequency range: 1 MHz to 1 GHz in 21 overlapping octave bands (lowest band covers two octaves).

Tuning: automatic within each band. Automatic phase control (APC) circuit responds to the Channel A input signal. Search and lock time, approximately 10 ms.

Isolation between channels:

1 to 300 MHz: greater than 100 dB.

300 to 1,000 MHz: greater than 80 dB.

Maximum ac input: 2 V peak.

Maximum dc input: ±50 V.

Voltage range (rms):

Channel	1 - 10 MHz	10 - 500 MHz	500 - 1000 MHz
A	1.5 mV - 1.0 V	300 μV - 1.0 V	500 μV - 1.0 V
B	100 μV - 1.0 V	100 μV - 1.0 V	100 μV - 1.0 V

Range of each channel is extended to 10 V with 11576A 10:1 Divider.

Voltmeter characteristics:

Meter ranges: 100 μV to 1 V rms full scale is 10-dB steps. Meter indicates amplitude of the fundamental component of the input signal.

Voltage ratio accuracy: <0.2 dB.

Phasemeter characteristics:

Phase range: 360° indicated on zero-center meter with end-scale ranges of ±180, ±60, ±18, and ±6°. Meter indicates phase difference between the fundamental components of the input signals.

Resolution: 0.1° at any phase angle.

Meter offset: ±180° in 10° steps.

Phase accuracy: at single frequency ±1.5° (equal voltages at Channel A and B).

Phase jitter vs. Channel B input level

Greater than 700 μV: typically less than 0.1° p-p.

125 to 700 μV: typically less than 0.5° p-p.

20 to 125 μV: typically less than 2° p-p.

Accessories furnished: two 11576A 10:1 Dividers to reduce voltage input 10 to 1; two 10216A Isolators to eliminate errors due to the effects of changing test point impedance; two 10218A BNC Adapters to convert probe tip to male BNC connector; six ground clips for 11576A or 10216A; six replacement probe tips.

Input impedance (nominal): 0.1 MΩ shunted by approximately 2.5 pF; 1 MΩ shunted by approximately 2 pF when 11576A 10:1 Divider is used; 0.1 MΩ shunted by approximately 5 pF when 10216A Isolator is used. AC-coupled.

Residual noise: less than 10 μV as indicated on the meter.

Bandwidth: 1 kHz.

RFI: conducted and radiated leakage limits are below those specified in MIL-1-6181D and MIL-1-16910C except for pulses emitted from probes. Spectral intensity of these pulses is approximately 60 μV/MHz; spectrum extends to approximately 2 GHz. Pulse rate varies from 1 to 2 MHz.

20-kHz IF output (each channel): reconstructed signals, with 20-kHz fundamental components, having the same amplitude, waveform, and phase relationship as the input signals. Output impedance, 1000 Ω in series with 2000 pF; BNC female connectors.

Recorder output:

Amplitude: 0 to +1 V dc ±6% open circuit, proportional to voltmeter reading in volts. Output tracks voltage reading within ±0.5% of full scale. Output impedance, 1000 Ω; BNC female connector.

Phase: 0 to ±0.5 V dc ±6%, proportional to phasemeter reading. External load greater than 10,000 Ω affects recorder output and meter reading less than 1%. Output tracks meter reading within ±1.5% of end scale; BNC female connector.

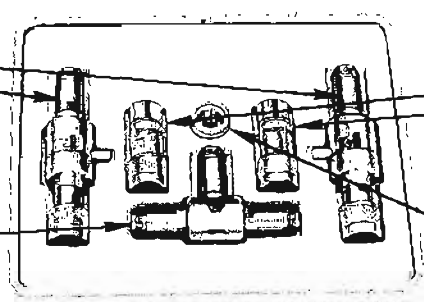
Power: 115 or 230 V ±10%, 50 to 400 Hz, 35 W.

Weight: net, 30 lb (13,5 kg). Shipping, 35 lb (15,8 kg).

Dimensions: 18⅜" x 7" x 16¾" (467 x 177 x 425 mm).

Price: Model 8405A, $2,750.

Option 02. Linear dB scale uppermost on voltmeter. Add $25.00.



8405A

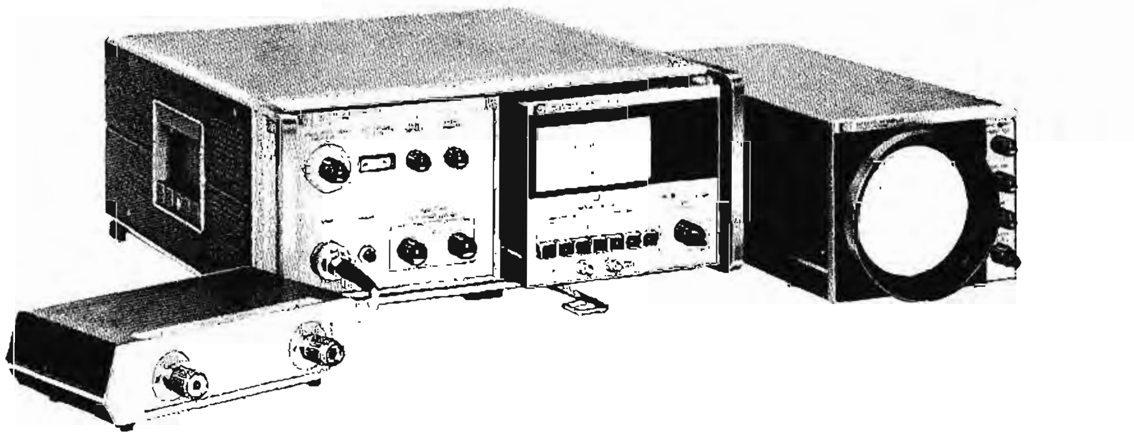
11570A Accessory Kit, required for measurements in 50 Ω systems. $318.00.

FULL NETWORK CHARACTERIZATION
0.11 to 12.4 GHz
Model 8410A

8410A Network Analyzer

• ATTENUATION • PHASE • GAIN • IMPEDANCE • ADMITTANCE • COMPLEX REFLECTION COEFFICIENT

110 MHz to 12.4 GHz With One Simple System!



This one compact, low cost system measures all network parameters from 110 MHz to 12.4 GHz.

Complete description of microwave devices

Phase and amplitude data give complete description of microwave devices. A powerful tool for component and systems design and test without ambiguity.

Direct readout with choice of display

Plug-in meter indicates magnitude and phase at spot frequencies. Wideband auxiliary outputs for swept displays on oscilloscope or X-Y recorder.

Plug-in CRT display for swept polar and Smith Chart readout. Auxiliary outputs for higher resolution X-Y plots.

Add display versatility with future plug-ins.

Fast sweeps over octave bands

Swept displays for fast testing over full band. Rapid sweep for dynamic CRT display—make adjustments to devices while viewing overall effects.

Wide dynamic range—high resolution

60 dB amplitude and 360° phase displays. Use precise offset controls to read amplitude and phase to 0.1 dB and 0.1 degree resolution. No phase ambiguity—meter indicates phase sense directly.

Easy setup

Transducer units complete the system; all RF hardware is connected and pre-calibrated inside convenient modules. They provide:

—A calibrated variable measurement plane (line stretcher) to determine electrical and physical length of unknown devices in transmission tests. To eliminate graphical Smith Chart transformations in reflection tests.

—Rigid coaxial air line for stable RF connections. Adjustable RF line length for easy connection to unknown without flexible cables.

—Specified overall system accuracy for easier error analysis.

—Pushbutton selection of device parameters.

—Swivel joints and air lines for connection to any geometrical configuration.

Accurate

Precision components assure basic system accuracy. Even greater accuracy is possible at spot frequencies because vector errors, such as reflectometer directivity, can easily be calibrated out. This is a direct benefit when measuring both phase and amplitude.

System description

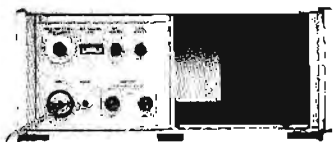
The Hewlett-Packard Network Analyzer consists of the 8410A mainframe, 8411A Harmonic Frequency Converter, and the 8431A Phase-Gain Indicator or 8414A Polar Display Unit plug-in modules. The 8410A/8411A provide automatic RF tuning and IF conversion to 20 MHz over frequencies from 100 MHz through 12.4 GHz for swept or CW measurements. The phase and amplitude relationships of the RF are preserved in the IF. The 8410A/8411A include sampling and automatic tuning circuitry, IF amplifiers, precision IF gain control, amplitude and phase verniers, and frequency range selection.

The 8413A includes phase and amplitude circuitry, meter readout, log converter circuitry, and calibrated analog outputs at 50 mV/dB and 10 mV/deg. Expansion of the meter scale is accomplished with pushbutton ease in ranges of ±3, ±10, ±30 dB and ±6, ±18, ±60, ±180 degrees full scale. Phase offset in 10-degree steps allows higher resolution for phase readout. The 8414A includes polar conversion circuitry for direct polar readout of ratio coefficient and phase shift. Full scale ratio is dependent upon the gain setting on the 8410A mainframe.

A transducer unit or units selected to suit application and frequency range completes the system.

NETWORK ANALYZER
Broadband measurement systems to suit your application

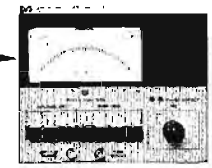
8410A Network Analyzer System



8410A Network Analyzer — Mainframe for readout modules includes tuning circuits, IF amplifiers, and precision IF attenuator.

8411A Harmonic Convertor — Converts 2 RF input signals (110 MHz-12.4 GHz) into 20 MHz IF signals.

Phase/Gain



8413A Phase-Gain Indicator

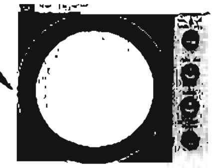
Meter readout module for 8410A Mainframe. Provides CW display of relative amplitude and phase between input signals. Auxiliary outputs provide swept frequency displays on a scope or X-Y recorder.

11587A Accessory Kit

Accessories normally used for transmission and reflection tests contained in sturdy carrying case.

Couplers

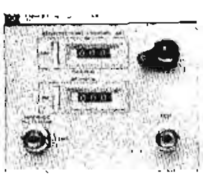
Polar Display



8414A Polar Display

CRT polar display module for 8410A Mainframe. Provides swept frequency display of relative amplitude and phase between input signals. Smith Chart overlays give direct impedance readout. Auxiliary X-Y outputs allow high resolution polar and Smith Chart plots.

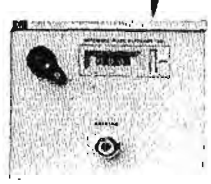
Transmission Only
0.10 - 12.4 GHz



8740A Transmission Test Unit

Transmission measurements only. RF input signal is split into reference and test channels. Calibrated line stretcher in test channel varies the linear phase shift between channels.

Reflection Only
0.10 - 2.0 GHz



8741A Reflection Test Unit

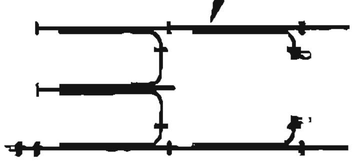
Reflection measurements only. Wide band reflectometer. Calibrated line stretcher in reference channel varies the linear phase shift between channels.

Reflection Only
2.0 - 12.4 GHz

8742A Reflection Test Unit

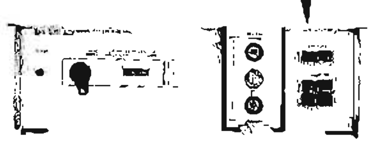
Reflection measurements only. Ultra-wide band reflectometer. Calibrated line stretcher in reference channel varies the linear phase shift between channels.

Transmission/Reflection
(Waveguide)
X-Band (8 - 12.4 GHz)
P-Band (12.4 - 18 GHz)



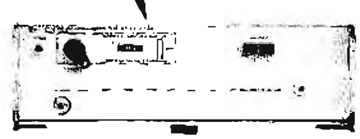
X8747A/P-8747A Waveguide Reflection/Transmission Test Unit — For reflection and transmission measurements of waveguide components. Has calibrated sliding short for varying phase shift between channels. Two models, for X-band and for P-band.

Transmission/Reflection
(Transistors)
0.10 - 2.0 GHz
two-port



8745A S Parameter Test Set — Four pushbuttons (S_{11}, S_{12}, S_{21}, S_{22}) switch between reflection and transmission response of two-ports. Calibrated line stretcher in reference channel varies linear phase shift between channels.

Transmission/Reflection
2.0 - 12.4 GHz



8743A Reflection/Transmission Test Unit — Two pushbuttons switch between reflection and transmission measurements. Calibrated line stretcher in reference channel varies linear phase shift between channels.

APPLICATION	TRANSDUCER UNIT	8413A PHASE—GAIN INDICATOR	8414A POLAR DISPLAY UNIT
TRANSMISSION TESTS ONLY	Accessories including adapters, pads, air lines are recommended (11587A)	8413A recommended for all transmission measurements.	See 8413A for X-Y readout of transmission characteristics.
Wide Dynamic Range Filters, attenuators, paramps, IC amplifiers, modulators, antennas	**8740A Transmission Test Unit** 60 dB Dynamic Window for viewing amplitude excursion of attenuation or gain. Correct power level relations between reference and test channels must be used according to type of response to be viewed. Power levels will not be the same for attenuation as for gain.	Accurate meter readout for CW measurements. IF offset attenuator allows greater resolution about any amplitude. Phase offset in 10° steps allows greater resolution about any phase shift. Swept frequency readout is provided thru analog outputs at 50 mV/dB and 10 mV/deg.	Direct magnitude and phase readout of transmission coefficient of test device. Either CW or swept frequency display in polar coordinates. Markers allow frequency readout.
Insertion Loss and Phase (Residual Conditions) Unbiased PIN modulator, coaxial pads, switches, cables, variable attenuators, pass band of filters	Comparison against amplitude and phase offsets. Coaxial pads in reference and test channels reduce mismatch ambiguity in measurement of low amplitude values.	Readout to within 1 dB and 6° is provided with amplitude and phase offsets. Resolution from meter is then to .05 dB and .1°. Generally used where low insertion measurements are made.	The polar plot provides easy direct readout of both magnitude and phase for transmission coefficient. An X-Y recording allows resolution to within 1% of full scale.
Component Matching Pads, cables, antennas, amplifiers, phase shifters.	Standard device in reference channel, unknowns in test channel. Actual deviation of test device from standard may be plotted directly.	CW tests can be made accurately with meter. Residual tracking between channels as a function of frequency can be eliminated by X-Y recording the system response at the desired offsets.	CW tests of amplitude and phase variation shown as a dot on CRT. Swept display on CRT does not eliminate tracking error. X-Y recording allows greater resolution but tracking must be subtracted.
Group Delay Filters, cables, system components .11-12.4 GHz.	Physical length is compensated in reference channel. Corrections must be made with line stretcher to offset compensation.	Linearity of display on scope gives quick indication of constant group delay. By measuring phase for a given frequency change the group delay can be computed.	With ΔF sweep and phase read directly from polar display, group delay may be computed quickly. Linearity of phase with frequency is not readily detectable.
REFLECTION TESTS ONLY	Accessories including adapters, air lines, pads, shorts, are recommended. (11587A)		8414A recommended for all reflection measurements.
Reflection Coefficient 0.0–10.0 (VSWR 1.0–∞)	**8741A Reflection Test Unit** .1–2 GHz. **8742A Reflection Test Unit** 2–12.4 GHz. Pads in reference and test channels reduce mismatch ambiguity and allow greater measurement range. High directivity reflectometer systems allow accurate measurement of reflection coefficient.	CW and Swept measurement of return loss magnitude and phase referenced to a short circuit. Residual tracking may be eliminated using X-Y recorder.	Readout of reflection coefficient directly in both magnitude and phase. CW or swept frequency measurements appear as a dot per frequency on scope face. IF attenuator allows expansion and compression of scope scale to provide direct readout.
Impedance Antennas, loads, system components, impedance matching, cavities, filters, circuit design and test, dynamic tuning on swept frequency basis.	Standard reflectometer systems allow broadband coverage.	CW and swept return loss. Converting to enter Smith Chart with return loss and phase angle is time consuming. Use 8414A for direct Smith Chart plots.	CW and swept frequency display with transparent Smith Chart overlay for direct normalized impedance readout. Overlays are available for compressed, normal, and expanded Smith Chart.
TRANSMISSION AND REFLECTION TESTS	Accessories including adapters, pads, shorts are recommended (11587A).	Scope, X-Y recorder, or meter readout of selected parameters.	Polar readout of parameters of each port of a device.
Full Two-Port Characterization .11–2.0 GHz.	**8745A S-Parameter Test Set** Push button selection of S11, S21, S12, S22.		
Component Tests Amplifiers, unilateral and bilateral devices, filters, attenuators, phase shifters.	Use 8745A with 11604A Universal Extension calibrated at plane of connection to allow correct input and output measurements.		
Transistor Tests Any transistor, FET, etc. with the TO-5, TO-12, TO-18, or TO-72 package, with either B-E-C configuration or E-B-C configuration. Diodes for input impedance under various bias conditions.	Use: 11600A transistor fixture and 11601A Calibration Kit for TO-5 and TO-12 type transistors. 11602A transistor fixture and 11603A Calibration Kit for TO-18 and TO-72 type transistors.	CW with meter readout or swept with scope readout to show full response of device particularly for transmission characteristics—S21 and S12. The input and output reflection parameters S11, S22 can be displayed as return loss.	CW and swept Smith Chart readout of all S-Parameters. Direct impedance readout of S11 and S22 with Smith Chart overlays. Transmission coefficients S21 and S12 may be read directly from linear scale at phase shift indicated.
Single Port Characterization 2.0–12.4 GHz	**8743A Transmission/Reflection Test Unit**	Read amplitude and phase response of transistors in dB and degrees directly from meter for CW or from oscilloscope for swept frequency. Allows rapid characterization under a variety of bias conditions.	Read amplitude and phase response of transistors directly from polar plot for either CW or swept measurements. Test channel gain control allows gain and isolation as well as input and output impedance to be displayed.
Component Testing Amplifiers, pads, attenuators, phase shifters, cables, joints.	Pushbutton Selection of S11, S21, or S12, S22, depending on device orientation and connection. The 11605A Flexible arm (consists of coax swivel joints and rigid air line) allows rigid connection to any geometrical configuration.		
Waveguide—X-Band, P-Band, or others on request. Reflection or transmission depending on point of connection in system.	**8747A Waveguide Transmission/Reflection Test System.** Symmetrical bridge system using HP 752 directional couplers and a special power splitter. See Application Note 92.		

Table 1. System check list

Model	Function	Frequency	Trans.	Refl.	Price
MAINFRAME AND SAMPLER					
8410A Network analyzer	Mainframe for readout modules includes tuning circuits, IF amplifiers, and precision IF attenuator	0.11-12.4 GHz			$1800
8411A Harmonic convertor	Converts 2 RF input signals (110 MHz-12.4 GHz) into 20 MHz IF signals	0.11-12.4 GHz			$2500
DISPLAY					
8413A Phase-gain indicator	Meter readout module for 8410A Mainframe. Provides CW display of relative amplitude and phase between input signals. Auxiliary outputs provide swept frequency displays on a scope or X-Y recorder		x	*	$850
8414A Polar display	CRT polar display module for 8410A Mainframe. Provides swept frequency display of relative amplitude and phase between input signals. Smith Chart overlays give direct impedance readout. Auxiliary X-Y outputs allow high resolution polar and Smith Chart plots		*	x	$1100
Accessories					
11587A Accessory kit	Accessories normally used for transmission and reflection tests contained in sturdy carrying case. Accessories included are: (1) 11566A 10 cm and (1) 11567A 20 cm. Air Line Extension; (2) 11524A female and (2) 11525A male APC-7/N Coax Adapters; (2) 8492A, Option 10, 10 dB and (1) 8492A, Option 30, 30 dB Coax Attenuators; (1) 11511A female and (1) 11512A male type N coax short	—	x	x	$795
Transducers					
8740A Transmission test unit	Transmission measurements only. RF input signal is split into reference and test channels. Calibrated line stretcher in test channel varies the linear phase shift between channels	dc-12.4 GHz	x	—	$1300
8741A Reflection test unit	Reflection measurements only. Wide band reflectometer. Calibrated line stretcher in reference channel varies the linear phase shift between channels	0.11-2 GHz	—	x	$1500
8742A Reflection test unit	Reflection measurements only. Ultra-wide band reflectometer. Calibrated line stretcher in reference channel varies the linear phase shift between channels	2-12.4 GHz	—	x	$1500
8743A Reflection/transmission test unit	Two pushbuttons switch between reflection and transmission measurements. Calibrated line stretcher in reference channel varies linear phase shift between channels	2-12.4 GHz	x	x	$2450
11605A Flexible arm	Mounts on front of 8743A; connects to device under test. Rotary air lines and rotary joints connect any two-port geometry	dc-12.4 GHz	x	x	$550
8745A S parameter test set	Four pushbuttons (S_{11}', S_{12}', S_{21}', S_{22}') switch between reflection and transmission response of two-ports. Calibrated line stretcher in reference channel varies linear phase shift between channels	0.11-2 GHz	x	x	$3000
11599A Quick connect adapter	Mounts on front of 8745A; used for quickly connecting and disconnecting 11600A / 11602A transistor fixtures or 11604A Universal Extension		x	x	$75
11600A (11601A) and 11602A (11603A) Transistor Fixtures (Calibration kits)	Mount on front of 8745A: for TO-18/TO-72 or TO-5/TO-12 transistor packages, respectively. One transistor fixture provides common emitter-base-collector and common source-gate-drain test configurations. Each calibration kit provides three references for calibrating fixture	dc-2 GHz	x	x	$425 ($75) $425 ($75)
11604A Universal extension	For measuring microwave components. Mounts on front of 8745A and connects device under test. Rotary air lines and rotary joints connect to any two-port geometry	dc-2 GHz	x	x	$800
X8747A/P-8747A waveguide reflection/transmission test system	For reflection and transmission measurements of waveguide components. Has calibrated sliding short for varying phase shift between channels. Two models: X8747A for X-band. P-8747A for P-band	8.2-12.4 GHz 12.4-18.0 GHz	x	x	$1500 $1600

* Optional. x Recommended.

8410A/8411A Network analyzer

Measures: attenuation, gain, phase shift, reflection coefficient, return loss, and impedance. Single swept frequency measurements.

Frequency range: 110 MHz to 12.4 GHz (useable to 18 GHz).

Input power levels: +10 dBm or 10 mW, max.[1] over full frequency range.

Reference channel: −20 to −40 dBm typical (meter indicates proper range).

Test channel: −10 to −80 dBm (≈71 mV to 22 μV); not to exceed reference channel by >20 dB.

Dynamic range: 60 dB (observable on oscilloscope display).

Tuning: automatic over any octave band selected by front panel switch.

Swept-frequency measurements: all parameters observable versus frequency on oscilloscope display. Response time of network analyzer permits up to 100 sweeps per second for flicker-free display over any octave band.

Display: meter readout for attenuation, gain, phase, and return loss.

Amplitude range: ±3, 10, 30 dB full scale.

Phase range: ±6, 18, 60, 180° full scale.

Resolution: 0.1 dB, 0.1°.

Swept frequency readout: used with oscilloscope or recorder and HP 8413A Phase-Gain plug-in unit.

Amplitude: (attenuation, gain, return loss). Scale: dB/cm. Log. output of 50 mV/dB. 10 kHz bandwidth. Scale factor determined by scope or recorder input range switch. 60 dB display range.

Phase: scale: degrees/cm. 10 mV/deg. output. 10 kHz bandwidth. Scale factor determined by scope or recorder input range switch. 360° display range.

Reflection coefficient: with HP 8414A Polar Display.

Amplitude: polar coordinate display on cathode-ray tube. Calibration divisions 20% of full scale setting.

Phase: polar display: 10 deg. radials over continuous 360° range.

Impedance: Smith Chart readout overlay on polar display. Normalized impedance readout, $\frac{R \pm jX}{Z_0}$. Overlays provided for full scale reflection coefficient of 0.2 (1.5 SWR), 1.0 (∞ SWR), and 3.16.

Performance specifications

Transmission

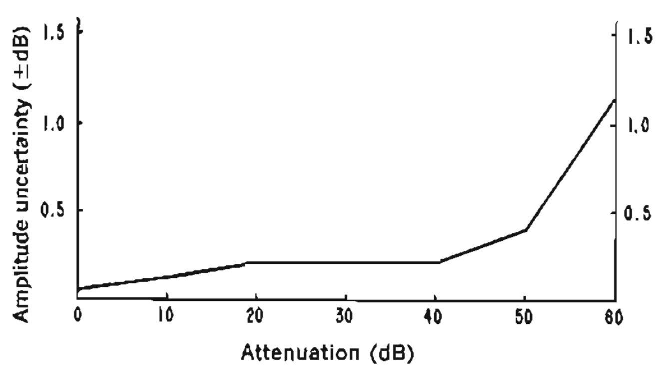
Amplitude: attenuation/gain.

Accuracy[1]**:** 0- to 60 dB range.

IF attenuator: ±0.1 dB/10 dB, ±0.05 dB/1 dB } ±.2 dB max. cumulative

Meter: ±.05 dB (for readings between 0 and 1 dB only).

Noise, crosstalk and mixer non-linearity: add ±0.2 dB error to above for 50 dB steps; add ±1.0 dB to above for 60 dB step.



Attenuator Accuracy vs. Dynamic Range

IF attenuator: 69 dB in 10- and 1-dB steps. Amplitude vernier: >2 dB range.

Frequency response[1]**:**

		Test unit
0.1 to 2 GHz	±0.35 dB	HP 8745A
2 to 12.4 GHz	±0.75 dB	HP 8743A
dc to 7 GHz	±0.50 dB	HP 8740A

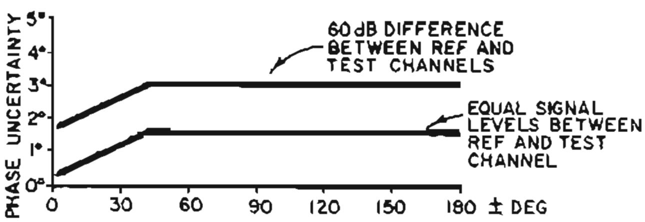
Phase shift

Accuracy:[4]

Phase offset: ±0.2° ±0.3°/10°, 1.5° max. for equal signal levels between test and reference channels.

Signal levels: ±1.5° max. for 60-dB difference between reference and test channels.

Meter: ±0.1° for meter reading between 0 and 10° only.



Phase Accuracy

Phase offset: ±180° in 10° steps. Phase vernier range 90°.

Line stretcher: 0 to 30 cm variable electrical length. Readout by digital indicators. Resolution 1 mm. Rear panel connection on HP 8743A and 8745A for extending reference arm electrical length with coaxial line.

		Test unit
0.11 to 2 GHz	±5°	HP 8745A
2 to 12.4 GHz	±5°	HP 8743A
dc to 7 GHz	±3°	HP 8740A

Test port VSWR

Frequency	VSWR	Test unit
0.11 to 2 GHz	1.12	HP 8745A
2 to 12.4 GHz	1.25	HP 8743A
dc to 7 GHz	1.15	HP 8740A
7 to 12.4 GHz	1.25	

Test port connector(s): precision 7mm (APC-7).[5]

Coupling factor (nominal):

	Test unit		
	HP 8740A	HP 8743A	HP 8745A
Input to test port	17 dB	20 dB	4 dB
Input to test chan. input	17 dB	20 dB	20 dB
Input to refer. chan. input	17 dB	30 dB	24 dB

Accessories

11587A Accessory Kit recommended for use in transmission and reflection measurements. Provides APC-7 to type N adapters, 10- and 20-cm air lines, two 10-dB and one 30-dB APC-7 attenuators, and type N female and male shorts.

Price: Model 11587A, $795.

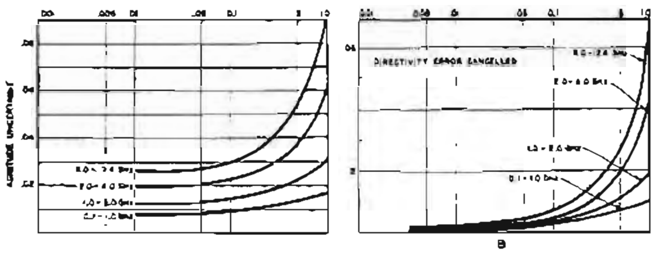
Reflection coefficient/impedance

Reflection coefficient measured using wide-band reflectometers, phase-balanced for swept or CW frequency measurements with 8410A Network Analyzer. Readout displayed on plug-in cathode-ray tube unit for swept-frequency display on polar coordinate system. Smith Chart overlays provide direct impedance readout.

Magnitude: $|\Gamma_u|$ Readout on HP 8414A Polar Display Unit. Displays amplitude and phase data in polar coordinates on 5-inch cathode-ray tube.

Frequency	Test unit		
	HP 8741A	HP 8745A	HP 8742A/8743A
0.11 to 1 GHz	$.015 + .05 \lvert\Gamma_L\rvert^2$	$.015 + .06 \lvert\Gamma_L\rvert^2$	– –
1.0 to 2.0 GHz	$.025 + .05 \lvert\Gamma_L\rvert^2$	$.025 + .06 \lvert\Gamma_L\rvert^2$	– –
2.0 to 8.0 GHz	–	–	$.032 + .03 \lvert\Gamma_L\rvert^2$
8.0 to 12.4 GHz	–	–	$.032 + .06 \lvert\Gamma_L\rvert^2$

(Γ_L = measured reflection coefficient)

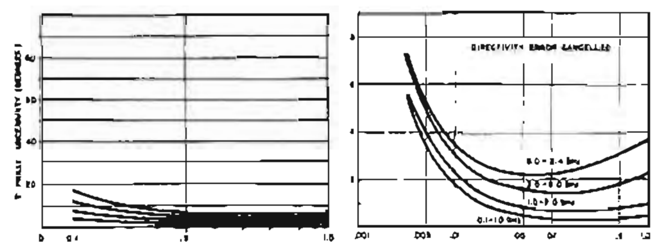


A1 Reflection coefficient measured A2

Curve A1 indicates typical errors when directivity errors are included in the measurement. By means of a sliding load technique, directivity can be measured and thus calibrated out of the system accuracy. Curve A2 is the result of typical errors with this technique.

Angle of reflection coefficient:

Accuracy $= \sin^{-1} \Gamma_u/\Gamma_L$ for $\phi \leq 90°$ (see magnitude error term, Γ_u, above).



B1 Reflection coefficient measured B2

Curve B1 includes directivity error, curve B2 does not (note scale changes).

Frequency response: incident and reflected outputs tracking.[6]

	Test unit			
	0.11 to 2 GHz		2 to 12.4 GHz	
	HP 8741A	HP 8745A	HP 8742A	HP 8743A
Magnitude	±6%	±6%	±9%	±9%
Phase	±3°	±5°	±7°	±7°

Connectors: input: type N female; test ports and inputs to network analyzer, APC-7.

Impedance: 50Ω.

Reference plane extension: 0 to 15 cm, variable electrical length; calibrated by digital dial indicator with 1-mm resolution. Adjustable for initial relative calibration. HP 8743A and HP 8745A models have rear panel connectors for extending reference plane with coaxial line.

Polar display unit (HP 8414A): cathode-ray tube with 5-inch, 5-kV post accelerator tube with P-2 phosphor; internal polar graticule.

Marker input: accepts markers from HP 690- and 8690-series Sweep Oscillators, −5 V peak. Markers displayed as intensified dot on CRT display.

Blanking input: accepts −4 V RF blanking pulse from HP 690- and 8690-series Sweep Oscillators to blank retrace during swept operation.

Accessories furnished: three Smith Chart CRT overlays. Plastic scales overlay 8414A Display Unit to convert readout directly to normalized impedance. Full scale Γ = 1.0, 0.2, and 3.16 (for negative impedances).

[1] With 20 dB coupling to test channel input.
[2] IF attenuator substitution method.
[3] Includes response of 8411A Harmonic Converter.
[4] Phase offset substitution method.
[5] Amphenol RF Division, Danbury, Conn.

TRANSMISSION AND REFLECTION TEST UNITS

Price:

Transmission Measurements only (Attenuation, Gain, Phase)

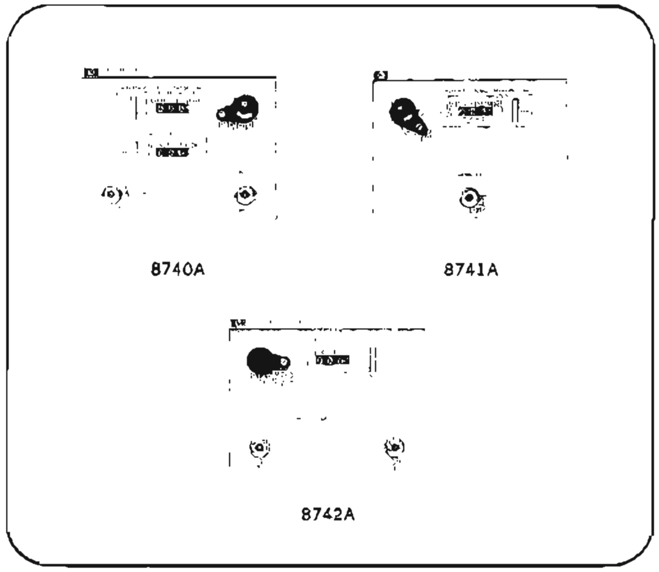
0.11 to 12.4 GHz		
HP 8410A Network Analyzer	$1800	
HP 8411A Harmonic Converter	2500	
		$4300
HP 8740A Transmission Test Unit		1300
HP 8413A Phase-Gain Indicator		850
HP 11587A Accessory Kit		795
		$7245

Reflection Coefficient/Impedance Measurements only

HP 8410A Network Analyzer	$1800	
HP 8411A Harmonic Converter	2500	
		$4300
HP 8414A Polar Display Unit		1100
(8413A optional for return loss)		($850)
HP 8741A Reflection Unit (0.1 to 2 GHz)		1500
or		
HP 8742A Reflection Unit (2.0 to 12.4 GHz)		1500
0.1 to 2 GHz or 2 to 12.4 GHz		**$6900**
(with Return Loss readout)		($6650)
0.1 to 12.4 GHz		**$8400**
(with Return Loss readout)		($8150)

Reflection and Transmission Measurements

HP 8410A Network Analyzer	$1800	
HP 8411A Harmonic Converter	2500	
	$4300	
HP 8414A Polar Display Unit	1100	
HP 8413A Phase-Gain Indicator	850	
		$6250
0.1 to 2 GHz		
HP 8745A S-Parameter Test Set	$3000	
HP 11604A 2-Port Adapter	800	
		3800
		$10,050
2.0 to 12.4 GHz		
HP 8743A Reflection/Transmission Test Set	$2450	
HP 11605A	550	
		3000
		$9250
0.11 to 12.4 GHz		**$13,050**



Description

The Model 8740A Transmission Test Unit splits RF power into reference and test channels for the 8411A inputs. The 8740A consists of a flat 50-ohm power splitter, calibrated 30-cm line stretcher, and a 10-cm mechanical extension.

The Model 8741A/8742A Reflection Test Units are broad band reflectometer systems. Calibrated line stretchers provide a movable reference plane as well as compensation for differences in reference and test channel lengths.

The 8740A/8741A/8742A units were designed for specialized broad band coverage of either transmission (8740A) or reflection (8741A/8742A). If both transmission and reflection characteristics are desired, the 8745A S-Parameter Test Set or 8743A Reflection/Transmission Test Unit should be used. They provide pushbutton selection of reflection and transmission parameters from 0.1 to 2 GHz and 2 to 12.4 GHz, respectively.

Specifications 8740A, 8741A, 8742A

Frequency range: 8740A, dc to 12.4 GHz; 8741A, 0.1 to 2 GHz; 8742A, 2.0 to 12.4 GHz.

Frequency response: 8740A, ±0.5 dB, $\pm3°$ to 7 GHz, ±1 dB, $\pm5°$ to 12.4 GHz; 8741A/8742A ±0.5 dB, $\pm5°$.

Impedance: 50Ω, test port reflection coefficient ≤0.07 (1.15 SWR) to 7 GHz; 0.11 (1.25 SWR) to 12.4 GHz.

Maximum RF input power: 1 watt when connected to 8411A.

Insertion loss to test device: 8740A, 17 dB; 8741A/8742A, 1 dB.

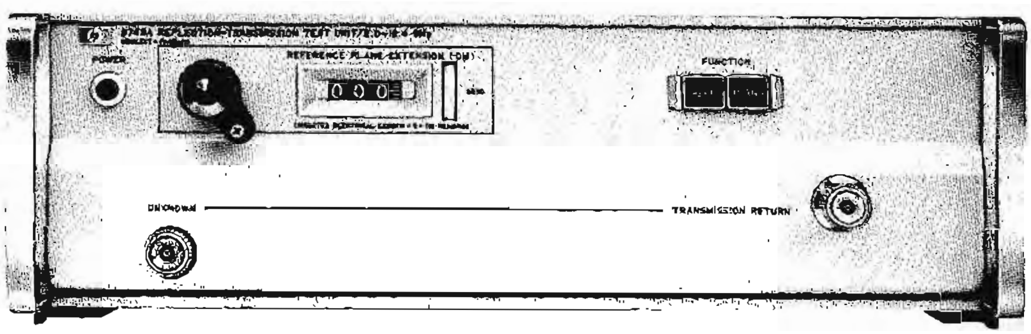
Directivity: 8741A, ≥36 dB, 0.11 to 1.0 GHz, ≥32 dB, 1.0 to 2.0 GHz; 8742A, ≥30 dB, 2.0 to 12.4 GHz.

Weight: 8740A, 17½ lb (7,9 kg); 8741A, 16½ lb (7,5 kg); 8742A, 14½ lb (7,0 kg).

Dimensions: 6" high, 16-3/16" deep, 7-9/32" wide (15,2 x 41 x 18,6 cm) excluding knobs and connectors.

Price: Model 8740A, $1300; Model 8741A, $1500; Model 8742A, $1500.

PUSHBUTTON
COAXIAL CHARACTERIZATION
Waveguide capability— Models 8743A, 8747A



8743A

Model 8743A

The Hewlett-Packard 8743A Reflection/Transmission Test Unit combines in one unit a broad band (2.0 to 12.4 GHz) reflectometer system and a transmission test system. Reflection and transmission characteristics can be selected by pushbutton. All measurements are made on the coupled ports of 20-dB couplers providing isolation from the RF source.

A calibrated line stretcher provides up to 15 cm of compensation for test device length for reflection tests and up to 30 cm compensation for test device length for transmission tests. To compensate for any excess length in the test channel which cannot be compensated by the line stretcher, rear panel access to the reference channel coaxial line is provided.

Connection to the test device is accomplished through front panel APC-7* connectors. The suggested transmission return path is the 11605A Flexible Arm consisting of three swivel joints and three swivel air lines which allow connection to virtually any geometrical configuration. The unit is constructed to allow calibration for both reflection and transmission at the plane of the unknown port.

Specifications

8743A

Frequency range: 2.0 to 12.4 GHz.

Frequency response: 1.5 dB, ±0.75 dB.

Impedance: 50Ω, Test port reflection coefficient $\leq$0.13 (1.3 SWR).

Maximum RF input: 50 mW when connected to 8411A converter.

Insertion loss to test device: 20 dB.

Directivity: $\geq$30 dB.

Connectors: input, Type N female stainless steel; all other connectors APC-7.

Power: 115 V ±10%, 50 Hz to 400 Hz.

Weight: 27 lb (12,2 kg).

Dimensions: 5½" high, 16¾" wide, 18⅜" deep.

Price: Model 8743A, $2450.

*Amphenol RF Division, Danbury, Connecticut.

11605A

Frequency range: dc to 12.4 GHz.

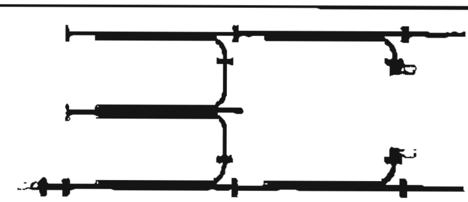
Impedance: 50Ω, port reflection coefficient $\leq$0.13 (1.3 SWR).

Insertion loss: 1.5 dB.

Price: HP 11605A, $550.

Model 8747A

The 8747A Waveguide Reflection/Transmission Test Systems allow tests to be made in waveguide using the 8410A. Available in X-band and P-band, the high directivity of waveguide couplers in conjunction with a waveguide power splitter and special coupler provides the ultimate in accurate phase and amplitude measurement. The symmetrical arrangement of couplers allows close tolerances for phase and amplitude tracking as a function of frequency between the two channels. A calibrated adjustable short in the reference channel acts as a line stretcher for matching reference and test channel signal paths. The test device is isolated from the source as well as from the waveguide-to-coax adapters on the input of the 8411A.



8747A

Specifications

Frequency range: waveguide band, X (8.2 to 12.4 GHz); P (12.4 to 18.0 GHz).

Frequency response: reference and test channels track within ±.75 dB and ±5°.

Impedance: waveguide characteristic impedance, test port reflection coefficient $\leq$.05 (1.1 SWR).

Insertion loss to test device: 5 dB.

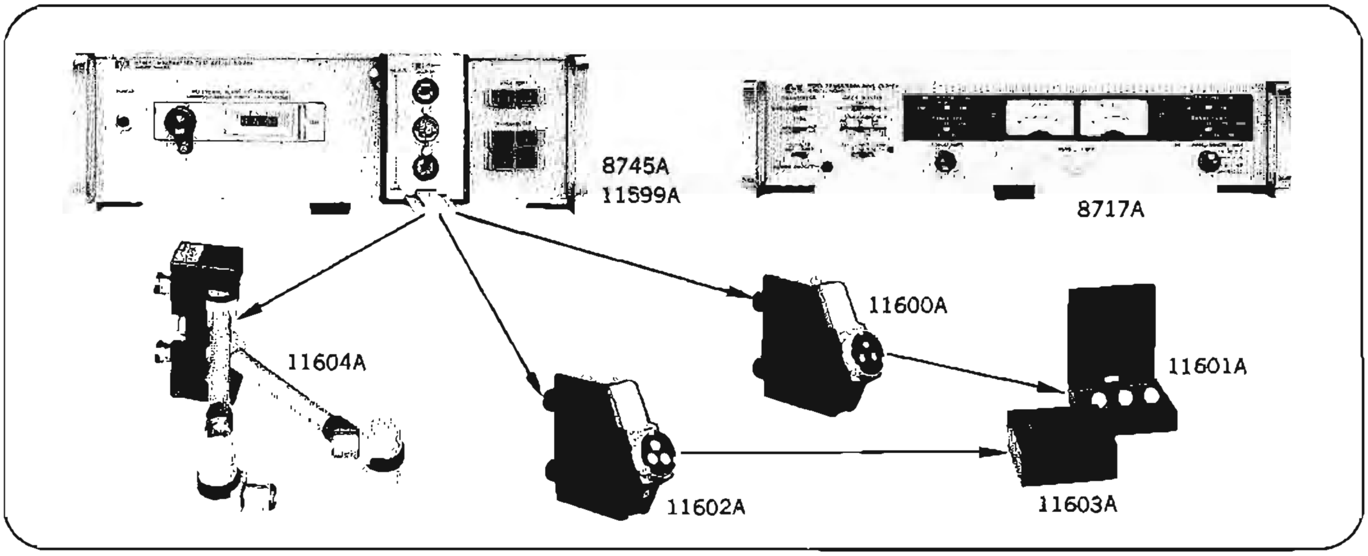
Directivity: $\geq$40 dB.

Weight: 10 lb (4,7 kg).

Price: X8747A, $1500; P8747A, $1600.

S-PARAMETER MEASUREMENT

Two-port reflection and transmission, 0.1-2 GHz
Model 8745A



8745A S-Parameter Test Set

The 8745A is used with the network analyzer or vector voltmeter to measure two-port reflection and transmission coefficients. The major components of the 8745A are two broadband directional couplers, a precision 30-cm line stretcher, and five coax switches. When an s-parameter button is pressed, the switches establish the measuring circuit and direct the proper coupler outputs to the network analyzer or vector voltmeter. The network analyzer or vector voltmeter reads the magnitude and phase of that parameter. Simply adjust the line stretcher and the 8745A is calibrated from 100 MHz to 2 GHz for all four s parameters. The 8745A is completely programmable and can be used for automatic testing. A rear panel connector provides for remotely selecting s-parameters and biasing transistors through a built-in biasing network.

11600A and 11602A Transistor Fixtures

The 11600A and 11602A Transistor Fixtures accept TO-18/TO-72, and TO-5/TO-12 device configurations and will accept diodes, tunnel diodes, and other devices. The fixtures mount on the front of the 8745A and provide common emitter-base-collector and common source-gate-drain connections for bipolar and field-effect transistors. Each fixture is usable from dc to 2 GHz and accepts leads up to 1½ inches long.

11604A Universal Extension

The 11604A Universal Extension mounts on the front of the 8745A and is used for measuring microwave components. Since it is composed of rotary joints and rotary air lines, its APC-7 connectors will connect to almost any two-port geometry. The 11604A provides the flexibility of cable yet retains the accuracy of rigid air line.

11599A Quick-Connect Adapter

The 11599A Quick-Connect Adapter quickly connects the 11604A Universal Extension or the 11600A/11602A Transistor Fixtures to the 8745A by merely throwing a lever. Because connectors do not have to be screwed together, the accessory is ideal for production-line testing and prolongs the life of the APC-7 connectors.

Specifications

Model 8745A S-Parameter Test Set

Function: the 8745A S-Parameter Test Set supplies the circuitry necessary to measure two-port s parameters with the 8405A Vector Voltmeter or the 8410A Network Analyzer.

Frequency range: 100 MHz to 2 GHz.

Impedance: 50Ω nominal.

Load match: 110 to 200 MHz, <1.22; 200 MHz-2 GHz, <1.13.

Source match: <1.06 at 110 MHz; <1.12 at 2 GHz.

Maximum RF power: 2 W.

Insertion loss: from RF input to test ports, 4 dB nominal. From test ports to 8405A or 8410A outputs, 20 dB nominal, increases 6 dB/octave below 120 MHz.

Tracking or frequency response
- **Magnitude:** ±0.35 dB.
- **Phase:** ±5°.

Reference plane extension: maximum length 30 cm, 0.01 cm precision. Extends reference plane 0 to 15 cm beyond an 11600A or 11602A Transistor Fixture or 11604A Universal Extension.

Connectors
- **RF input:** Type N female.
- **Test ports:** APC-7 precision connectors.
- **Outputs to 8405A or 8410A:** mates with APC-7 precision connectors.

Microwave coax switches: maximum switching time, 50 ms. Estimated switch lifetime >1 million cycles.

Remote programming: remote s parameter selection by closing 2 contacts of 36-pin rear panel connector to ground pin. Contact is at 12 volts and short to ground will draw 12 mA.

Transistor biasing: accomplished through 36-pin rear panel connector. Bias and bias sensing connections are made to biasing networks built into the 8745A.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 40 watts.

Weight: net, 35 lb (15,9 kg).

Dimensions: 5½" x 16¾" x 25¾" (139 x 423 x 650 mm).

Price: HP 8745A, $3,000.

Models 11600A and 11602A Transistor Fixtures

Function: used with or without the 8745A to measure transistors and other semiconductor devices. Mount directly on the 8745A and provide common emitter-base-collector and common source-gate-drain connections. Require 11601A or 11603A Calibration Kits.

Model 11600A: for TO-18/TO-72 or similar transistor packages. Has four snap-on dials, two for bipolars and two for FET's.

Model 11602A: for TO-5/TO-12 or similar transistor packages. It has two snap-on dials for bipolars.

Frequency: dc to 2 GHz.
Lead lengths: accepts leads up to 1.5 inches long.
Lead diameters: 0.016 to 0.019 inch.
Impedance: 50Ω ±2Ω.
Connectors: APC-7* precision connectors for input and output.
Option 01: precision type N connectors for input and output.
Maximum power: 10 W including RF signals.
Dimensions: 4⅜" x 6" x 1½" (119 x 152 x 38 mm).
Weight: 38 oz (1,1 kg).
Price: 11600A, $425; 11602A, $425.

Models 11601A and 11603A Calibration Kits

Function: Model 11601A used to calibrate the 11600A, and Model 11603A used to calibrate the 11602A Transistor Fixture. Three calibration references: a short termination, a 50Ω termination, and a 50Ω through section are contained in a protective case.
Case dimensions: 2¾" x 2¾" x 1⅛" (70 x 70 x 29 mm).
Weight: 3 oz (84 g) including case.
Price: 11601A, $75; 11603A, $75.

Model 11604A Universal Extension

Function: used with the 8745A to test microwave components. Mounts on the front of the 8745A and connects to almost any two-port geometry.
Frequency range: dc to 2 GHz.
Connectors: APC-7 precision connectors.
Test port VSWR: 1.07:1.
Price: HP 11604A, $800.

Model 11599A Quick Connect Adapter

Function: quickly connects the 8745A and the 11600A, 11602A, or the 11604A.
Dimensions: 3" x 5" x 4¼" (76 x 127 x 108 mm).
Weight: 12 oz (21 g).
Price: HP 11599A, $75.

8717A

8717A Transistor Bias Supply

The 8717A is a companion unit to the 11600A/11602A Transistor Fixtures. It is an accurate, stable, manual and/or digitally programmable transistor bias supply. It features switching for convenience in test set-ups and provides metering for accurate voltage/current settings and readings. Front panel switches on the 8717A quickly establish stable bias conditions for all transistor configurations used in the 11600A/11602A transistor fixtures. This eliminates the need for external wiring changes for each new configuration, i.e., common emitter-base-collector or common source-gate-drain. The transistor under test is biased in a feedback circuit which maintains a highly accurate collector-emitter voltage and emitter current every time a different transistor is biased, when a common lead configuration is changed, or when temperature changes. Two meters independently measure one of the voltages and one of the currents on any of the three leads of the transistor under test. Transistors are protected by an emitter current limit shutdown circuit which removes biasing when the preset limit is exceeded.

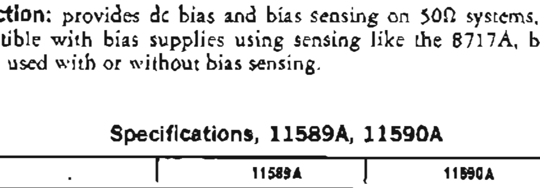
The 8717A is digitally programmed through an optional D/A converter plug-in with which the two internal supplies can be switched into an independent constant voltage supply and an independent constant current supply. All the features otherwise remain the same as above.

Ripple: V_{CE} (V_{DS}) <5 mV, I_E(I_S) <100 μA.
Option 01: digital/analog converter for remote programming capability.
Power: 115 or 230 V ±10%, 50 to 400 Hz, 65 watts.
Dimensions: 16¾" x 3⅜" x 13½" (425 x 86 x 336 mm).
Weight: 17.75 lb (8,0 kg).
Price: HP 8717A, $1295.
Option 01: programmable A-D Converter, $500.

Specifications, 8717A

Outputs:		Manual control	Programmed control
Normal Mode	V_{CE} (V_{DS}): 0–31.75 V	continuously variable	min. step size: 0.25 V
	I_E (I_S), 0–500mA	continuously variable (4 ranges) 0.01–1; 0.1–10; 1-100; 10–1000 mA	min. step size. 3.2% of full range
Independent Mode	Voltage supply: 0 to ±31.75 V @ 0.5 A	continuously variable	min. step size. 0.25 V
	Current supply: 0 to 100 mA @ ±10 V	continuously variable (3 ranges) 0.01–1, 0.1–10; 1-100 mA	min. step size: 3.2% of full range
Normal or Independent	Voltage accuracy	4% of meter full scale	0.2 V+2% of normal
	Current accuracy	4% of meter full scale	2% of programmed value

Meters:	Volts	Milliamps
Meter functions	V_{CE}, V_{BE}, V_{CB} or V_{DS}, V_{DG}, V_{GS}	I_E, I_C, I_B or I_S, I_G, I_D
Full scale ranges	1, 3, 10, 30, 100 V	0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000 mA



11590A 11589A

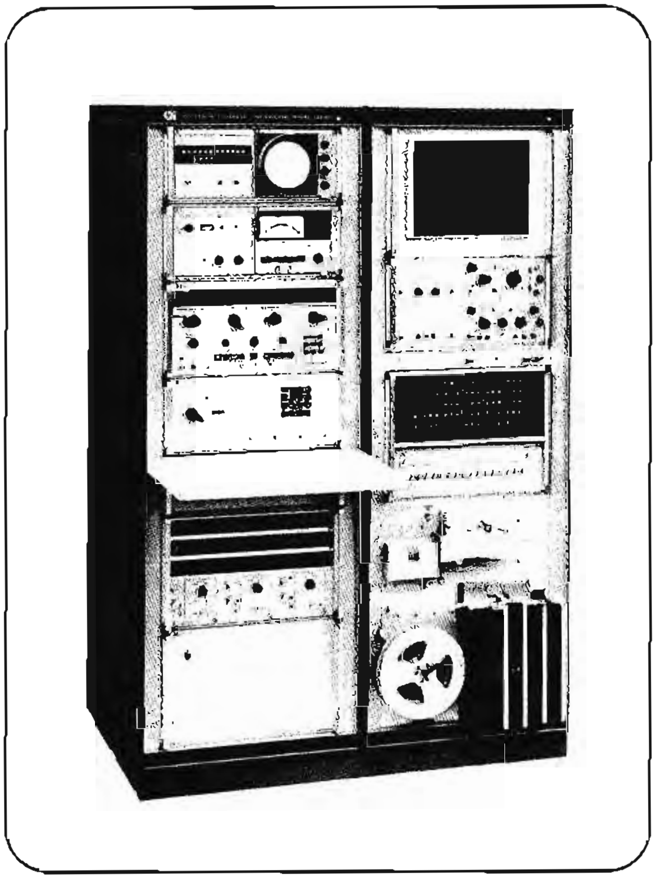
11589A and 11590A Bias Networks

Function: provides dc bias and bias sensing on 50Ω systems. Compatible with bias supplies using sensing like the 8717A, but can be used with or without bias sensing.

Specifications, 11589A, 11590A

	11589A	11590A
Frequency range:	100 MHz–3 GHz	1 GHz–12.4 GHz
VSWR	<1.2	<1.2
Insertion loss	<0.5dB	<0.5dB
Max bias voltage	100 V	100 V
Max bias current	1 A	0.5 A
RF Connectors	APC-7	APC-7
Price	Available on request	Available on request

AUTOMATIC NETWORK ANALYZER
Complete device characterization
8540 Series Systems



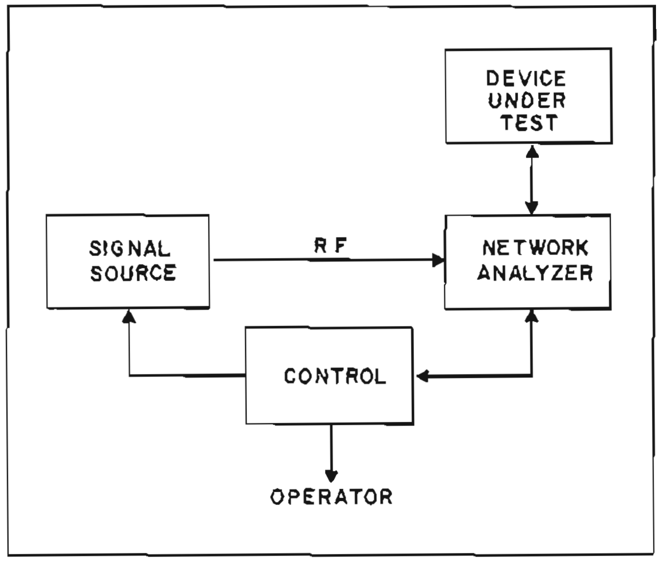


Figure 1. Simplified system block diagram.

General description

The HP 8540-series Automatic Network Analyzer measures transmission and reflection characteristics of devices, providing output data in numerous forms, VSWR, return loss, impedance, admittance, gain or loss, nonlinear phase shift group delay, h and s parameters being common examples. Either active or passive devices may be completely characterized with both the amplitude and phase angle data of each measured parameter obtained over the frequency range from 110 MHz to 12.4 GHz.

Each system consists of three basic subsystems which are available with a large number of options enabling configurations to fit most application needs. A simplified block diagram of the system is shown in Figure 1. These subsystems are the Programmable Signal Source or the Multiband Programmable Signal Source (depending on whether one or more than one RF frequency range is to be covered), a Programmable Network Analyzer and a Control Section. Figure 2 shows a complete multiband system configuration.

System advantages

The 8540-series system provides a great many advantages over conventional measuring systems. These advantages stem primarily from the system's ability to make very accurate measurements at high speed. By coupling the network analyzer's complete characterization of microwave signals in magnitude and phase angle with the computer's ability to store data and solve complex mathematics, the system can perform sophisticated error-correction procedures that are difficult or impractical to perform manually. Thus, 8540A-series operation typically breaks into two parts: calibration and a measurement sequence using stored calibration data. For reflection measurements the system is calibrated by measuring three precision standards: a sliding load, a short and an offset short (a short located a precise distance along a precision air line). These three standards have highly predictable behaviors based upon precise physical dimensions. The system's reflection errors are computed from the difference between the standards' measured and theoretical values. For transmission measurements, the test ports are connected together and the transmission errors are determined from the measurement data with the reflection errors subtracted. All of the calibration data is stored for later correction of test data.

The calibration procedure is spelled out step-by-step on the teletype. Therefore, there is no need to remember a complicated procedure. After the system types each instruction, such as "connect short", the teletype waits for the operator to perform the operation and answer. The system then measures the standard at all frequencies requested, performs any mathematics necessary, and goes to the next instruction in the procedure.

This calibration procedure is supplied ready to use with enough options to cover a wide variety of test situations: fixed or sliding load, coaxial line or waveguide, single or multiband tests. Normally, the calibration procedure is followed by one of several standard test tapes designed to perform the most commonly needed measurements or by a special program written in either FORTRAN or BASIC.

A more complete discussion of the basic subsystems provides insight into how the system obtains its many advantages over manual measurements using conventional instruments.

Table 1. Frequency range options available for either single-band or multi-band programmable signal sources.

RF Source Frequency Range[1]	RF Units	Number of Programmable Steps over Frequency Range
{100 MHz–2.0 GHz[2] / 2.0 GHz–4.0 GHz}	C04-8699B	{1000 steps: 100 MHz–2.0 GHz / 1000 steps: 2.0 GHz–4.0 GHz}
1.0 GHz–2.0 GHz	C04-8691D	1000 steps
2.0 GHz–4.0 GHz	C04-8692B	1000 steps
4.0 GHz–8.0 GHz	C04-8693B	1000 steps
8.0 GHz–12.4 GHz	C04-8694B	1000 steps
12.4 GHz–18.0 GHz[3]	C05-8695A	1000 steps

1 Other frequency ranges are available on special order — for example: 1.4 GHz - 2.9 GHz, 1.7 GHz - 3.4 GHz, and 7.0 GHz - 12.4 GHz.

2 The two bands in this option are selected manually in the single-band configurations and automatically in the multiband configurations.

3 The system's measurement accuracy is unspecified over this frequency range.

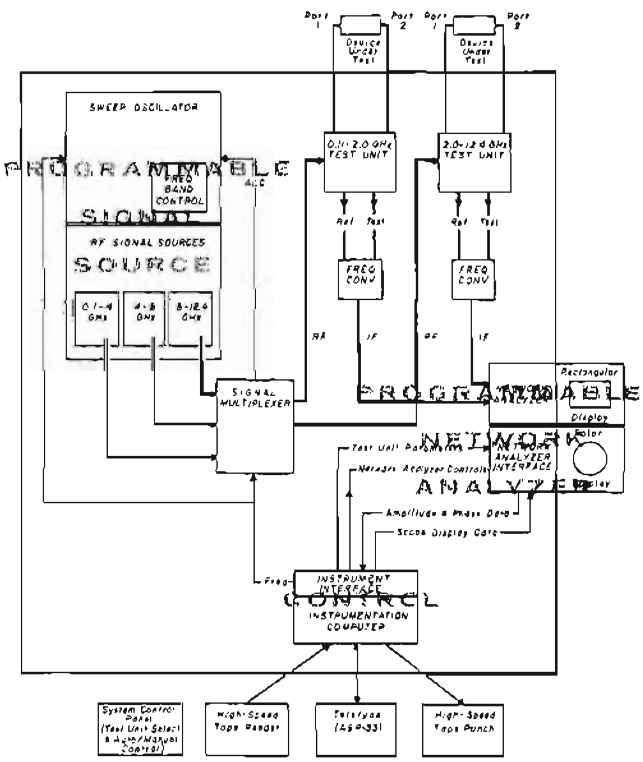


Figure 2. Complete multiband system.

Subsystem description

Signal source subsystem

For systems covering a single frequency range as listed in Table 1, the Programmable Signal Source is used in the system. The hardware in this subsystem includes a programmable sweep oscillator, RF signal source, computer interface register, and leveling circuitry. For frequency ranges covering more than a single frequency range, the Multiband Programmable Signal Source must be used. The hardware comprising this subsystem includes a programmable sweep oscillator, RF signal sources, multiband RF unit holder and control, signal multiplexer, computer interface register, and leveling circuitry. The modifications to the programmable sweep oscillator consist primarily of a digital frequency controller which permits the sweep oscillator to be operated either in its normal manner or under computer control. While under computer control, the RF signal frequency is set by first programming the desired frequency band and then selecting the correct frequency within this band. The desired test unit is selected manually from the system control panel and the multiplexer switches the RF signal to it automatically. A portion of the RF signal is detected in the multiplexing unit, permitting automatic level control (ALC). The single-band subsystem contains the same programmable sweep oscillator, but an RF signal source is used in place of the frequency-band control unit. The RF unit holder and signal multiplexer are not needed. Since the signal sources are easily removable plug-in units, this subsystem is ideal for those applications where all of the measurements are within one of the frequency range options or where changing RF plug-in units is not inconvenient.

Programmable network analyzer

This subsystem measures both magnitude and phase angle of the transmission and reflection coefficients over 360° of phase shift and 80 dB of dynamic amplitude range. The RF signal entering the subsystem is directed to the test unit which converts transmission or reflection measurements into a test and reference signal for the network analyzer. Table 2 describes the test unit options available.

Table 2. Test unit options

Test Unit Options Available for Programmable Network Analyzers

Test Unit Number	Frequency Range (GHz)	Type of Measurements Possible	Nominal Input Power To Device Under Test[1]	Precision Flexible Extension	Transistor Fixtures
8743A	2.0–18.0	Transmission (s_{21}) and Reflection (s_{11})— For all four s parameters, the device under test must be turned around.	—25 dBm	Yes	No
8744A	0.5–18.0	Transmission and Reflection for up to four-port devices— sixteen s parameters maximum	—5 dBm[2]	Yes	No
8745A	0.11–2.0	Transmission (s_{21} and s_{12}) and Reflection (s_{11} and s_{22}) with one connection of the device under test.	—5 dBm	Yes	Yes

1 This level can be reduced by inserting attenuators at the input port. All power levels shown are approximate and can be adjusted or will vary about 10 dB from the nominal.

2 This power level can be reduced in 10-dB steps from —5 dBm to —75 dBm under computer control.

AUTOMATIC NETWORK ANALYZER

High accuracy from 110 MHz to 12.4 GHz

8540 Series Systems

In the test unit, the RF input is split into two signals. One is connected to the reference channel of the frequency converter. The other signal goes to the device under test. For transmission measurements, the signal through the device is connected to the test channel of the frequency converter. For reflection measurements, the signal reflected from the device is connected to the test channel. In both types of measurements, the network analyzer measures the magnitude ratio and phase difference between the test and reference signals. These ratios are sent to the network analyzer interface where the analog information is converted to digital form for processing by the computer.

Control subsystem

This subsystem consists of an 8000-word instrumentation computer and its associated peripheral devices such as a teleprinter, high-speed tape reader, high-speed tape punch, and a system control panel. The control subsystem performs the following functions:

Controls all instruments in the system.

Stores the calibration and measurement data.

Performs programmed calculations.

Displays data in the desired form on either an oscilloscope or teleprinter.

Three input/output peripheral devices are included with the system. The teleprinter (modified ASR-33) is used for programming and command and provides readout of data in "hard-copy" form. The teleprinter can also be used to generate a paper tape copy of a computer program.

The tape reader is used for high-speed entry of the punched paper tape programs into the computer. A high-speed tape punch is used for punching paper tapes for data outputs, edited versions of computer program tapes, or for the output of the FORTRAN or BASIC compilers. This peripheral device is especially useful in writing and compiling special computer programs since it is capable of punching tapes twelve times faster than the teleprinter. Optional peripheral devices are:

Heavy-duty Teleprinter (Modified ASR-35).

Disc Memory (and Direct Memory Access).

X-Y Plotter.

Large Screen Oscilloscope Display.

Programmable Power Supplies.

For further information on the 8540 series System components, refer to the information in this catalog on the Instrumentation Computers, the 8410A Network Analyzer, and the 8690-Series Sweep Oscillators.

System features

Software

Although the standard software supplied makes most of the commonly needed tests, the need to tailor a program to a specific engineering or production test also arises. Since the 8540A-series hardware is general-purpose, its character is largely determined by the software, giving the user a high degree of flexibility in designing special procedures. Two computer languages are available: BASIC and FORTRAN. Both are supplied with standard, corrected-measurement subroutines using data stored by the programmed calibration routines. Thus, a minimum of programming effort is required of the user. BASIC is an easy-to-learn, conversational computer language; the program can be typed into the teletype and executed immediately. A combination of key words and instant feedback makes it possible to teach any engineer how to use the BASIC language within a few hours.

For users familiar with FORTRAN, a compiler comparable to FORTRAN 2 is supplied with a complete library of measurement, complex math, and display subroutines.

Pricing

These advanced microwave measurement systems are tailored to meet individual customer needs and range in price from $77,000 for a 1-2 GHz single-band system to $95,000 for a 110 MHz - 12.4 GHz multi-band system. Included in the price of each system are installation and two days of on-site training by factory personnel. Preventive maintenance and service of the system will be performed for 90 days at no charge.

Leasing

The 8540A-series systems are also available on a four-year lease contract. To provide maximum on-site system support, a Hewlett-Packard Customer Assistance Agreement may be obtained.

For complete system information or a quotation on a system designed to meet your needs, call your local Hewlett-Packard field engineer.

Amplifiers

Amplifiers have two basic functions in instrumentation: 1) to amplify signals that are too low in level for intended applications, and 2) to isolate circuits.

General-purpose amplifiers

A typical general-purpose ac amplifier is the HP 465A. Designed to amplify low-level signals, it has a noise level of 25 µV and a bandwidth of 1 MHz.

This solid-state amplifier is ideal for increasing the power output of transistorized oscillators or amplifiers. Output power of HP oscillators can be increased 14 times into a 600Ω load with the 465A, or by a factor of 180 into a 50Ω load.

The HP 467A Power Amplifier has an average ac power capability of 5 watts over a frequency range from dc to beyond 1 MHz, (10-watt peak-power output). It has an output impedance that is virtually zero (<0.005Ω in series with 1 µH).

If signals >40 volts p-p are needed, two power amplifiers, driven from a differential source such as the HP 200CD Oscillator, may be connected in a push-pull arrangement. This combination will develop 80 volts p-p at 1 ampere.

When the 465A Amplifier is cascaded with the 467A Power Amplifier, Figure 1, the combination achieves 10-watt peak-power output, an overall stable gain of 60 dB and a 1 MHz frequency response.

The 467A also serves as a power supply with an adjustable control that can provide maximum-negative to maximum-positive output voltage. The output voltage polarity may thus be changed without switching or lead changing, a useful feature in diode testing, where both reverse and forward bias are required.

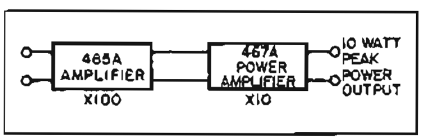


Figure 1. Cascading the HP 467A Power Amplifier with the HP 465A Amplifier results in a stable 60 dB amplifier with 10 MΩ input impedance and 10 W peak-power output.

Precision ac amplifier

Recently introduced, the HP 463A is a precision, all solid-state amplifier delivering 100 volts rms at 5 watts. Augmenting these features is the ultra-low distortion specification and three fixed-gain ranges (10, 100 and 1000) with a continuously-adjustable gain capability from 0 to 1000.

The 463A is valuable not only in precision measurements and calibration set-ups, but as a general-purpose amplifier. It is ideal for amplifying the output of stable solid-state oscillators, or to isolate thermocouple transfer measurements.

High-frequency ac amplifiers

The HP Models 461A and 462A Amplifiers have wide bandwidths plus input and output emitter-followers to match 50Ω coaxial lines. The 461A frequency response extends to 150 MHz. The 462A is rolled off along a Gaussian curve to preserve the wave-shapes of complex waveforms.

Sources of radio frequency interference generated by high-frequency or fast-pulse circuits can be located and identified by combining the HP Model 140A/1410A/1425A Sampling Oscilloscope with a 461A/462A Amplifier. An exploring loop of two or three turns of wire attached to the amplifier input cable serves as a convenient probe as shown in Figure 2.

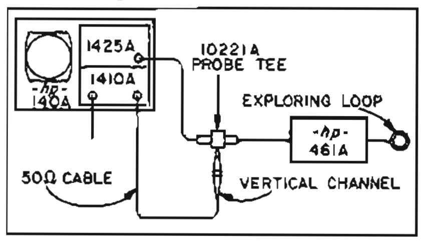


Figure 2. Block diagram shows use of amplifier with search exploring loop and oscilloscope to probe for RF radiation sources.

Power amplifier

An increasing demand has developed for higher RF power output levels for the testing of communications systems and for general laboratory measurements. The need for higher power signal sources stems mainly from the strong signal and cross modulation requirements of certain receiver tests and the large input signal requirements of bridge-type devices. Because of the large number of existing signal generators in the 0 dBm maximum output category, HP developed the Model 230A tunable Power Amplifier for use as an accessory to amplify the RF output power of these instruments. Consisting essentially of three tracked-tuned, cascaded stages of grounded-grid amplification, the 230A is capable of providing up to 30 dB RF gain and 4.5 watts of power over a 10 to 500 MHz frequency range.

DC amplifiers

A widely-used technique for circumventing the drift problems of direct-coupled amplifiers is to convert the dc to an equivalent ac (modulation). The ac is amplified in a gain-stable ac amplifier and reconverted to dc (demodulation). During amplification, the signal is represented by the difference between the maximum and minimum excursions of the ac waveform and is not affected by drift in the absolute voltage levels within the amplifier.

One method of converting the dc to ac is to switch the amplifier input alternately to both sides of a transformer, as shown in Figure 3. This periodically inverts the polarity of the signal applied to the amplifier. The switches illustrated may be mechanical, transistor or photoconductive. Another pair of contacts at the output establishes the ground level for a storage capacitor in series with the output. The output storage capacitor becomes charged to a level corresponding to the amplitude of the output square wave. Synchronous detection preserves the polarity of the input voltage and recovers both positive and negative voltages with the correct polarity.

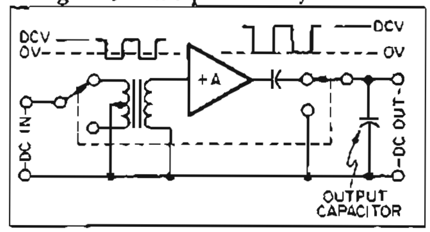


Figure 3. Modulated amplifier.

The dc amplifiers just described offer drift-free amplification of low-level signals in the microvolt region. Another modulation technique uses two photoconductors—one in series with, and one parallel to the amplifier input, shown in Figure 4.

Photoconductors' resistance is proportional to their illumination. By illuminating the photoconductors alternately, the amplifier input is connected to the signal and to ground. Photoconductors perform well as modulators at microvolt levels. They can be isolated from the driving signal and designed with very low offset voltages.

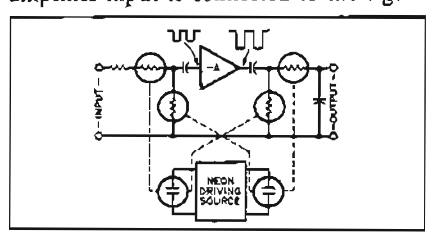


Figure 4. Amplifier with photoconductive modulator.

Differential amplifiers

Differential data amplifiers have two identical input channels that function in push-pull fashion. The output generally is single-ended and represents the amplified difference between the two input channels. This arrangement cancels hum or other interference picked up on the signal leads which appear in phase to the amplifier inputs (referred to as common-mode signals). Examples are the HP Models 2470A and 8875A.

Since a differential amplifier is sensitive only to the difference between the two input signals, the transducer or other signal source need not be grounded. Therefore, differential amplifiers allow a bridge-type transducer to be used with a grounded power supply.

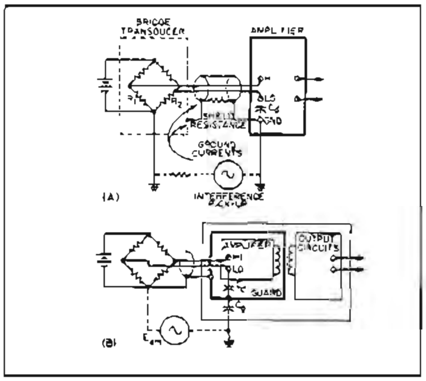


Figure 5. Guard reduces capacitance between signal leads and ground.

The differential amplifier configuration also allows injection of a fixed dc voltage into either channel to permit establishment of a new voltage-reference level at the output (zero suppression).

When the input is floating, cable shielding may be connected to chassis ground rather than to signal ground. However, both ac and dc potentials can exist between two widely-separated earth grounds, and common-mode currents may circulate. The signal leads and the internal capacitances are shown lumped as C_d in Figure 5. Consequently, a ground loop may inject interference into the signal path. A guard shield (Figure 5) providing an electrostatic shield around the input circuitry breaks the stray capacitance into two series capacitances, C_d and C_g. A much higher impedance is then presented to the flow of common-mode signals. This type is termed a floated and guarded amplifier.

DC amplifiers using choppers are able to couple the signal information out of the guard shield by means of transformers. No dc connection between the output and input grounds is necessary; and no ground loops are formed between the input circuits and equipment connected to the output.

Amplifiers designed for use with guarded digital voltmeters or other guarded equipment (Models 2411A and 860-4300) continue the guard shield through the output.

Microwave amplifiers

There often are applications requiring high-quality microwave signals, such as those obtained from precision signal generators where the magnitude of signal power needed is greater than that available directly from the signal generator. Amplification of the signal generator output will fill this requirement. At frequencies from 1 to 12.4 GHz this is accomplished by HP microwave amplifiers. Four broadband amplifiers are available, each using a traveling-wave tube that delivers at least one watt output with one milliwatt or less input. Excellent stability is achieved through the use of highly regulated power supplies for all elements of the TWT, including the filament. The amplifiers have provision for amplitude modulation and since the internal modulation amplifier is dc-coupled, remote programming and power leveling are possible. Sensitivity is high for large output power changes from relatively small modulation signals, obviating the need for an external modulation amplifier.

Selecting an amplifier

Stability, noise and input-output impedances, as well as cost, are basic considerations. If an amplifier is to be used for general-purpose applications, low distortion and preservation of magnitude relations are essential. When selecting an amplifier for pulse applications, low rise times and low sag are of prime importance. The differential amplifier is the most logical choice when interference from other connecting equipment is likely. To preserve guarding features of voltmeters or other connecting equipment, or to suppress common-mode noise, a floated and guarded amplifier is essential.

All the Hewlett-Packard amplifiers described have been designed to maximize performance for specific applications while minimizing cost. A Hewlett-Packard amplifier is available to meet your specific requirements. Refer to tables for relative functions and features.

General-purpose amplifiers

Model	Frequency response	Gain	Input Z	Noise (max)	Output (max)	See page
450A	±0.5 dB, 10 Hz - 1 MHz ±1 dB, 5 - 10 Hz and 1 - 2 MHz ±0.5 dB, 5 Hz - 1 MHz ±1 dB, 2 - 5 Hz and 1 - 1.2 MHz	40 dB 20 dB	1 MΩ/15 pF	250 μV (referred to input)	10 V into 3000Ω	485
461A/462A	±1 dB, 1 kHz - 150 MHz into 50Ω load	40 dB 20 dB	50Ω	<40 μV at 40 dB	0.5 V into 50Ω load	488
465A	±0.1 dB, 100 Hz - 50 kHz <2 dB, at 5 Hz and 1 MHz	40 dB 20 dB	10 MΩ/20 pF	25 μV referred to input	5 V rms into 50Ω 10 V open circuit	486
466A	±0.5 dB, 10 Hz - 1 MHz <3 dB at 5 Hz and 2 MHz	40 dB 20 dB	1 MΩ/25 pF	75 μV rms	1.5 V rms into 1500Ω	485
467A	±1%, dc - 100 kHz ±10%, 100 kHz - 1 MHz	X1, X2, X5, X10	50 KΩ/ 100 pF	<5 mV p - p	±20 V peak at 0.5 A peak	486
463A	<±0.01%, 10 Hz - 10 kHz <±0.1%, 10 kHz - 100 kHz <±0.1%, 10 Hz - 20 kHz <±1%, 20 kHz - 100 kHz <±0.3%, 10 Hz - 20 kHz <±3% 20 kHz 100 kHz	X10 X100 X1000	1 MΩ/<35 pF (fixed gain) 50 kΩ/ <200 pF (Adj. gain)	(rms referred to input) 1.5 mV 150 μV 50 μV	100 V rms (5 W continuous)	487

Power and voltage amplifiers

Model	Instrument	Frequency response	Gain	Output	See Page
467A	Power amplifier is also ±1 V to ±20 V ½ amp power supply, input Z 50 kΩ/100 pF, noise<5 mV p-p.	dc - 100 kHz (±1%) 100 kHz - 1MHz (±10%)	X1, X2, X5, X10	20 V peak-0.5 A peak	486
230A	Tunable Power Amplifier, source of high-level rf power when used with signal generators.	10-500 MHz	30, 27, 24 dB, depending on frequency	0-15 V into 50Ω	489
489A	Microwave power amplifiers; TWT devices; amplitude modulation capability with internal 20 dB, 500 kHz modulation amplifier.	1-2 GHz	30 dB	1 W	490
491C		2-4 GHz	30 dB	1 W	490
493A		4-8 GHz	30 dB	1 W	490
495A		7-12.4 GHz	30 dB	1 W	490

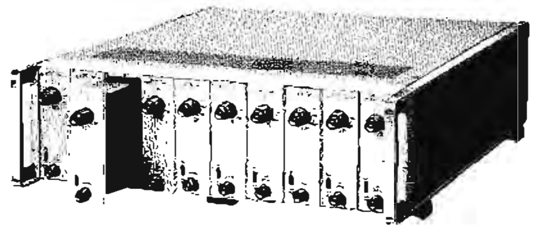
Data amplifiers

Model	Instrument	Frequency response	Gain	Noise (max)	Output	See Page
2470A	Differential data amplifier (with internal power supply)	dc-50 kHz	1, 10, 30, 100, 300, 1000	5 μV rms rti	±10 V	484
8875A	Differential data amplifier (with internal power supply)	dc-75 kHz	1-1000	5 μV rms rti	±10 V	483

DIFFERENTIAL AMPLIFIER
Wideband amplifier for data acquisition systems
Model 8875A

The Model 8875A is a differential dc amplifier that provides high gain (up to 3000) and wide bandwidth. It features low drift for reliable, long term measurements, a common mode rejection of at least 120 dB at 60 Hz (500 ohm source unbalance, gain of 1000) and a common mode tolerance of ±20 V. Intermodulation distortion is avoided by use of direct-coupled input circuits (no choppers or modulators are used). An output having a capability of ±10 V at ±100 mA is standard, with a second independent output of ±10 V at ±10 mA optional. The 8875A is available as a single unit, in banks of up to 10 channels for rack mounting or in portable cases.

The 8875A is ideal for use with thermocouples, dc excited strain gages and other low level sources, with read out to devices such as digital voltmeters, optical oscillographs, analog-digital converters and similar units. Applications include space vehicle checkout, monitoring of physical variables, wind tunnel tests and arrangements with either input or output multiplexers.



8875A

Electrical Specifications

Bandwidth: dc to 75 Hz within 3 dB, at fixed gain steps. Can be narrowed to as low as dc to 2 Hz with optional switch-selectable filter.

Gain: fixed steps of 1, 3, 10, 30, 100, 300, 1000 plus OFF, on any range, variable gain potentiometer may be switched to provide uncalibrated gain up to 3X gain switch setting. Gain accuracy ±0.1%; gain vernier allows setting any one fixed gain to an accuracy of 0.01%.

Input circuit: differential, active guarded; will accept floating input without ground return; may be used single-ended.

Input impedance: differential, 20 MΩ (±5%) with less than 0.001 μF shunt; common mode (guarded), greater than 2000 MΩ with less than 2 pF shunt.

Common mode rejection: at least 120 dB from dc to 60 Hz for up to 500Ω source impedance either side of input at gain of 1000; 66 dB minimum at gain of 1.

Common mode tolerance: ±20 V.

Input overload tolerance: ±30 V differential; ±70 V common mode will not damage the amplifier.

Output circuit: ±10 V across 100Ω (100 mA), output impedance (dc) 0.2Ω max. Short circuit proof; current limited to approx 150 mA. Will not oscillate with any value of capacity load.

Zero drift: ±3 μV referred to input, ±0.2 mV referred to output, at constant ambient temperature for 30 days. ±1 μV/°C referred to input, ±0.2 mV/°C referred to output. ±2 mV referred to output for ±10% change in line voltage.

Gain stability: ±0.01% at constant ambient temperature for 30 days, ±0.005%/°C (fixed gain steps only). ±0.01% for ±10% change in line voltage.

Nonlinearity: less than 0.01% of full scale 10 V output (zero based terminal linearity).

Current feed to source: 0.001 μA max at constant ambient temperature; ±0.001 μA/°C.

Settling time: 100 μsec to 99.9% of final value for step input.

Overload recovery time: from differential overload signal of ±10 V at gains of 300 to 1000, recovery in 10 msec to within 10 μV, referred to input plus 10 mV referred to output; for gains of 1 to 100, recovery in 1 msec. For a 10X full scale overload of any duration, recovery in 2 msec for gains of 300 to 100, and 100 μsec for gains of 1 to 100.

Noise: measured at gain of 1000 with respect to input, 1000Ω source impedance:

Bandwidth	Noise	Bandwidth	Noise
dc-10 Hz	1 μV pp	dc-10 kHz	3 μV rms
dc-100 Hz	3 μV pp	dc-50 kHz	4 μV rms
dc-1 kHz	6 μV pp	dc-250 kHz	5 μV rms

Slewing: gain of 1 or 3, 0.7 μV/sec; gain greater than 3, 1 μV/sec referred to output, for 10 mV dc offset at output with resistive load of 100Ω or greater.

Input-output isolation: greater than 200 MΩ shunted by less than 2 pF.

Temperature range: 0°C to 55°C.

General Specifications

Power: 115/230 V ±10%, 50 to 400 Hz, 6 W.

Dimensions: 4¾" high, 1-9/16" wide, 15" deep (121 x 40 x 381 mm).

Weight: 3.5 lbs (1,6 kg).

Prices: 8875A Differential Amplifier, $495.

Option 01: dual outputs (10 mA and 100 mA capability; short on one has negligible effect on other), add $75.

Option 02: switch selected filters (single-pole, low pass, with corner frequencies of 2, 200, 2000 and 20,000 Hz), add $75.

Option 03: gain ranges of 10, 20, 50, 100, 200, 500 and 1000, add $25.

Option 04: 14010A Cord Connector Set for bench-top use (required for single-channel operation), add $65.

Option 05: combines Option 01 and 02 (filters on 10 mA output only), add $150.

Option 06: combines Option 02 and 03, add $100.

Note: must order 1069-01A case for multichannel banks of 10 or less, $365. Sufficient blank panels (01069-61069) to fill case are required to maintain temperature stability specifications, $10 each.

DATA AMPLIFIER

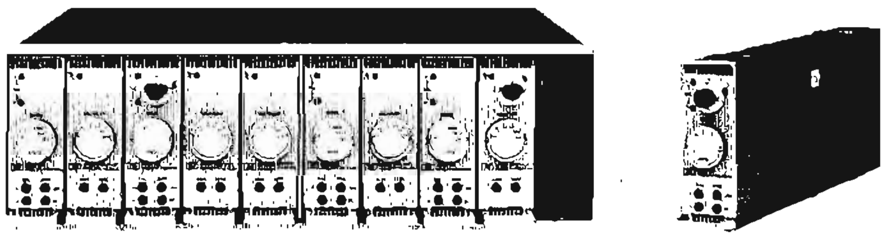
Solid-state, wideband differential amplifier

Model 2470A

The HP 2470A Amplifier is a flexible wideband differential amplifier exhibiting low drift and noise, achieved without the use of a chopper. The instrument will supply up to 1 watt output to a resistive or reactive load. Exceptionally high reliability and accuracy are achieved by the use of silicon semiconductors.

Applications include amplification of strain gage bridge, thermocouple and other low-impedance sensors. Amplifier provides an output suitable for data acquisition devices, including recording galvanometers and oscillographs, analog recorders, servo control systems. Low instrument cost keeps per-channel price to the minimum. The 2470A also applies directly to many general-purpose laboratory uses, both differential and single-ended.

The amplifier with its power supply is packaged compactly. Ten instruments fit side-by-side in 5¼" of standard 19" rack space, or two instruments may be installed in a portable case as shown on page 247.



2470A Amplifier shown in combining case.

Specifications

Specifications include ±10% line voltage variation, hold for 1K max. source resistance, any unbalance, and assume calibration after specified warmup.

DC gain: 6 fixed steps of x1, x10, x30, x100, x300, x1000. Optional vernier (10-turn potentiometer) extends gain to x3.5.

DC gain accuracy: calibrated gain: .01% at output; other gains: .03%, consisting of .02% gain-to-gain accuracy and .01% gain trim resolution.

Gain stability: dc: ±.005% of output per month; ac: ±.1% per month, for ac to 2 kHz; temp. coeff: ±.001% per °C.

Linearity: dc: ±.002% of full scale, referred to straight line through zero and full scale output. AC: ±.01% of full scale; inputs to 2 kHz.

Zero drift (offset): per day: ±5 μV rti (referred to input) ±200 μV rto (referred to output); per month: ±25 μV rti ±500 μV rto: temp. coeff: ±1 μV ±.5 namp rti ±40 μV rto per °C.

Maximum input signal: ±11 V, differential plus common mode.

Differential input impedance: 10^9 ohms shunted by .001 μF.

Common mode rejection: 120 dB at 60 Hz for gains of x30 and higher.

Common mode return: from input common to output common; 1 megohm, max.

Noise: 0 to 10 Hz: 1 μV p-p rti and 10 μV p-p rto; to 50 kHz: 5 μV rms rti and 500 μV rms rto.

Output: ±10 V max, 0 to 100 mA. Self-limits.

Output impedance: 0.1 ohm in series with 10 μH max.

Load capability: 100 ohms or .01 μF for full output.

Slewing: 10^6 V/sec at gain of 1; 5 x 10^6 V/sec at gain of 30.

Bandwidth: for any gain step, 0 to 50 kHz ±3 dB; 0 to 15 kHz ±1 dB; 0 to 5 kHz ±1%; 0 to 1.5 kHz ±.1%; 0 to 500 Hz ±.01%.

Settling time: 100 μs to .01% of final value.

Overload recovery: 200 μs to .01% of final value for signal of 10 times full scale, but less than 10 V; less than 5 ms for signal plus common mode up to 20 V.

Overload signal: −17.5 to −19.5 V with no overload, 0 to −1 V in overload; 5 mA drive capability; front panel lamp indication.

Operating conditions: ambient temperatures 0 to 55°C; relative humidity to 95% at 40°C.

Warmup: operates immediately after turn-on, but requires 1½ hours in free air, 30 minutes in Portable Case or Combining Case (plus 1 hour additional warmup for each 10°C difference between storage temperature and operating ambient) for specified accuracy and zero drift.

Reliability: predicted MTBF (90% confidence) 20,000 hours when operated at 25°C ambient.

Power: 115 or 230 V ±10%, 50 to 400 Hz, 10 W max.

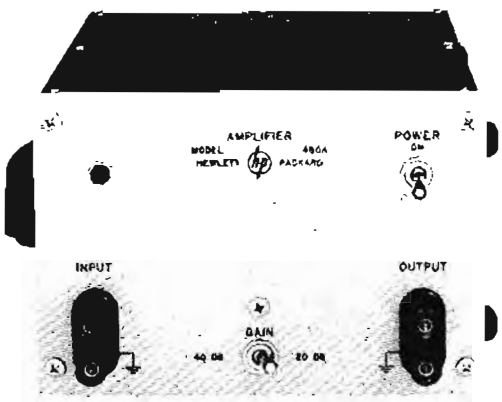
Dimensions: 1-9/16" wide, 4⅞" high, 15" deep (39.7 x 123.9 x 381 mm).

Weight: net 4 lbs (1,8 kg); shipping 6½ lbs (2,9 kg).

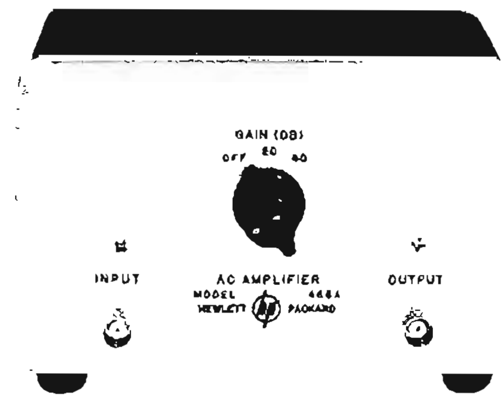
Accessories available: mating rear connector; mating rear connector with power cord, input/output cables; combining case: contains up to 10 instruments in 5¼" of standard 19" rack space (mating connectors furnished) includes power cord and fan; portable case: holds two amplifiers (mating connectors furnished) and includes power switch, pilot light, power cord and fan.

Price: HP 2470A Data Amplifier, $600.

AMPLIFIERS
Offer 20 or 40 dB gain
Models 450A, 466A



450A



466A

450A Stabilized Amplifier

The HP Model 450A is ideal as a general-purpose instrument wherever wide-frequency range and stable gain are essential. The instrument has an extremely stable 20 dB or 40 dB gain over a continuous frequency range of 10 Hz to 1 MHz. Either gain may be selected quickly with a toggle switch on the front panel.

The amplifier is resistance-coupled and does not use peaking or compensating networks. Optimum performance is obtained entirely from a straightforward amplifier design in combination with inverse feedback.

Specifications, 450A

Gain: 20 dB (X10) or 40 dB (X100) ±0.125 dB at 1000 Hz.

Frequency response: 40 dB gain: ±0.5 dB, 10 Hz to 1 MHz; ±1 dB, 5 Hz to 2 MHz; 20 dB gain: ±0.5 dB, 5 Hz to 1 MHz; ±1 dB, 2 Hz to 1.2 MHz (open circuit).

Stability: ±2%, includes line voltage variation 115 or 230 V ±10%.

Impedance: input, 1 megohm, 15 pF shunt; internal, less than 150 ohms.

Distortion: less than 1%, 2 Hz to 100 kHz at maximum output and rated load; 2% above 100 kHz.

Output: 10 V maximum into 3000-ohm or greater load.

Noise referred to input: 40 dB gain, 40 μV; 20 dB gain, 250 μV.

Power: 115 or (230 V must be specified) ±10%, 50 to 400 Hz, 50 watts.

Dimensions: cabinet: 8⅜" wide, 5½" high, 10¾" deep (219 x 140 x 273 mm); rack mount: 19" wide, 5¼" high, 10⅝" deep behind panel (483 x 133 x 270 mm).

Weight: net 10 lbs (4,5 kg), shipping 15 lbs (6,8 kg) (cabinet); net 11 lbs (5 kg), shipping 23 lbs (10,4 kg) (rack mount).

Price: HP 450A, $220 (cabinet); HP 450AR, $225 (rack mount).

466A AC Amplifier

The HP Model 466A AC Amplifier is ideal wherever low distortion, stability, wide-frequency range, and portability are desirable; and it may be used to increase the sensitivity of voltmeters and oscilloscopes, since its gain is accurate and stable.

Model 466A is normally furnished with a plug-in supply for ac operation. For portable operation or for isolation from power lines, the supply may be quickly removed and replaced with batteries. If desired, specify batteries in lieu of the plug-in supply (Option 01).

Specifications, 466A

Gain: 20 dB (X10) or 40 dB (X100) ±0.2 dB at 1000 Hz.

Frequency response: ±0.5 dB, 10 Hz to 1 MHz down 3 dB, or less at 5 Hz and 2 MHz.

Output voltage: 1.5 V rms across 1500 ohms.

Output current: 1 mA rms maximum.

Noise: 75 μV rms referred to input, 100,000-ohm source.

Impedance: input, 1 megohm, 25 pF shunt; output, 50 ohms in series with 100 μF.

Distortion: less than 1%, 10 Hz to 100 kHz; less than 5% to 1 MHz.

Power: 115 or (230 V must be specified) ± 10%, 50 to 400 Hz, 1 watt (supply normally furnished); battery operation optional: radio-type mercury batteries, TR234-316649 or equivalent, 3 required (HP #1420-0006); battery life, 150 hours.

Dimensions: 6¼" wide, 4" high, 6¼" deep (159 x 102 x 159 mm).

Weight: net 2½ lbs (1,13 kg); shipping 3½ lbs (1,58 kg).

Price: HP 466A, $180, ac operation

HP 466A Option 01: batteries in lieu of ac supply, deduct $15

SOLID-STATE AMPLIFIERS

Precision general-purpose amplifiers

Models 465A, 467A

465A

HP 465A Amplifier

The HP Model 465A is a general-purpose amplifier and an excellent impedance converter (10 megohms to 50 ohms). This amplifier has extremely stable 20 dB or 40 dB gain over a continuous frequency range of 5 Hz to 1 MHz. Either gain may be selected rapidly with a switch on the front panel.

This solid-state amplifier is ideal for increasing the power output of solid-state oscillators or amplifiers. The output stage provides low-output impedance and wide dynamic range. The HP 465A is a three-terminal device isolated from chassis and may be floated up to 500 volts dc above chassis ground.

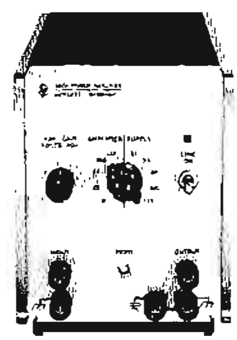
465A Specifications

Voltage gain: 20 dB (X10) or 40 dB (X100), open circuit.
Gain accuracy: ±0.1 dB (±1%) at 1000 Hz.
Frequency response: ±0.1 dB, 100 Hz to 50 kHz <2 dB down at 5 Hz and 1 MHz.
Output: >10 volts rms open circuit; >5 volts rms into 50 ohms (0.5 watt).
Distortion: <1%, 10 Hz to 100 kHz, <2%, 5 Hz to 10 Hz and 100 kHz to 1 MHz.
Input impedance: 10 megohms shunted by <20 pF.
Output impedance: 50 ohms.
Noise: <25 μV rms referred to input (with 1 megohm source resistance).
Temperature range: 0 to +50°C.
Power: 115 or 230 V ±10%, 50 to 400 Hz, 10 watts at full load.
Dimensions: 5⅛" wide, 3" high (without removable feet), 11" deep (130 x 76 x 279 mm).
Weight: net: 4 lbs (1,8 kg) shipping: 6 lbs (2,7 kg).
Price: HP 465A, $210.

HP 467A Amplifier/Power Supply

The solid-state HP 467A Power Amplifier/Supply is a 10-watt peak power amplifier and −20 to +20 volt dc power supply. The power amplifier has a wide bandwidth and low dc drift, suitable for many applications wherever a power source is required. Unique features are low distortion (<0.01%), low drift and high-gain accuracy.

An output greater than ±20 volts peak and ±0.5 A peak is available from dc up to 1 MHz. At full output the distortion of the 467A is less than 3% up to 1 MHz. The amplifier is a three-terminal device isolated from chassis and may be floated up to 200 volts dc above chassis ground.



467A

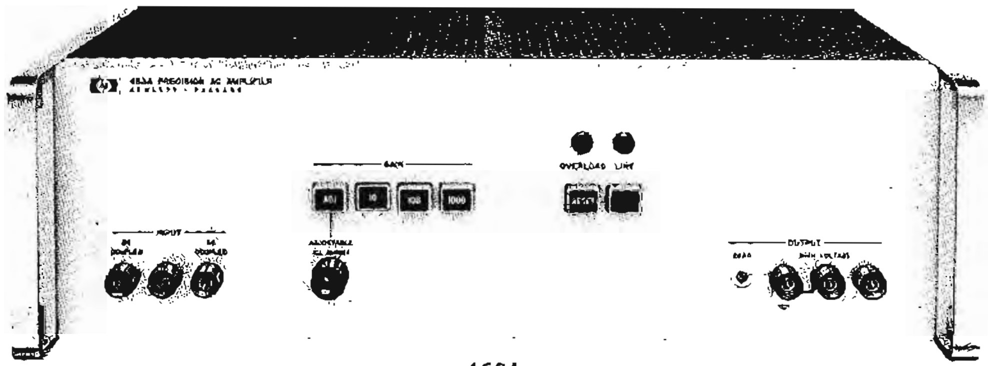
467A Specifications

Power amplifier
Voltage gain (non-inverting): fixed steps: X1,X2,X5,X10.
Variable: 0-10 resolution is better than 0.1% of full output.
Accuracy: ±0.3% from dc to 10 kHz; ±1.0% from 10 kHz to 100 kHz; ±10% from 100 kHz to 1 MHz with load of >40 ohms.
Output: ±20 V peak at 0.5 A peak.
Distortion: <0.01% at 1 kHz; <1% at 100 kHz; <3% at 1 MHz.
Input impedance: 50k ohms shunted by 100 pF.

DC power supply
Voltage range: >±20 V, ±10 V, ±4 V, ±2 V, ±1 V; with adjustable vernier. Resolution: better than 0.1% of full output.
Current: ±0.5 A peak.
Load regulation: (front panel) <10 mV, no load to full load.
Line regulation: <10 mV for a ±10% change in line voltage.

General
Output impedance: (front panel): 5 MΩ in series with 1 μH.
Capacitance load: 0.01 μF or less does not cause instability.
Ripple and noise: <5 mV p-p (referred to output) for amplifier and power supply.
Current limit: <800 mA.
Temperature coefficient: <±0.05%/°C of output or ±2 mV/°C at output, whichever is greater.
Input-output terminals: front panel: ¾" spaced banana terminals for input, output, and chassis. Rear panel: BNC terminals. Circuit ground can be floated 200 V dc above chassis ground.
Operating temperature range: 0 to +50°C.
Power required: 115 or 230 V ±10%, 50-400 Hz; <35 W, full load.
Dimensions: 5⅛" wide, 6¼" high (without removable feet), 11" deep (130 x 159 x 279 mm).
Weight: net: 10 lbs (4,5 kg); shipping: 16 lbs (7,2 kg).
Price: HP 467A, $595.

PRECISION AC AMPLIFIER
Low level measurements; precision application
Model 463A



463A

Description

A precision ac amplifier, the solid-state HP 463A has gain accuracy better than 0.01% with long-term stability of 100 ppm/yr., distortion below 0.01%, and output capability up to 100 volts rms at 5 watts continuous. The 463A has a bandwidth from dc to 100 kHz offering use in many applications. Unusual precision in the performance of the 463A Amplifier suggests its usefulness in ac calibration procedures; an example is calibrating precision attenuators. The 100-volt output capability makes it practical to measure as much as 110 dB of attenuation. It is ideal to amplify the output of the most stable solid-state oscillators, or to use as an isolator for thermocouple transfer measurements. The Hewlett-Packard Model 463A Precision AC Amplifier was designed to meet the most critical requirements for wide-range, low-distortion applications.

Specifications*

Fixed Gain (DC Coupled)

X10 Range

Accuracy: Dc to 10 Hz, <±0.3%**; 10 Hz to 10 kHz, <±0.01%; 10 kHz to 100 kHz, <±0.1%.

Distortion (100 V output, full load): 10 Hz to 10 kHz, <0.01%; 10 kHz to 100 kHz, <0.1%.

X100 Range

Accuracy: Dc to 10 Hz, <±3%**; 10 Hz to 20 kHz, <±0.1%; 20 kHz to 100 kHz, <±1.0%.

Distortion (100 V output, full load): 10 Hz to 10 kHz, <0.03%; 10 kHz to 100 kHz, <0.1%.

X1000 Range

Accuracy: Dc to 10 Hz, <±30%**; 10 Hz to 20 kHz, <±0.3%; 20 kHz to 100 kHz, <±3.0%.

Distortion (100 V output, full load): 10 Hz to 10 kHz, <0.1%; 10 kHz to 100 kHz, <0.5%.

Fixed gain (AC Coupled): identical to dc coupled except coupling capacitor causes 0.01% error at 25 Hz to 3 dB error at 0.35 Hz.

Adjustable gain (ac or dc coupled): gain may be adjusted from 0 to 100% of the fixed gain range.

*For complete data refer to Technical Data Sheet.
**Includes temperature coefficient and short term stability.
†From 6 Hz to 50 kHz.

Distortion: same as fixed gain range.

Long term stability (Fixed Gain):

Frequency	X10	Gain, X100	X1000
10 Hz to 10 kHz	0.003%/mo or 0.01%/yr	0.03%/mo or 0.1%/yr	0.3%/mo or 1%/yr
10 kHz to 100 kHz	0.03%/mo	0.3%/mo	3%/mo

Temperature coefficient: X10 (10 Hz to 10 kHz) 10 ppm/°C (10 kHz to 100 kHz) 50 ppm/°C; X100 (10 Hz to 10 kHz) 50 ppm/°C (10 kHz to 100 kHz) 250 ppm/°C; X1000 (10 Hz to 10 kHz) 100 ppm/°C (10 kHz to 100 kHz) 500 ppm/°? (deviation from Cal. Temp. for fixed gain).

DC zero stability:

Short term: (23°C ±1°C)

Gain range	V/hr. (output)
X10	0.05
X100	0.5
X1000	5.0

Input impedance: fixed gain; 1 MΩ (±5%), <35 pF; adjustable gain; 50 kΩ, <200 pF.

Maximum input voltage: protected to ±150 volts. Ac coupling capacitor ±500 volts peak.

Noise (rms referred to input):

Gain range	<1 kΩ source	>1 kΩ source‡
X10	1.5 mV	1.5 mV
X100	150 μV	300 μV
X1000	50 μV	200 μV

‡with input shielded

Output characteristics:

Voltage: dc: 100 V, 20 mA; ac: 100 V rms, 50 mA.†

Power: 5 W continuous.

Impedance: from 0.05Ω to 20Ω.

Minimum resistive load: 100Ω.

Maximum capacitive load: 300 pF on the X10 range to 5000 pF on the X1000 range (capacitive drive increased with a resistor in series with the output).

General:

Temperature range: 0 to +50°C.

Power: 115 or 230 V, ±10%, 50 to 400 Hz, 50 W full load.

Dimensions: 16¾" wide, 5" high (without removable feet), 13¼" deep (426 x 127 x 337 mm).

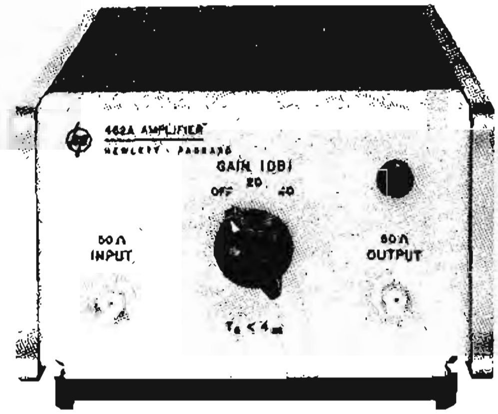
Weight: net 19 lbs. (8,6 kg); shipping 25 lbs (11,3 kg).

Accessories furnished: rack mounting kit for 19" rack.

Price: HP 463A, $690.

SOLID STATE AMPLIFIERS
Wide band, 40 dB solid-state amplifiers
Models 461A, 462A

461A



462A

The solid-state HP 461A and 462A Amplifiers are excellent wherever wide-frequency range, low distortion and portability are desired.

The 461A Amplifier is a general-purpose instrument designed to deliver stable gain over a wide-frequency range. Either 20 dB or 40 dB gain may be selected with a front-panel switch. Figure 1 illustrates the typical frequency response of the 461A. Both input and output impedances are matched to 50 ohms. Maximum output is ½ volt rms.

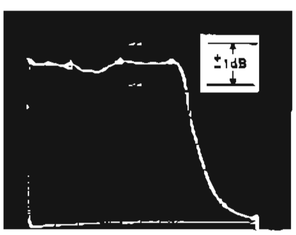


Figure 1. Frequency response curve of HP 461A. Markers shown from left to right are: 50, 100, 150 and 200 MHz. Gain control is set in 20 or 40 dB position.

The ability of the 462A to amplify very fast pulses can be seen in Figure 2. The upper trace (A) shows a 20 ns pulse applied to the input of the 462A Amplifier. The lower trace shows the same pulse amplified at 40 dB, as viewed on the HP 185B Sampling Oscilloscope.

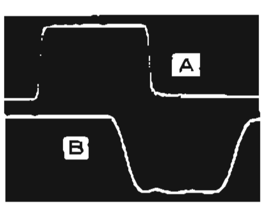


Figure 2. (A) Input Pulse to HP 462A (5 mV peak to peak). (B) Output Pulse of HP 462A (500 mV peak to peak). Gain control is set in 40 dB position. Sweep speed is 5 ns/cm.

This amplifier gives maximum usefulness for fast-pulse applications, television, and vhf work.

Specifications, 461A

Frequency range: 1 kHz to 150 MHz.

Frequency response: ±1 dB, 1 kHz to 150 MHz, when operating into a 50-ohm resistive load (500 kHz reference).

Gain at 500 kHz: 40 dB ±0.5 dB; or 20 dB ±1.0 dB, selected by front-panel switch (inverting).

Input impedance: nominal 50 ohms.

Maximum input: 1 volt rms or 2 volts p-p pulse.

Maximum dc input: ±2 volts.*

Output: 0.5 volt rms into 50-ohm resistive load.

Equivalent wideband input noise level: less than 40 μV in 40 dB position.

Distortion: <5% at maximum output and rated load.

Overload recovery: <1 μs for 10 times overload.

Specifications, 462A

Pulse response: leading edge and trailing edge: rise time, <4 nanoseconds; overshoot, <5%.

Pulse overload recovery: less than 1 μs for 10 times overload.

Pulse duration for 10% droop: 30 μs.

Equivalent input noise level: less than 40 μV in 40 dB position.

Input impedance: nominal 50 ohms.

Maximum input: 1 volt rms or 2 volts p-p pulse.

Maximum dc input: ±2 volts.*

Gain: 20 or 40 dB selected by front-panel switch (inverting).

Output: 1 volt peak-to-peak into 50-ohm resistive load.

Delay: nominally 12 to 14 nanoseconds.

General Specifications

Dimensions: 5⅛" wide, 3" high (without removable feet), 11" deep (130 x 76 x 279 mm).

Weight: net 3¼ lbs (1,5 kg); shipping 5 lbs (2,3 kg).

Power: 115 or 230 volts ±10%, 50 to 400 Hz, 5 watts.

Connectors: BNC female.

Accessories available: 11048B 50-Ohm Feed-thru Termination, $10; Combining Cases: 1051A, $110, or 1052A $120, (each holds six HP 461A, Amplifiers).

Price: HP 461A, $325; HP 462A, $325.

*For the protection of the input circuitry.

POWER AMPLIFIER

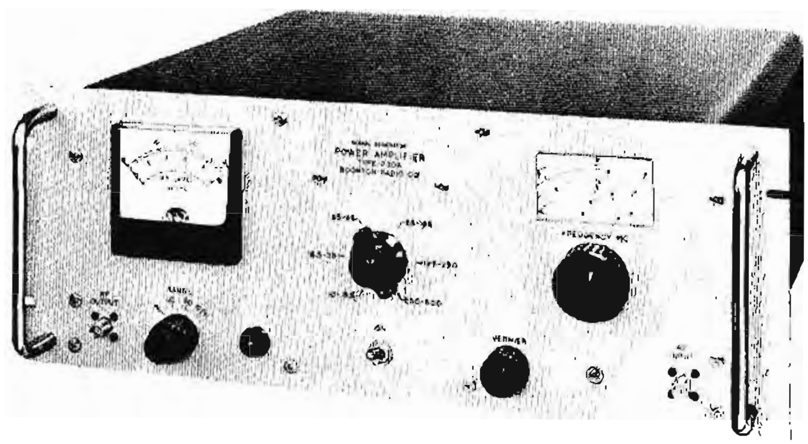
Provides more than 4.5 watts, 10 to 500 MHz

Model 230A

The HP 230A Signal Generator Power Amplifier is the ideal solution to high RF power requirements, including receiver testing, wattmeter calibration, antenna testing, filter and component testing and attenuation measurements.

The amplifier may be conveniently driven with any conventional signal generator and is designed to reproduce AM, FM and pulse modulation characteristics of the driving generator with minimum distortion.

The 230A employs three tuned, cascaded stages of grounded-grid amplification fed from a regulated power supply. An RF output voltmeter is also included and the unit is designed for either standard 19" rack or cabinet use.



230A

Specifications

Radio frequency characteristics

RF range: total range: 10 to 500 MHz; number bands: 6; band ranges: 10 to 18.5 MHz, 18.5 to 35 MHz, 35 to 65 MHz, 65 to 125 MHz, 125 to 250 MHz, 250 to 500 MHz.

RF calibration: increments of approximately 10%, accurate to ±10%.

RF output: range: up to 15 volts (across external 50-ohm load); calibration: 0.2 to 3 volts f.s., increments of approx. 5%; 1 to 10 volts f.s., increments of approx. 5%; 2 to 30 volts f.s., increments of approx. 5%; accuracy: ±1 dB of f.s. (10 to 250 MHz), ±1.5 dB of f.s. (250 to 500 MHz); leakage: effective shielding is greater than 40 dB.

RF bandwidth:* >700 kHz (10 to 150 MHz; >1.4 MHz (150 to 500 MHz).

RF input: level**: ≤0.316 volts, 30 dB gain, (10 to 125 MHz); ≤0.446 volts, 27 dB gain, (125 to 250 MHz); ≤0.63 volts, 24 dB gain, (250 to 500 MHz).

*Frequency interval between points 3 dB down from max. response.
**For 10 volts output into 50 ohms.

Amplitude modulation characteristics

AM range: reproduces modulation of driving signal generator 0 to 100%†.

AM distortion: <10% added to distortion of driving signal generator†.

Frequency modulation characteristics

FM range: reproduces modulation of driving signal generator except as limited by the RF bandwidth.

Incidental AM: <10% added to modulation of driving signal generator (at 150 kHz deviation).

FM distortion: negligible distortion added to distortion of driving signal generator for <150 kHz deviations and modulation frequencies.

Physical characteristics

Dimensions: 16¾" wide, 7-3/16" high, 18-1/16" deep (425 x 183 x 459 mm).

Weight: net 37 lbs (16,7 kg); shipping 57 lbs (25,7 kg).

Power: 105 to 125 or 210 to 250 V, 50 to 60 Hz, 150 W.

Price: HP 230A, $1350.

†Up to 5 volt max. carrier output for up to 100% AM.

MICROWAVE AMPLIFIERS

Broadband, high-gain, high-power amplification

Models 489A-495A

Advantages:

DC-coupled modulation circuitry allows power leveling and remote programming

PPM focusing means fewer alignment problems

Uses:

Antenna efficiency and pattern measurements

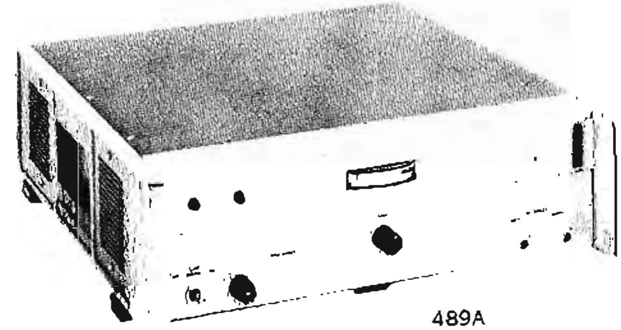
Extends attenuation measuring systems capability by at least 30 dB.

Description

Amplification of frequencies from 1 to 12.4 GHz is accomplished in four ranges by the Hewlett-Packard microwave amplifiers. Each delivers at least 1 watt with an input of 1 mW or less, a gain of at least 30 dB.

Amplitude modulation circuitry has been designed for wide bandwidth (down to dc) and with internal amplification, so that small modulation signals cause a large output power change. This unique modulation circuitry also permits power leveling with external elements, plus remote programming. Spurious phase modulation of 0.1° or less and residual AM at least 45 dB below carrier are assured by regulation of the filament, anode, and helix power supplies. TWT cathode current is monitored by a front-panel meter and can be controlled by the gain adjustment for rated power output or for reducing tube current to extend tube life when full output power is not required. Helix, collector, and anode current can be measured at an easily accessible test point board.

Periodic permanent magnet focusing reduces weight, size, and power consumption and at the same time alleviates alignment problems. Protective features incorporated to prevent TWT failure include an overload relay on the helix power supply, a three-minute time delay on the beam supply, and a fail-safe circuit that disconnects ac power whenever the regulated filament supply voltage exceeds a predetermined level.



489A

Specifications

	489A	491C	493A	495A
Frequency range (GHz)	1-2	2-4	4-8	7-12.4
Power output (with 1 mW or less input)	1 W	1 W	1 W	1 W
Gain at rated output	30 dB	30 dB	30 dB	30 dB
Gain variation with freq. at rated output	≤6 dB	≤6 dB	≤6 dB	≤6 dB
small signal across any 10% of band	≤5 dB	≤5 dB	≤5 dB	≤5 dB (for 300 MHz)
across full band	≤10 dB	≤10 dB	≤12 dB	≤10 dB
Gain variation with ±10% variation from rated line voltage	≤1 dB	≤1 dB	≤1 dB	≤1 dB
Noise max. noise figure	30 dB	30 dB	30 dB	30 dB
typ. noise power out	−10 dBm	−10 dBm	0 dBm	0 dBm
Price	$2350	$2350	$2700	$2700

For all models

Maximum RF input: 100 mW.

Input/output characteristics: impedance, 50Ω; reflection coefficient (cold), ≤0.43 (2.5 SWR, 7.3 dB return loss); connectors, type N female.

Amplitude modulation

Sensitivity: a modulation input of −20 V peak or more reduces the RF output by more than 20 dB from dc to 50 kHz. Above 50 kHz modulation decreases approximately 6 dB per octave.

Frequency response: dc to 500 kHz (3 dB).

Input impedance: 100 kΩ shunted by approx. 50 pF.

Pulse response: < 1 μs rise and fall times.

Residual AM: at least 45 dB below carrier.

Dimensions: 16¾" wide, 5½" high, 18⅜" deep (426 x 141 x 467 mm); hardware furnished for conversion to rack mount 19" wide, 5-7/32" high, 16⅜" deep behind panel (483 x 133 x 416 mm).

Weight: net 38 lb (17,1 kg); shipping 43 lb (29,4 kg).

Power: 115 or 230 volts ±10%, 50 to 60 Hz, approx. 225 watts.

Accessories available: 11500A Cable Assembly, $15; 11501A Cable Assembly, $15.

The oscilloscope is an extremely fast X-Y plotter which displays one input signal versus another signal, or versus time. The variations are displayed on the face of the cathode-ray tube. The "stylus" is a luminous spot which moves over the CRT in response to input voltages. In the usual scope application the X axis represents time. To do this a linear ramp of voltage is generated internally which moves the spot uniformly from left to right across the face of the CRT. The voltage being examined is applied to the Y axis input, moving the spot up or down in accordance with its instantaneous value. The spot then traces a curve which shows how the input voltage varies as a function of time.

Because the oscilloscope can display time varying voltages, it has become a universal tool in all kinds of electronic investigations. In addition, the oscilloscope can present a visual display of a variety of dynamic phenomena by the use of transducers which convert current, strain, acceleration, pressure, sound and other physical quantities into voltages.

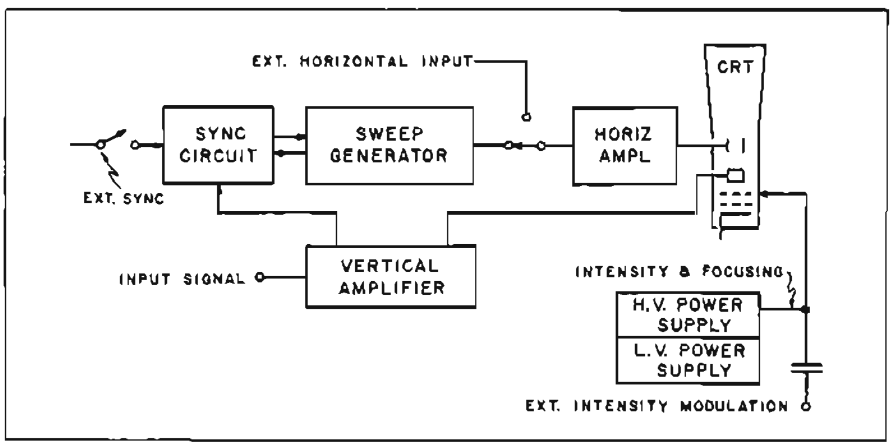


Figure 1. Oscilloscope block diagram.

The primary sub-systems of an oscilloscope are the vertical deflection system, horizontal deflection system, power supplies, and the cathode-ray tube. The vertical deflection system processes the Y axis input signal to control the up and down movement of the CRT spot. The horizontal deflection system either generates the sweep to move the spot across the CRT or processes an external signal to control the horizontal movement of the spot. The low voltage power supply provides power for the scope circuitry and the high voltage power supply provides power for the cathode-ray tube. The CRT is the readout device that displays the plot of Y versus X or Y versus time.

Cathode-ray Tube

The cathode-ray tube is the heart of the oscilloscope, with the rest of the instrument consisting of circuitry for operating the CRT. As is commonly known, the tube has an electron gun at one end and a phosphor display screen at the other end. The electron gun is made up of a thermonic cathode, various accelerating electrodes for directing emitted electrons toward the display screen, and controls necessary for focus and intensity. The resulting narrow beam of electrons from the gun strikes the phosphor in a small spot with enough energy to cause flourescence.

On leaving the gun, the electron stream passes between each of two pairs of deflection electrodes. Voltages applied to these electrodes bend the beam. Voltages on one pair of electrodes move the beam up and down and voltages on the other pair move it from side to side. The electrodes that move the beam up and down are the vertical deflection plates and the pair that moves the spot sideways are called the horizontal deflection plates. These movements are independent of each other so that the spot may be positioned anywhere on the phosphor screen by the appropriate input voltages.

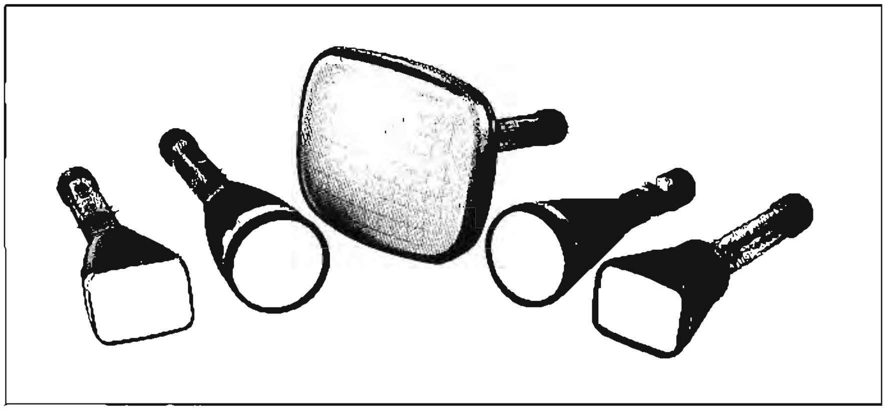


Figure 2. Some of the CRT's made in Hewlett-Packard's cathode-ray tube facility.

The accuracy with which the viewed waveform corresponds to the deflection voltages depends to a large measure on the performance of the cathode-ray tube. Careful design of the electron gun structure and precision manufacturing techniques of the Hewlett-Packard cathode-ray tube facility insure that the beam moves linearly with respect to the deflection voltages. Precision CRT's make it possible to measure accurately the input voltage amplitude at any point on the waveform by measuring the amount of deflection of the fluorescent spot.

In order to make measurements of the spot deflection a rectangular grid (called a graticule) is scribed on transparent material and attached to the face plate of the CRT. All HP CRT's however, incorporate an internal graticule. This type of graticule consists of lines placed in the same plane as the phosphor. The internal graticule avoids errors caused by parallax which exists when the graticule is external to the tube, separated from the phosphor by the thickness of the glass face plate.

Vertical deflection system

The vertical deflection system is made up of an input attenuator and an amplifier chain. Since the CRT is limited as to the range of voltage that can be applied to deflection plates, considerations must be made to handle signals outside this range. For signal amplitudes below this range the amplifier chain is used to increase the amplitude. If the signal is too large the attenuator reduces the signal so that it can be displayed. By calibrating the attenuator and amplifiers the deflection factor is known for each setting of the attenuator. That is, the graticule is calibrated in so many volts/cm depending on the attenuator setting.

The amplifiers in Hewlett-Packard oscilloscopes are stable enough to permit voltage measurements with confidence to at least ±3% accuracy. To verify amplifier accuracy, all HP scopes have built-in calibrators which supply precisely controlled signals for use as calibrating test signals.

High amplifier gain, with minimum drift and noise, is obtained in HP scopes by careful circuit design. This allows scopes to be built with high sensitivity. Large amounts of negative feedback, aided by the use of regulated power supplies, achieve gain stability for measurement accuracy.

DC coupling preserves the waveform of slowly varying signals and also permits a dc reference line to be established on the display, facilitating precise amplitude measurements. DC coupling is not desirable though when a small ac component on a relatively large dc voltage is examined. All HP scopes have provision for switching decoupling capacitors into the signal line when dc coupling is not desired.

Horizontal deflection system

The horizontal deflection system supplies drive voltages for moving the electron beam horizontally. Since so many measurements are concerned with plotting voltages versus time, the horizontal deflection system also includes sawtooth waveform generators for sweeping the beam horizontally at a uniform rate. Since the rate of sweep is uniform the scope can be calibrated for so many s/cm of horizontal display. To accept signals that vary over a wide range of frequencies, a switch is used to vary the sweep rate. Each position of the switch is calibrated so that the time scale can be varied from s/cm to ms/cm to μs/cm.

Also necessary are synchronizing circuits for starting the horizontal sweep at a specific instant with respect to the measured waveform. Starting the sweep (triggering) is quick and easy with HP scopes through the use of automatic triggering. Preset adjustments produce synchronized sweeps with little or no adjustment of the front-panel controls. An automatic baseline, present on many HP scopes, facilitates setting up the display in the absense of an input signal. The sweep magnifier feature is valuable for close examination of trace segments which occur too late in time after the start of the trace to be examined with faster sweeps.

The horizontal amplifiers of most Hewlett-Packard scopes may be used separately from the sweep generating circuits for deflecting the horizontal beam in response to external waveforms, a useful technique for making X-Y plots Phase shift measurements can also be made in this mode of operation by selecting a scope that has horizontal and vertical amplifiers with identical characteristics.

Power supplies

The low voltage power supply provides regulated voltages to the various circuits of the scope. The high voltage supply provides the voltage necessary to operate the CRT cathode.

Probes

A probe is used to transfer the signal from the circuit under test to the vertical amplifier of the oscilloscope. The characteristics of a probe should be such that

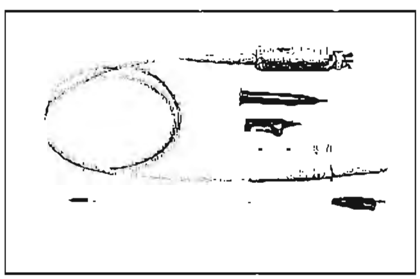


Figure 3. One type of probe used to transfer the signal from the test circuit to the scope.

it does not disturb in any way the circuit that is being tested or the performance of the oscilloscope. To accomplish this the probe has a very high impedance, say 10 MΩ, and a variable capacitor to adjust for high frequency components of the signal. Most probes are of the voltage divider type which reduce the signal amplitude. The typical division ratio is 10:1. There are types of probes other than voltage divider, such as active probes, current probes and sampling probes. Each of these types of probes performs the same basic function, that is, to get the signal from the circuit under test, to the input of the oscilloscope with little or no distortion.

State of the art

There is quite a bit more to an oscilloscope than was covered in the previous general discussion. Also the technology in this area is advancing at a rapid rate. Some of the areas where HP is advancing the technology are: sampling oscilloscopes, storage and variable persistence, large screen displays, all solid-state units using FET's, and strip delay lines to name a few.

Storage and variable persistence

The Hewlett-Packard Models 141A/181A oscilloscopes are effectively three scopes in one. They are first of all, a normal oscilloscope; secondly a storage scope capable of storing traces for periods of up to an hour; and thirdly a variable persistence oscilloscope. By persistence we mean the time it takes for the trace to fade to 10% of its original brightness. The persistence of these scopes is continuously variable from .2 seconds to more than a minute. These versatile oscilloscopes were made possible by uniquely designed CRT's and persistence control circuitry.

Sampling oscilloscopes

Conventional or "real time" oscilloscopes are limited in bandwidth to frequencies in the megahertz region. Sampling scopes, however, have bandwidths to 12.4 GHz, (12.4×10^9 hertz). This type of oscilloscope uses a stroboscopic approach to reconstruct the input waveform from samples taken during many recurrences of the waveform. This technique is illustrated by the waveforms of Figure 4. In reconstructing a waveform,

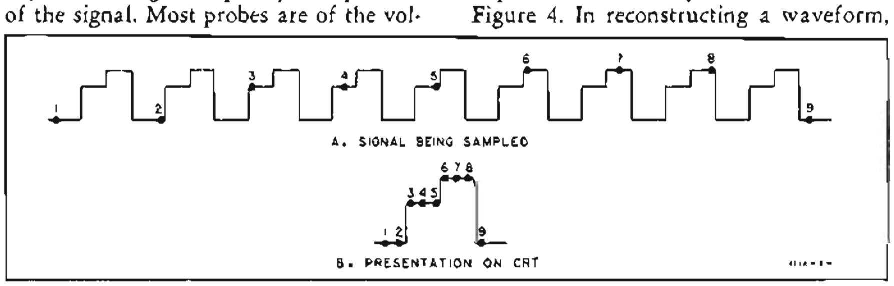


Figure 4. The sampling oscilloscope reconstructs the test signal by taking up to 1000 samples.

the sampling pulse "turns on" the sampling circuit for an extremely short interval and the waveform voltage at that instant is measured. The CRT spot is positioned vertically to correspond to this voltage amplitude.

The next sample is taken during a subsequent cycle at a slightly later point on the input waveform. The CRT spot moves horizontally a short distance and is repositioned vertically to the new voltage. In this way, the scope plots the waveform point by point, as many as 1000 samples being used to reconstruct the waveform.

A bright trace is obtained regardless of sampling rate, sweep speed, or waveform duty cycle, since each CRT spot remains "ON" during the full interval between samples.

The unique sampling circuit developed by HP, minimizes circuit loading with its high input impedance. During a sampling interval, sampling pulses momentarily bias the diodes of the balanced sampling gate in the forward direction, briefly connecting input capacitance to the test point. The balanced bridge minimizes coupling of the sampling pulses back into the test circuit. The capacitance is charged slightly toward the new voltage level. This charge is then amplified to the original value present in the test circuit and fed back to the input. In effect, the circuit detects the "error" signal between the previous and new samples and nulls out the difference. High sensitivity and gain stability are thus achieved. All HP wideband sampling scopes feature feedthrough inputs for monitoring signals without terminating, or otherwise disturbing them.

Large screen displays

Another area in which HP is advancing the technology is that of cathode-ray tube design. The ideal oscilloscope would have a very large viewing area in a very short tube. However, since the electron beam is initially deflected at the gun structure and continues at a given deflection angle, the displacement depends on the distance from the gun to the screen. To get a larger display in a shorter tube, the electron beam must be re-deflected between the gun and screen. The Model 140A CRT was the first in which a wire expansion mesh was used, placing a voltage on the mesh to create an electrostatic field to further bend the beam. The next step in the expansion-mesh technology was to change the radius of the mesh, thereby obtaining greater magnification. This resulted in the 180A CRT which has 30% more viewing area in a tube that is four inches shorter than previous high frequency tubes. One of the most recent developments is the 8 inch by 10 inch CRT display in the 1300A. This is the first time that a tube with this size display area has been designed into an 18" long tube with a deflection factor of only 14 volts for 1 inch of display.

Selecting an oscilloscope

Choice of an oscilloscope is based largely on considerations of both performance capabilities and versatility. However the complexity of the plug-in scope necessitates higher costs. Non-plug-in scopes that are designed to meet specific needs can be produced at lower costs.

Bandwidth and deflection factor of the vertical amplifiers are the primary characteristics which describe an oscilloscope's performance capabilities. Wide bandwidth is obtained at the expense of more complicated circuitry and more expensive cathode-ray tubes. A low deflection factor requires more amplifier stages and added refinements for minimizing dc drift and noise. In addition to these two primary considerations and the question of plug-ins or not, there are special requirements and features that can dictate which scope is selected. Refer to page 554 for a glossary of oscilloscope terminology and information on CRT phosphors.

Non-plug-in oscilloscopes

Hewlett-Packard's non-plug-in oscilloscopes make accurate voltage and time measurements on a wide variety of waveforms in the subsonic, audio, ultrasonic and low radio frequency ranges. These scopes are intended for analysis of waveforms in which little importance is attached to frequency components beyond 500 kHz. The dc amplifiers and long sweep rates are suitable for medical and mechanical observations, as well as for low-frequency electrical work. At the same time, faster sweep speeds are provided in these instruments for detailed studies of transient phenomena, vibration effects, audio analysis and other medium frequency events.

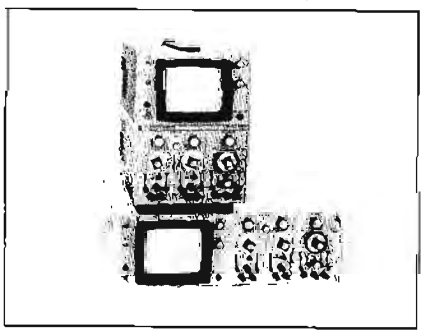


Figure 5. Model 1200A/B 500 kHz bandwidth oscilloscope is all solid-state non-plug-in instrument. This is one in 1200-series scopes offering wide selection of specifications and configurations.

Since these instruments have relatively simple circuitry and construction they are the most economical type of osilloscope. In applications such as systems, where the scope performs a limited number of functions and the added expense of plug-in flexibility is not needed, the non-plug-in oscilloscope provides maximum economy.

Plug-in oscilloscopes

Hewlett-Packard plug-in oscilloscopes enable the user to make a very wide variety of measurements with just one oscilloscope. The instrument characteristics can be altered by simply changing the vertical and horizontal plug-ins. Bandwidth, deflection factor, number of channels, and time base can all be tailored to exact needs. Other features such as sampling or TDR can be added at will. Plug-in capability also enables a scope's performance to be updated as new plug-ins become available.

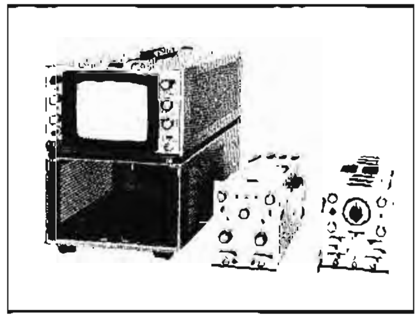


Figure 6. The Model 180A plug-in oscilloscope features aircraft type frame construction for maximum ruggedness with minimum weight.

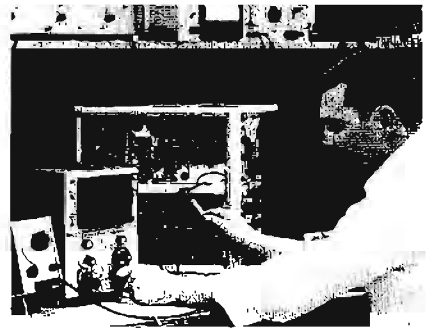
In determining which scope to buy, the considerations are: Will the needs change in the future?—if so, a plug-in scope would be the best buy; is cost a major consideration?—if so, then a non-plug-in scope might fill the bill; or is there a special function that is desired?—this then dictates the type of scope. A general rule for selection would be to determine the basic requirements of the oscilloscope based on the intended application and then use the Selection Charts to determine the one best suited for the task.

If there is any question as to which oscilloscope to choose, it is recommended that the customer consult with the local HP field engineer. HP field engineers are trained in the use and applications of all HP instruments and can assist in solving the particular applications problem in the most economical way.

SELECTION CHART
Choose the oscilloscope for the application

180AR

141A



1202A

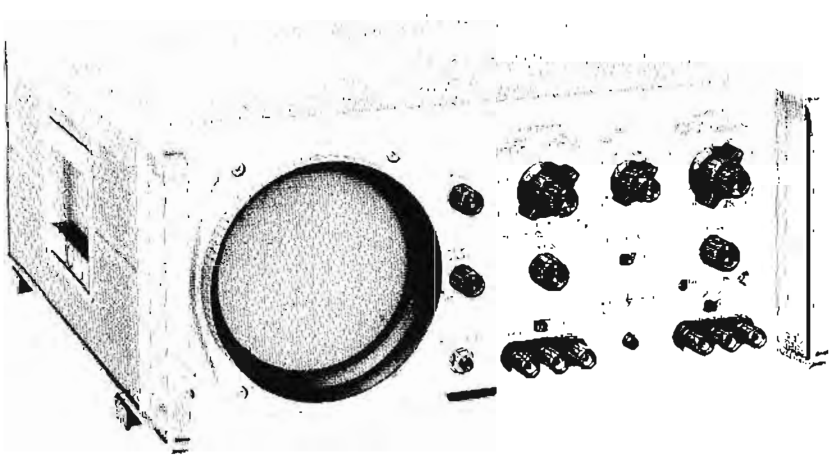
Type	Non plug-in										Plug-in	
									X-Y displays			
Model no.												
Bandwidth												
Minimum deflection factor	mV/cm	mV/cm	μV/cm	μV/cm	μV/div	μV/div	mV/div	mV/div	mV/div	V/in.	μV/div	mV/div
Sampling											•	•
Storage											•	•
Variable persistence											•	•
Differential input	•	•	•	•	•	•	•	•	•		•	•
8 in. x 10 in. CRT										•	•	
Two channel		•		•	•		•				•	•
Four channel												•
TDR											•	•
DC offset											•	•
Swept frequency											•	
Delayed sweep											•	•
Price	$530	$775	$750	$1395	$990	$790	$875	$715	$540	$1900	$1070 and up	$1950 and up
Page	495	496	497	498	500	500	500	500	500	506	508	533

450 kHz OSCILLOSCOPE

Easy-to-use, general-purpose 10 mV/cm scope

Model 120B

The HP Model 120B Oscilloscope is an easy-to-use, general-purpose oscilloscope for both laboratory and industrial applications. It combines accurately calibrated horizontal sweep times and vertical deflection sensitivities with an internal graticule CRT that eliminates parallax error. In addition, the front panel controls are logically grouped by function to simplify operation. The automatic triggering feature synchronizes the sweep circuitry with the displayed waveform, eliminating time-consuming trigger adjustments. The Hewlett-Packard modular enclosure is equally well suited for bench use or for rack mounting with the hardware provided with each instrument. Moreover, the removable top and bottom covers of the modular enclosure permit access to all components and adjustments within the instrument for easy routine maintenance. Several instrument options are available as indicated in the Specifications.



120B

Specifications

Time base

Range: 5 μs/cm to 200 ms/cm, 15 ranges in a 1, 2, 5, sequence; accuracy ±5%; vernier provides continuous adjustment between steps and extends the 200 ms/cm step to at least 0.5 s/cm.

Magnifier: X5 sweep expansion may be used on all ranges and expands the fastest sweep to 1 μs/cm; expanded sweep accuracy is ±10%.

Automatic triggering (baseline displayed in the absence of an input signal):

Internal: 50 Hz to 450 kHz for most signals causing 1.0 cm or more vertical deflection; also from line voltage.

External: 50 to 450 kHz for most signals at least 1.5 volts peak-to-peak.

Trigger slope: positive or negative slope of vertical deflection signal; or negative slope of external sync signal.

Amplitude selection triggering:

Internal: 10 Hz to 450 kHz for signals causing 0.5 cm or more vertical deflection.

External: 10 Hz to 450 kHz for signals at least 1.5 volts, peak-to-peak.

Trigger point and slope: from any point on the vertical waveform presented on CRT; or continuously variable from −7 to +7 volts on the negative slope of external sync signal.

Vertical amplifier

Bandwidth: dc coupled, dc to 450 kHz; ac coupled, 2 Hz to 450 kHz.

Deflection factor (sensitivity): 10 mV/cm to 10 volts/cm in 4 calibrated steps; accuracy ±3%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 100 V/cm.

Maximum input: 500 V peak (dc + ac).

Internal calibrator: calibrating signal automatically connected to vertical amplifier for setting amplifier gain, accuracy ±2%.

Input RC: 1 megohm shunted by approximately 50 pF.

Balanced input: on 10 mV/cm range; input RC, 2 megohms shunted by approximately 25 pF; common mode rejection at least 40 dB; common mode signal must not exceed ±3 volts peak.

Phase shift: vertical and horizontal amplifiers have same phase characteristics within ±2° to 100 kHz (with verniers in Cal).

Horizontal amplifier

Bandwidth: dc coupled, dc to 300 kHz; ac coupled, 2 Hz to 300 kHz.

Deflection factor (sensitivity): 0.1 volt/cm to 10 volts/cm in 3 calibrated steps; accuracy ±5%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 100 V/cm.

Input RC: 1 megohm, nominal, shunted by approximately 100 pF.

General

Cathode-ray tube: mono-accelerator, 2700-volt accelerating potential; aluminized P31 phosphor (other phosphors available, see modifications); etched safety glass face plate reduces glare.

Graticule: 10 cm x 10 cm parallax-free internal graticule marked in cm squares; major horizontal and vertical axes have 2 mm sub-divisions.

Beam finder: pressing beam finder control brings trace on CRT screen, regardless of settings of horizontal, vertical, or intensity controls.

Intensity modulation: +20 volt pulse will blank trace of normal intensity; input terminals on front panel.

Dimensions: 16¾" wide, 7½" high, 18⅜" deep overall (426 x 191 x 466 mm); hardware furnished for quick conversion to 7" x 19" (178 x 483 mm) rack mount.

Weight: net 29 lbs (13 kg); shipping 35 lbs (15.8 kg).

Power: 115 or 230 volts ±10%; 50 to 1000 Hz; approximately 95 W.

Price: HP Model 120B, $530.

Modifications: CRT phosphors (specify by phosphor number); P31 standard; P2, P7 with amber filter, P11 available, no charge.

Special order: chassis slides and adapter kit; fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40.

Options: (specify by option number)

05: external graticule CRT with P31 phosphor (P2, P7, P11 available, please specify) in lieu of standard internal graticule, add $25; includes edge-lighting of external graticule.

06: rear terminals in parallel with front panel terminals; two 3-pin AN connectors for horizontal, vertical, and trigger inputs, add $30; mating AN connectors supplied.

10: provision for single-sweep operation, as well as conventional triggered sweep, add $35.

13: plain 3/16" x 7" x 19" front panel for rack mounting only; suitable for installing special handles to match existing equipment in system or console, add $20.

DUAL-TRACE OSCILLOSCOPE

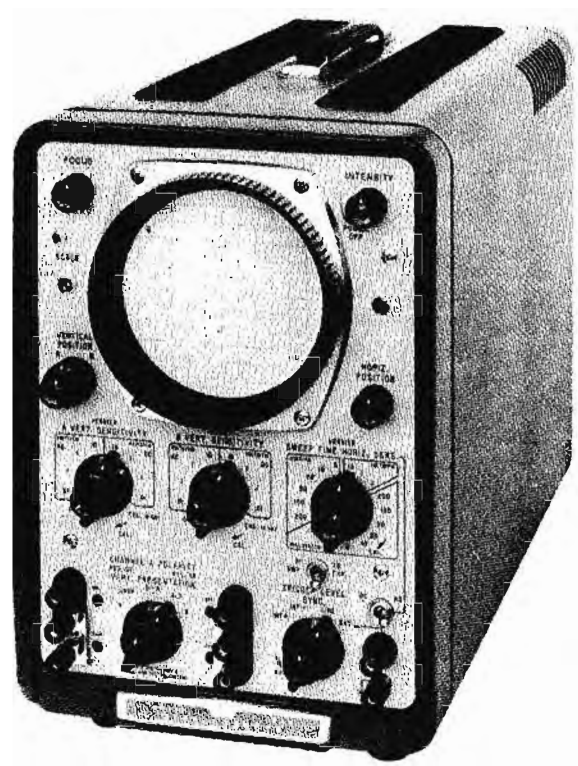
Economical versatility—200 kHz 10 mV/cm

Models 122A, 122AR

The Model 122A/AR is a dual trace, 200 kHz bandwidth oscilloscope which simplifies observation and measurement of electrical and mechanical equipment performance. It can be used as an ordinary scope with a single trace, or, when a comparison of two quantities is required it can provide two separate traces which in many ways is like having two scopes.

Personnel quickly learn the operation of this instrument and can use it with confidence since it has guaranteed calibration on both its sweep (time base) and voltage amplitude measurements.

Signals may be compared simultaneously and directly due to the twin vertical amplifiers which may be used separately or automatically switched. Input and output signals of amplifiers, filters, and other networks may be viewed simultaneously and transmission or rejection characteristics seen immediately. Since dc coupling is available, very low frequency square-waves may be used for testing, or the scope may be ac coupled to eliminate an unwanted dc signal.



122A

Specifications

Time base

Range: 5 μs/cm to 200 ms/cm, 15 ranges in a 1, 2, 5 sequence; accuracy ±5%; vernier provides continuous adjustment between steps, and extends the 200 ms/cm step to at least 0.5 s/cm.

Magnifier: X5 sweep expansion may be used on all ranges and expands the fastest sweep to 1 μs/cm; expanded sweep accuracy is ±10%.

Automatic triggering (baseline displayed in the absence of an input signal):

- **Internal:** 50 Hz to 250 kHz for signals causing 0.5 cm or more vertical deflection; also from line voltage.
- **External:** 50 Hz to 250 kHz for signals at least 2.5 volts peak-to-peak.
- **Trigger slope:** positive or negative slope of vertical deflection signals; or negative slope of external sync signals.

Amplitude selection triggering:

- **Internal:** 10 Hz to 250 kHz for signals causing 0.5 cm or more vertical deflection.
- **External:** 10 Hz to 250 kHz for signals at least 2.5 volts peak-to-peak.
- **Trigger point and slope:** from any point on the vertical waveform presented on crt; or continuously variable from −10 to +10 volts on negative slope of external sync signal.

Vertical amplifiers

Bandwidth: dc coupled, dc to 200 kHz; ac coupled, 2 Hz to 200 kHz.

Deflection factor (sensitivity): 10 mV/cm to 10 volts/cm in 4 calibrated steps; accuracy ±3%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 100 V/cm.

Maximum input: 500 V peak (dc + ac).

Internal calibrator: calibrating signal automatically connected to vertical amplifier for setting amplifier gain, accuracy ±2%.

Input RC: 1 megohm shunted by approximately 50 pF.

Balanced input: on 10 mV/cm range; input RC, 2 megohms shunted by approximately 25 pF; common mode rejection at least 40 dB; common mode signal must not exceed ±3 volts peak.

Phase shift: vertical and horizontal amplifiers have same phase characteristics within ±2° to 100 kHz (with verniers in Cal).

Isolation: greater than 80 dB between Channels A and B from dc to 200 kHz.

Difference input: both input signals may be switched to one channel to give differential input on all sensitivity ranges; the sensitivity controls may be set separately to allow mixing signals of different levels; common mode rejection is at least 40 dB with both controls in most sensitive range, 30 dB on other ranges.

Vertical presentation: control selects; A only, B only, B-A, Alternate, or Chopped.

Horizontal amplifier

Bandwidth: dc coupled, dc to 200 kHz; ac coupled, 2 Hz to 200 kHz.

Deflection factor (sensitivity): 0.1 volt/cm to 10 volts/cm in 3 calibrated steps; accuracy ±5%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 100 V/cm.

Input RC: 1 megohm, nominal, shunted by approximately 100 pF.

General

Cathode-ray tube: mono-accelerator, 3000-volt accelerating potential; aluminized P31 phosphor (other phosphors available, see modifications); etched safety glass face plate reduces glare.

Graticule: 10 cm x 10 cm parallax-free internal graticule marked in cm squares; major horizontal and vertical axes have 2 mm sub-divisions.

CRT plates: direct connection to crt deflection plates via terminals on rear panel; deflection factor approximately 20 V/cm.

Intensity modulation: +20 volt pulse will blank trace of normal intensity; input terminals on rear panel.

Dimensions: cabinet: 9¾" wide, 15" high, 21¼" deep overall (248 x 310 x 540 mm); rack mount: 19" wide, 7" high, 19½" deep behind panel (483 x 178 x 495 mm).

Weight: cabinet: net, 35 lbs (15.8 kg); shipping, 45 lbs (20.3 kg); rack mount: net, 34 lbs (15.4 kg); shipping, 49 lbs (22 kg).

Power: 115 or 230 volts ±10%; 50 to 1000 Hz; approximately 150 W.

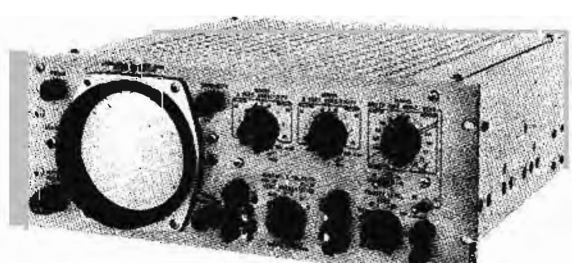
Price: HP Model 122A (cabinet), $775; HP Model 122AR (rack mount), $775; for single sweep operation specify H15-122A or H15-122AR, $845.

Modifications

CRT phosphors (specify by phosphor number): P31 standard; P2, P7 with amber filter, P11 available, no charge.

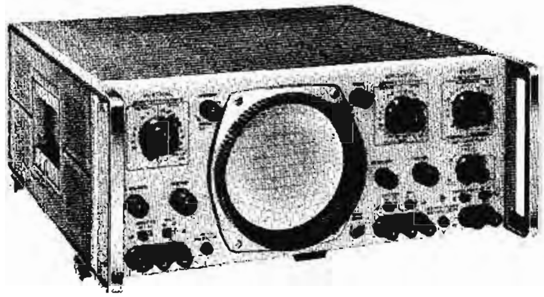
Options: (specify by option number)

- 05 External graticule CRT with P31 phosphor (P2, P7, P11 available, please specify) in lieu of standard internal graticule, add $25; includes edge-lighting of external graticule.
- 06 Rear terminals in parallel with front panel terminals; three 3-pin AN connectors for horizontal, vertical, and trigger inputs, add $40; mating AN connectors supplied.



122AR

200 μV/CM OSCILLOSCOPE
Features identical amplifiers for x-y plots
Model 130C



130C

The HP Model 130C Oscilloscope is a versatile all-purpose instrument for laboratory, production line, industrial process measurements and medical applications. The outputs of rf detectors, strain gauges, transducers and other low-level devices may be viewed directly without preamplification. Calibrated sweeps allow accurate time measurements, and the identical horizontal and vertical amplifiers permit simple and precise measurement of phase shifts within ±1° up to 100 kHz.

The Model 130C is easy to operate even by inexperienced personnel. Controls are color coded to front-panel markings and are logically arranged by function. An internal-graticule crt provides a bright, clear, non-glare display without parallax. Automatic triggering minimizes adjustments. Positive pushbutton beam finder immediately locates an off-screen trace.

Specifications

Time base

Range: 1 μs/cm to 5 s/cm, 21 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends the 5 s/cm step to at least 12.5 s/cm.

Magnifier: X2, X5, X10, X20, X50; overall sweep accuracy within ±5% for sweep rates which do not exceed a maximum rate of 0.2 μs/cm.

Automatic triggering (baseline displayed in the absence of an input signal):

Internal: 50 Hz to 500 kHz for signals causing 0.5 cm or more vertical deflection; also from line voltage.

External: 50 Hz to 500 kHz for signals at least 0.5 volt peak-to-peak.

Trigger slope: positive or negative slope of external sync signal or internal vertical deflection signal.

Amplitude selection triggering:

Internal: 10 Hz to 500 kHz for signals causing 0.5 cm or more vertical deflection.

External: for signals at least 0.5 volt peak-to-peak; dc coupled, dc to 500 kHz; ac coupled, 20 Hz to 500 kHz.

Trigger point and slope: from any point on the vertical waveform presented on CRT; or continuously variable from −10 to +10 volts on either positive or negative slope of external sync signal.

Single sweep: front panel switch permits single sweep operation.

Vertical and horizontal amplifiers

Bandwidth: dc coupled, dc to 500 kHz; ac coupled (input), 2 Hz to 500 kHz; ac coupled (amplifier), 25 Hz to 500 kHz at 0.2 mV/cm deflection factor; lower cut-off frequency (f_{co}) is reduced as deflection factor is increased; at 20 mV/cm, f_{co} is 0.25 Hz; on less sensitive ranges, response extends to dc.

Deflection factor (sensitivity): 0.2 mV/cm to 20 volts/cm, 16 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 20 V/cm step to at least 50 V/cm.

Maximum input: 500 V peak (dc + ac).

Internal calibrator: calibrating signal (line frequency square wave, 5 cm ±3%) for setting amplifier gain, is automatically connected to amplifier when sensitivity vernier is set to Cal.

Input RC: 1 megohm shunted by approximately 45 pF; constant on all ranges.

Balanced inputs: on all sensitivity ranges.

Common mode rejection (dc to 50 kHz): at least 40 dB from 0.2 mV/cm to 0.1 V/cm sensitivities, common mode signal maximum 4 volts pk-pk; at least 30 dB from 0.2 V/cm to 20 V/cm sensitivities, common mode signal maximum 4 volts pk-pk on the 0.2 V/cm range, 40 volts pk-pk on the 0.5 V/cm to 2 V/cm ranges, or 400 volts pk-pk on the 5 V/cm to 20 V/cm ranges.

Phase shift: amplifiers have same phase characteristics within ±1° to 100 kHz (with verniers in Cal, and equal input sensitivities).

General

Calibrator: line frequency square wave, 500 mV ±2% provided through jack on front panel.

Cathode-ray tube: mono-accelerator, 3000-volt accelerating potential; aluminized P31 phosphor (other phosphors available, see modifications); etched safety glass face plate reduces glare.

Graticule: 10 cm x 10 cm parallax-free internal graticule marked in cm squares; major horizontal and vertical axes have 2 mm sub-divisions.

Beam finder: pressing beam finder control brings trace on CRT screen, regardless of setting of horizontal, vertical, or intensity controls.

Intensity modulation: +20 volt pulse will blank trace of normal intensity; input terminals on rear panel.

Dimensions: 16¾" wide, 7½" high, 18⅜" deep overall (426 x 191 x 466 mm); hardware furnished for quick conversion to 7" x 19" (178 x 483 mm) rack mount.

Weight: net, 31 lbs (14 kg); shipping, 38 lbs (17,1 kg).

Power: 115 or 230 volts ±10%; 50 to 1000 Hz; approximately 90 W.

Price: HP Model 130C, $750.

Modifications: CRT phosphors (specify by phosphor number); P31 standard; P2, P7 with amber filter, P11 available, no charge.

Special order: chassis slides and adapter kit; fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40.

Options (specify by Option number)

05 External graticule CRT with P31 phosphor (P2, P7, P11 available, please specify) in lieu of standard internal graticule, add $25; includes edge-lighting of external graticule.

06 Rear terminals in parallel with front panel terminals; two 3-pin AN connectors for horizontal and vertical signal inputs, BNC for trigger input, add $45; mating AN connectors supplied.

13 Plain 3/16" x 7" x 19" panel for rack mounting only; suitable for installing special handles to match existing equipment in system or console, add $20.

DUAL-BEAM OSCILLOSCOPE
Two completely independent beams
Model 132A

The HP Model 132A Dual Beam Oscilloscope is designed to perform many electronic, scientific, bio-medical and mechanical measurements. Its 100 μV/cm sensitivity, 500 kHz bandwidth, two completely independent beams, and low microphonics and drift assure ease and accuracy in a wide variety of applications.

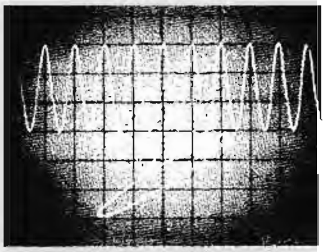


Figure 1. Simultaneous x-y and time plots are possible with Model 132A, since it has two completely independent CRT beams.

Unusual versatility is available with the Model 132A through its many different display capabilities. Functions such as pressure vs. volume, the outputs of vector cardiographs, or phase shift may be shown in x-y form on one channel, while related rate functions are displayed vs. time on the other. Also, slow and fast signals may be viewed simultaneously on different sweep speeds, or the same signal may be studied at two different sweep rates.

The Model 132A is ideal for use in areas of vibration or noise, since the amplifiers have very low microphonics and dc drift. Each input stage has nuvistor tubes contained in a shock-mounted block of aluminum. Besides isolating the nuvistors from vibration, the block also serves to keep the temperature of the tubes identical, thus providing excellent dc stability.

Differential operation is provided on all ranges for the elimination of common mode pickup such as 60-Hz hum. Rejection ratios as high as 20,000 to 1 (86 dB) assure completely clean waveforms even in the presence of high common mode interference.

Waveforms look the same from range to range with the

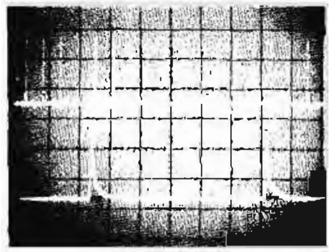
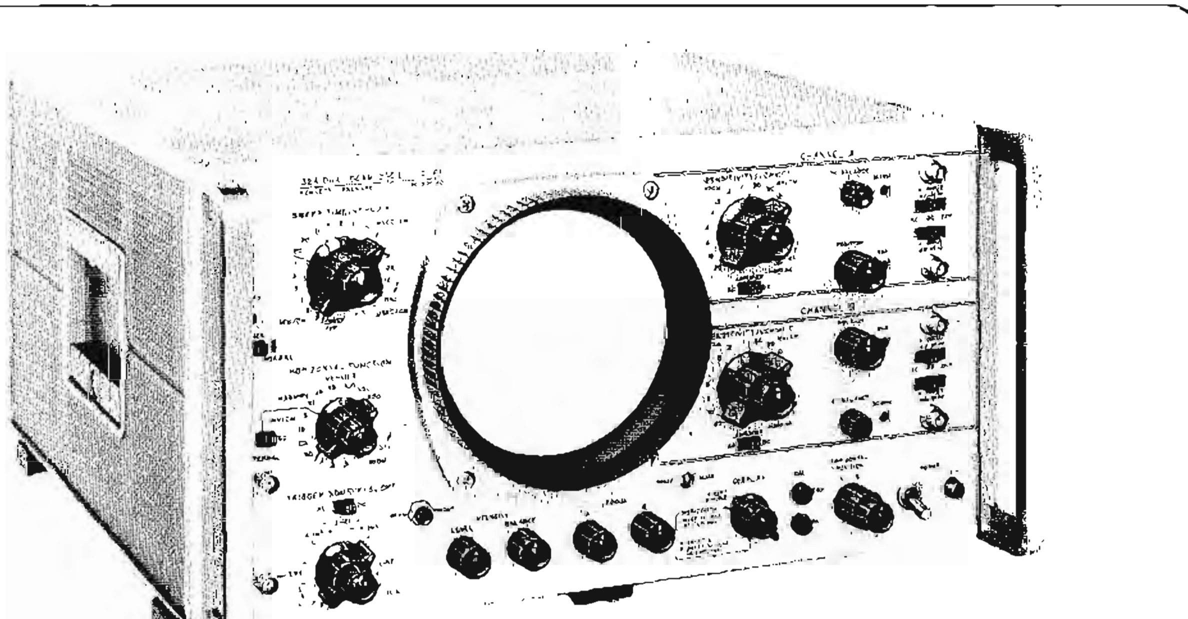


Figure 2. The same signal may be shown at two different sweep speeds with the slower sweep intensified to show location of fast sweep.

Model 132A, since the full 500 kHz bandwidth is retained at sensitivities from 1 mV/cm through 20 V/cm. At the most sensitive range, 100 μV/cm, bandwidth becomes 150 kHz.

Each vertical amplifier has an output at the rear panel of the Model 132A, allowing the user to monitor displays with an rms voltmeter, or drive a tape recorder.

The 3.5 kV aluminized CRT provides displays that are brighter than those previously available, making the Model 132A an excellent instrument for observing single-shot phenomena. A beam finder facilitates locating an off-screen trace by simply depressing a front-panel control. The internal graticule of the CRT eliminates parallax error, thus increasing measurement accuracy.



132A

Specifications

Time base

Range: may be selected for both beams, or one beam only with the other driven externally; 1 μs/cm to 5 s/cm, 21 ranges in a 1, 2, 5 sequence; vernier provides continuous adjustment between steps, and extends 5 s/cm step to at least 12.5 s/cm.

Magnifier: X2, X5, X10, X20, X50; may be selected for both channels together, or Channel B only; vernier provides continuous adjustment between steps; with same vertical input applied to both channels, any portion of the display may be magnified on Channel B and the magnified portion will be intensified on Channel A display.

Automatic triggering (baseline displayed in the absence of an input signal):

Internal: 50 Hz to 500 kHz for signals causing 0.5 cm or more vertical deflection; selected from either channel input, or from line voltage.

External: 50 Hz to 500 kHz, for signals at least 0.5 volt peak-to-peak.

Trigger slope: positive or negative slope of external sync signal or internal vertical deflection signals.

Amplitude selection triggering

Internal: for signals causing 0.5 volt or more vertical deflection; dc coupled, dc to 500 kHz; ac coupled, 20 Hz to 500 kHz; selected from either channel signal, or from line voltage.

External: for signals at least 0.5 volt peak-to-peak; dc coupled, dc to 500 kHz; ac coupled, 20 Hz to 500 kHz.

Trigger point and slope: from any point on vertical waveform presented on CRT or continuously variable from −10 to +10 volts on either positive or negative slope of external signal.

External trigger input RC: ac coupled, 0.01 μF in series with 1 megohm; dc coupled, 1 megohm.

Sweep delay time: a pretrigger of approximately 1 μs will allow the leading edge of non-recurrent waveform to be visible.

Single sweep: front panel switch and pushbutton permit single sweep operation.

Identical vertical amplifiers

Deflection factor (sensitivity): 100 μV/cm to 20 V/cm; 17 ranges in a 1, 2, 5 sequence; accuracy ±3%; verniers provide continuous adjustment between steps, and extend 20 V/cm steps to at least 50 V/cm.

Bandwidth: dc to greater than 500 kHz (10% to 90% rise time less than 0.7 μs) on ranges 20 V/cm through 1 mV/cm, decreasing to greater than 150 kHz at 100 μV/cm; input may be ac coupled with 2 Hz lower cutoff; amplifier may be ac coupled (to eliminate drift) with 2.5 Hz lower cutoff at 100 μV/cm, decreasing to 0.1 Hz at 20 mV/cm.

Differential input: differential input may be selected on all attenuator ranges; the following common mode signals will not overdrive the amplifier:

Deflection factor	Input: DC
0.1 mV/cm to 0.2 V/cm	±2 V peak
0.5 V/cm to 2.0 V/cm	±20 V peak
5.0 V/cm to 20 V/cm	±200 V peak

When a sine wave not exceeding the above limits is simultaneously applied from a low-impedance source to the dc coupled amplifier inputs, the vertical amplifiers have the following rejection ratios:

Deflection factor	60 Hz	1 kHz	50 kHz
0.1 mV/cm	86 dB	80 dB	74 dB
1 mV/cm	66 dB	66 dB	66 dB
0.2 V/cm	40 dB	40 dB	40 dB
0.5 V/cm to 20 V/cm	30 dB	30 dB	30 dB

With input ac coupled, maximum CMRR at 60 Hz is 60 dB.

Inputs: two BNC connectors for + and − polarities; AC, DC, or Off may be selected for each input; input RC is 1 megohm shunted by 50 pF, constant on all ranges: max. input voltage is ±500 V peak (dc + ac).

Amplifier outputs: a single-ended, dc-coupled output for each amplifier is provided on the rear panel; voltage output is approx. 2 V/cm from a 2 k ohm source impedance; bandwidth is approx. 500 kHz with a non-capacitive load.

External horizontal amplifier

Functions: may be used on both beams simultaneously, or on one beam only while the other is sweeping unmagnified.

Deflection factor (sensitivity): 5 mV/cm to 2 V/cm; 9 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 2 V/cm step to at least 5 V/cm.

Bandwidth: dc to greater than 300 kHz (with vernier in Cal); ac coupled, lower limit is 2 Hz.

Input: BNC connector; input RC, 1 megohm shunted by 50 pF, constant on all ranges; max. input voltage, ±500 volts peak (dc + ac).

X-Y operation

Single beam: x-y curve tracing; one of the vertical amplifiers can be switched to the horizontal deflection plates of the other beam, allowing x-y operation of the two identical amplifiers; the unused beam is positioned off screen; relative phase shift between + inputs is within ±2° for frequencies up to 50 kHz with verniers in Cal and equal input sensitivities.

Dual-beam: x-y plots can be made between the external horizontal amplifier and the B vertical amplifier while the other beam is operating normally with the sweep and A vertical amplifier, or, dual plots can be made using the external horizontal amplifier driving both beams; relative phase shift is normally within ±2° for frequencies up to 10 kHz with vernier in Cal and equal input sensitivities.

General

Calibrator: approximately 350 Hz square wave, 0.5 V and 0.5 mV, provided through jacks on front panel; accuracy ±2%.

Cathode-ray tube: mono-accelerator, 3500-volt accelerating potential; aluminized P2 phosphor (other phosphors available, see modifications); dual gun and two independent sets of vertical and horizontal deflection plates; etched safety glass face plate reduces glare.

Graticule: 10 cm x 10 cm parallax-free internal graticule marked in cm squares; display area for each beam is 8 cm x 10 cm, with 6 cm vertical overlap in center; vertical and horizontal axes for each beam have 2 mm subdivisions.

Beam finder: pressing beam finder control brings both traces on CRT screen, regardless of vertical, horizontal, or intensity control settings.

Intensity modulation: +20 volt pulse will blank traces of normal intensity; input terminals on rear panel; input time constant is approximately 125 μsec (9400 pF and 13.5 k ohms).

Dimensions: 16¾" wide, 9" high, 18⅜" deep overall (426 x 229 x 466 mm); hardware furnished for quick conversion to 19" x 8¾" x 16⅜" behind panel (483 x 222 x 416 mm) rack mount.

Weight: net 43 lbs (19,4 kg); shipping 55 lbs (24,8 kg).

Power: 115 or 230 volts ±10%; 50 to 1000 Hz; approximately 130 W.

Price: HP Model 132A, $1395.

Modifications: CRT phosphors (specify by phosphor number); P7, P11, P31 available; no charge.

Special order: chassis slides and adapter kit; fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40.

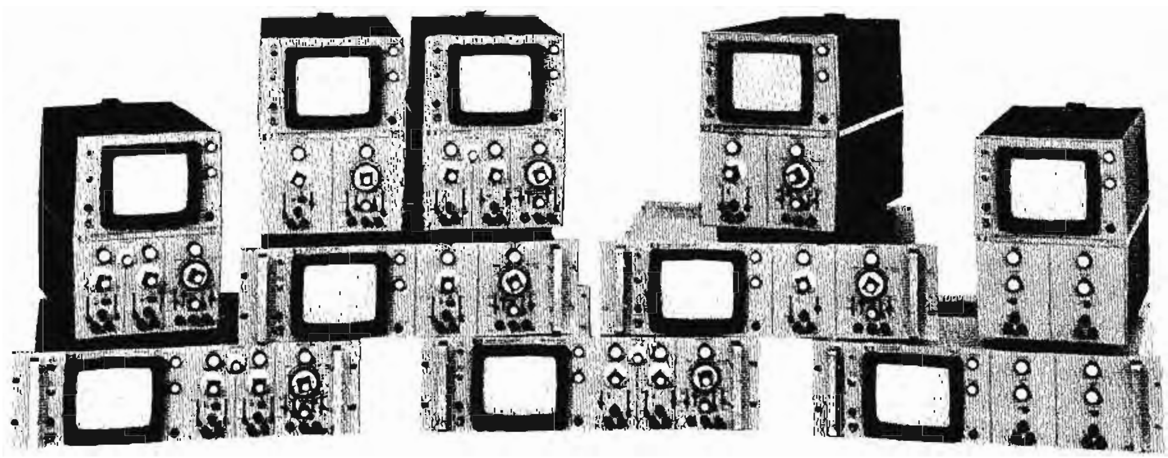
Options: (specify by option number)

05 External graticule CRT with P2 phosphor (P7, P11, P31 available, please specify) in lieu of standard internal graticule, includes edge-lighting of external graticule, add $25.

06 Rear terminal in parallel with front panel terminals; 3-pin AN connectors for vertical signal inputs; BNC for horizontal and trigger signal inputs, mating AN connectors supplied, add $45.

500 kHz OSCILLOSCOPES
Solid-state, low drift, 100 μV/div
Model 1200-series

Single or dual channel | Cabinet or 5¼" rack | 100 μV/div or 5 mV/div



The totally new, all solid-state, low frequency 1200-series oscilloscopes offer advanced performance with operating features previously available only on much wider bandwidth, more expensive instruments. A wide selection allows you to choose the right instrument for your exact need. Bandwidth on the basic instruments is 500 kHz; 600 kHz on X-Y version. (Refer to selection chart below.)

Solid-state circuit design throughout the 1200-series oscilloscopes provides portable, reliable, stable, and versatile operation in a variety of measurements. Typical applications include:

- R & D laboratory design
- Production line testing
- Scientific research
- Systems instrumentation
- Information display
- Educational laboratories

Testmobiles, probes, cameras, and other accessories for use with the 1200-series are shown on pages 548 through 553.

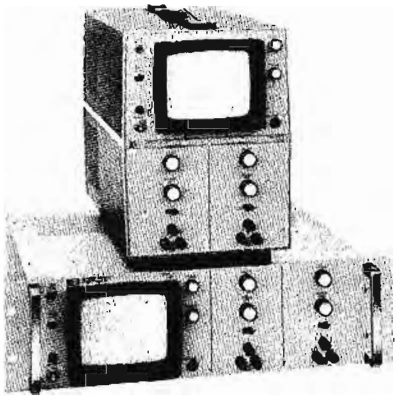
Instrument selection chart

FEATURE	1200A/B*	1202A/B*	1205A/B*	1206A/B*	1208A/B*
Deflection Factor	0.1 mV/div to 20 V/div	0.1 mV/div to 20 V/div	5 mV/div to 20 V/div	5 mV/div to 20 V/div	100 mV/div to 1 V/div
Bandwidth	500 kHz	500 kHz	500 kHz	500 kHz	600 kHz
Number of Traces	2	1	2	1	1
Differential Input	all ranges	all ranges	all ranges	all ranges	all ranges
Common-mode Rejection	100 dB (100,000:1)	100 dB (100,000:1)	50 dB	50 dB	40 dB
Common-mode Signal Maximum	±10 V	±10 V	±3 V	±3 V	±4 V
Phase Shift	1° to 100 kHz	–	1° to 100 kHz	–	1° to 500 kHz
Sweep Speeds	1 μsec/div to 5 sec/div	1 μsec/div to 5 sec/div	1 μsec/div to 5 sec/div	1 μsec/div to 5 sec/div	X–Y only
Ext. Horiz. Input	yes	yes	yes	yes	X-axis
DC-coupled Z-axis	yes	yes	yes	yes	yes
Page	502 and 503	504 and 505	502 and 503	504 and 505	501
Price	$990	$790	$875	$715	$540

*"A" denotes standard bench model, e.g. 1200A. "B" denotes standard rack model, e.g. 1200B.

System display, solid-state
X-Y display Model 1208A/B

1208A



1208B

Rack version Model 1208B is only 5¼" high, saving valuable space and allowing addition of other instruments to provide a more complete, more versatile system.

Low frequency X-Y displays are obtained easily and accurately with the Model 1208A (cabinet) or Model 1208B (rack) Display. Horizontal and vertical amplifiers are identical, each with a bandwidth of dc to 600 kHz.

All solid-state circuitry has been used by Hewlett-Packard in the Model 1208A/B, bringing low power portability and reliability to X-Y display instrumentation.

Selection of deflection factor for each amplifier is continuously variable from less than 100 mV/div to greater than 1 V/div. Provision has been made to easily modify internal circuitry to permit use of any larger deflection factor.

Model 1208A/B exhibits less than 1° phase shift up to 500 kHz for equal X and Y deflection factors below 0.2 V/div, and up to 100 kHz for equal X and Y deflection factors above 0.2 V/div. For any combination of X and Y deflection factors, phase shift is less than 3°, up to 100 kHz.

The dc-coupled Z-axis amplifier, well-suited for computer information displays, allows CRT intensity modulation, with signals of +2 volts blanking a display of normal intensity. A +8 V signal will blank a display of any intensity. Amplifier risetime is approximately 200 nanoseconds.

Applications for X-Y displays

Model 1208A/B can be used to display an X-Y plot of one input versus the other for a wide variety of signals. It is a useful measurement tool in such applications as the following:

- Pressure vs. volume diagrams.
- Component testing to determine characteristics such as voltage or temperature coefficients.
- Semiconductor diode characteristic V vs. I curves.
- Determine characteristics of ferromagnetic materials.
- Measure performance of limiting- or expanding-amplifiers.
- Measurement of distortion in linear amplifiers.
- Function generator, obtaining $y = f(x)$.
- Performance evaluation of various modulator and demodulator systems such as AM, FM, PTM, PAM, and suppressed carrier.

X-Y displays in systems

Solid-state circuitry in the Model 1208B results in direct benefits of special importance for systems applications:

- Lower maintenance costs, due to better component reliability and longer time between calibrations.
- No waiting for warm-up before measurements can be made and recorded.
- Low power (31 watts) eliminates need for fan, cuts system cooling requirements, and minimizes heat-related component failures.

Specifications, 1208A/B

Vertical and horizontal amplifiers

Bandwidth: dc to 600 kHz when dc-coupled; 20 Hz to 600 kHz when ac-coupled. (3 dB down from 8-div reference signal.)

Deflection factor: continuously variable from less than 0.1 V/div to greater than 1 V/div.

Input: differential or single-ended.

Input coupling: front panel selection of ac or dc.

Input RC: 100 k ohms shunted by approx. 70 pF.

Maximum input: ±200 V (dc + peak ac).

Common-mode

Rejection ratio: 40 dB (100:1).

Signal maximum: up to ±4 V (dc + peak ac).

Frequency: dc to 10 kHz.

Phase shift

Same X and Y deflection factor: less than 1°, to 500 kHz for deflection factors below 0.2 V/div. Less than 1°, to 100 kHz for deflection factors above 0.2 V/div.

Different X and Y deflection factors: less than 3°, to 100 kHz.

Cathode-ray tube and controls

Type: monoaccelerator, 3 kV accelerating potential; P31 phosphor standard (see modifications for other phosphors); etched safety glass faceplate reduces glare.

Graticule: 8 x 10 divisions, parallax-free internal graticule. 0.2-div subdivision markings on major axes. 1 div = 1 cm. Front panel screwdriver adjust aligns trace with graticule.

Beam finder: pressing Find Beam control brings trace on CRT screen regardless of setting of horizontal, vertical, or intensity controls.

Intensity modulation: +2-volt signal blanks trace of normal intensity; +8-volt signal blanks any intensity. DC-coupled input on rear panel; amplifier risetime approx. 200 ns; input R is 5 k ohms.

Calibrator

Type: line frequency square wave.

Output: 1 volt ±1.5%, front panel connector (banana plug).

General

Weight

Cabinet: (Model 1208A) net, 21½ lbs (9,8 kg); shipping, 31 lbs (14,7 kg).

Rack: (Model 1208B) net, 20½ lbs (9,3 kg); shipping, 33 lbs (15,0 kg).

Power: 115 or 230 volts ±10%, 50 to 400 Hz, approx. 31 watts.

Dimensions

Cabinet: 8-5/16" wide x 11¾" high x 18⅛" deep (211,1 x 298,5 x 474,4 mm).

Rack: 19" wide x 5¼" high x 15⅜" deep behind panel (483 x 132,5 x 390,5 mm).

Modifications

CRT phosphors: (specify by phosphor number) P31 standard; P1, P2, P4, P7 (with amber filter), and P11 available at no extra cost.

Options and specials: special versions available with deflection factor ranges down to either 5 mV/div or 100 μV/div. Consult your Hewlett-Packard Field Engineer for latest information.

Accessories available: for testmobiles, probes, cameras, and other accessories for use with Model 1208A/B, refer to pages 548 through 553.

Price: HP Model 1208A or HP Model 1208B, $540.

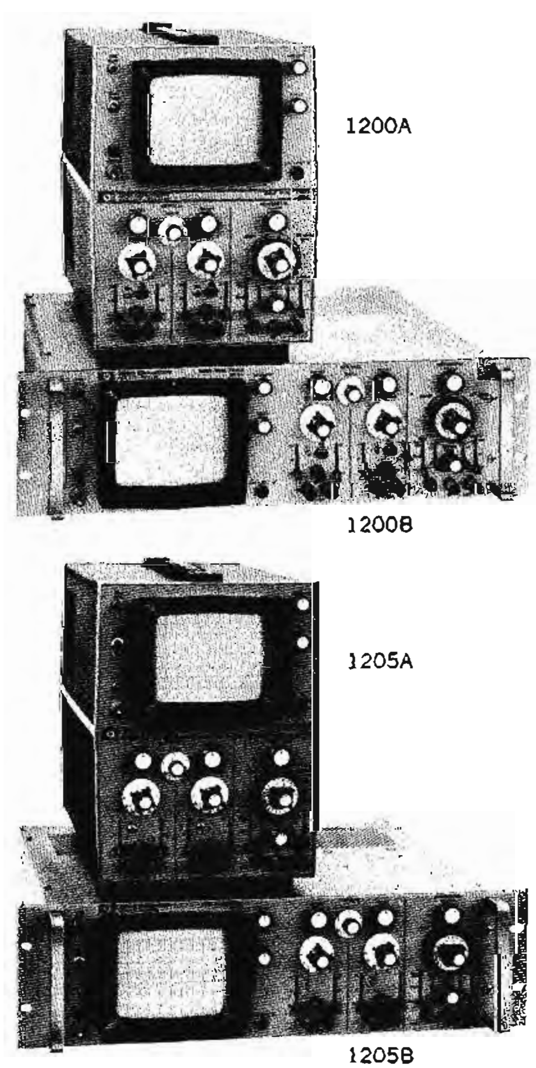
Dual channel, solid-state, versatile sweep

Models 1200A/B, 1205A/B

Models 1200A/B and 1205A/B Dual Trace Oscilloscopes have the same basic display capabilities, but differ in deflection factor and common-mode and noise characteristics.

Both the Model 1200A/B and the Model 1205A/B include many improved operation features which are standard on the 1200-series oscilloscopes. These include: 500 kHz bandwidth, all-range differential inputs, dc-coupled Z-axis, single sweep, auto and amplitude selection triggering, external horizontal input, and all solid-state circuitry.

Two signals can be compared simultaneously and directly by automatic switching between traces in either Chop or Alternate modes. In Chop operation, switching occurs at approximately 100 kHz between traces during the sweep; either internal time base or an external horizontal input signal can be used. In Alternate operation, switching occurs alternately between channels at the end of each sweep.



Rack version Models 1200B and 1205B are only 5¼" high, saving valuable space and allowing addition of other instruments to provide a more complete, more versatile system.

In Chop or Alternate operation, internal triggering of the start of the sweep is always derived from the signal on Channel A. This technique maintains the time relationship between the two vertical input signals.

Dual trace displays are useful for viewing both the input and output signals of amplifier, filters, and other networks to determine transmission or rejection characteristics. In vibration studies a rapid analysis is possible since the vibration pattern and the driving source waveform can be displayed at the same time.

The Channel A vs. B mode, selected by a front panel control, provides convenient X-Y displays of two variables. The two vertical amplifiers are identical, with less than 1° phase shift up to 100 kHz.

Model 1200A/B

Model 1200A/B provides the capability to accurately measure and analyze low level signals. In addition to 100 μV/div deflection factor, both vertical amplifiers have very low drift of typically less than 50 μV per hour and low noise of less than 50 μV pk-pk.

The low drift, very stable characteristics of the Model 1200A/B result in simpler operation and in less frequent circuit calibration. Operation is so stable that the balance control requires only infrequent adjustment. AC-coupling in the amplifier is no longer necessary as a means of eliminating drift, again simplifying operating controls.

Model 1200A/B has a common-mode rejection ratio of 100,000 to 1 (100 dB) on the lowest deflection factor of .1 mV/div, over a dc to 10 kHz frequency range. This high CMRR is made even more useful by the ±10 volts common-mode signal maximum on the lower deflection factors, a combination not previously available in low frequency oscilloscopes.

There are many measurement areas for which the Model 1200A/B is well-suited. These include: audio systems, biological research, circuit design, drift measurement, filter design, phase measurement, servo design, strain gage and transducer monitoring, educational instruction, and X-Y displays.

Model 1205A/B

Model 1205A/B is a highly portable, reliable dual trace oscilloscope for low frequency applications which do not require the lower deflection factor and common-mode characteristics of the Model 1200A/B.

Many systems applications are met satisfactorily by the size, economy and versatility offered in the Model 1205A/B.

Deflection factors are provided from 5 mV/div to 20 V/div with a vernier extending maximum deflection factor to 50 V/div. At least 50 dB common-mode rejection ratio with a ±3 volt common-mode signal maximum is specified for the six lowest deflection factors.

Measurement applications for the Model 1205A/B include: circuit design, component testing, computer information display, filter design, phase measurement, research and educational laboratories, swept frequency indicator, timing measurement, ultrasonic systems, and X-Y displays.

Specifications, 1200A/B

Vertical amplifiers

Reflection factor

Ranges: from 0.1 mV/div to 20 V/div (17 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position.

Vernier: continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Bandwidth: dc to 500 kHz with a maximum risetime of 0.7 μsec. 2 Hz to 500 kHz when ac-coupled. Front panel control provided to reduce upper frequency limit to approx. 50 kHz.

Noise: less than 50 μV peak-to-peak at full bandwidth.

Input: differential or single-ended on all ranges, selectable by front panel control.

Common-mode:

Frequency: dc to 10 kHz on all ranges.

Rejection ratio: at least 100 dB (100,000 to 1) on 0.1 mV/div range, decreasing by less than 20 dB per decade of deflection factor to at least 40 dB on the 0.2 V/div range; CMRR at least 30 dB on 0.5 V/div to 20 V/div ranges.

Signal maximum: ±10 V (dc + peak ac) on 0.1 mV/div to 0.2 V/div ranges; ±400 V (dc + peak ac) other ranges.

Specifications, 1205A/B

Vertical amplifiers

Deflection factor

Ranges: from 5 mV/div to 20 V/div (12 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position.

Vernier: continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Bandwidth: dc to 500 kHz with a maximum risetime of 0.7 μsec. 2 Hz to 500 kHz when ac-coupled.

Input: differential or single-ended on all ranges, selectable by front panel control.

Comon mode:

Frequency: dc to 10 kHz on all ranges.

Rejection ratio: at least 50 dB on 5 mV/div to 0.2 V/div ranges; CMRR is at least 30 dB on 0.5 V/div to 20 V/div ranges.

Signal maximum: ±3 V (dc + peak ac) on 5 mV/div to 0.2 V/div ranges; ±300 V (dc + peak ac) on all other ranges.

Following specifications apply to both Model 1200A/B and Model 1205A/B

Vertical amplifiers (continued)

Input coupling: front panel selection of dc, ac, or off for both + and − inputs.

Input RC: 1 megohm shunted by 45 pF; constant on all ranges.

Maximum input: ±400 volts (dc + peak ac).

Display:

1. Channel A.
2. Channel B.
3. Channels A and B (either Chop or Alternate).
4. Channels A and B vs. horizontal input (Chop only).
5. Channel A vs. B (A-vertical, B-horizontal).

Chop display frequency is approx. 100 kHz.

Internal trigger: by Channel A signal for A, Chop, and Alternate displays. By Channel B signal for B display.

Isolation: greater than 80 dB between channels at 500 kHz, with input connectors shielded.

Phase shift: (for Channel A vs. B) less than 1°, to 100 kHz (Verniers in calibrated position).

Time base

Sweep

Ranges: 1 μsec/div to 5 sec/div (21 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position.

Vernier: continuously variable between ranges; extends slowest sweep to at least 12.5 sec/div.

X10 magnifier: indicates magnified sweep directly with ±5% accuracy.

Automatic triggering: baseline is displayed in absence of an input signal.

Internal: 50 Hz to above 500 kHz on most signals causing 0.5 division or more vertical deflection. Triggering on line frequency also selectable.

External: 50 Hz to above 1 MHz on most signals at least 0.2 volt peak-to-peak.

Trigger slope: positive or negative slope on internal, external or line trigger signals.

Amplitude selection triggering

Internal: dc to above 500 kHz on signals causing 0.5 division or more vertical deflection.

External: dc to 1 MHz on signals at least 0.2 volt peak-to-peak. Input impedance is 1 megohm shunted by approx. 20 pF.

Trigger level and slope: internal, at any point on vertical waveform displayed; or continuously variable from +100 V to −100 V on either slope of the external trigger signal.

Trigger coupling: dc or ac for external, line, or internal triggering. Lower ac cut-off is 1.6 Hz for external; 5 Hz for internal.

Single sweep: selectable by front panel switch. Reset push button with armed indicator light.

Free run: selectable by front panel switch.

Maximum input: ±350 volts (dc + peak ac).

Horizontal amplifier

Bandwidth: dc to 300 kHz. With input ac-coupled, low frequency cut-off is 1.6 Hz.

Deflection factor

Ranges: 0.1 V/div, 0.2 V/div, 0.5 V/div, and 1 V/div.

Vernier: continuously variable between ranges; extends maximum deflection factor to at least 2.5 V/div.

Input: single-ended.

Input RC: 1 megohm shunted by approx. 20 pF.

Maximum input: ±350 volts (dc + peak ac).

General

Cathode-ray tube

Type: mono-accelerator, 3,000-volt accelerating potential; P31 phosphor standard (see Modifications for other phosphors); etched safety glass faceplate reduces glare.

Graticule: 8 x 10 divisions; parallax-free internal graticule; 0.2-div subdivision markings on horizontal and vertical major axes. 1 div = 1 cm. Front panel screwdriver adjust aligns trace with graticule.

Intensity modulation: +2-volt signal blanks trace of normal intensity; +8-volt signal blanks any intensity. DC-coupled input on rear panel; amplifier risetime approx. 200 ns; input resistance is 5 k ohms.

Calibrator

Type: line frequency square wave.

Output: 1 volt ±1.5%, front panel connector.

Beam finder: push button to locate beam on CRT screen regardless of setting of vertical, horizontal, intensity controls.

Dimensions

Cabinet: 8-5/16" wide x 11¾" high x 18-11/16" deep (211,1 x 298,5 x 474,4 mm).

Rack: 19" wide x 5¼" high x 15⅜" deep behind panel (483 x 132,5 x 390,5 mm).

Weight

Cabinet: net, 25 lbs (11,3 kg); shipping, 34½ lbs (15,6 kg).

Rack: net, 22½ lbs (10,2 kg); shipping, 35 lbs (15,8 kg).

Modifications

CRT phosphors (specify by phosphor number): P31 standard, P2, P7 (with amber filter), and P11 available at no extra cost.

Options and specials: check with Hewlett-Packard Sales Offices for latest information.

Accessories available: for testmobiles, probes, cameras, and other accessories for use with Models 1200A/B and 1205A/B, refer to pages 548 through 553.

Price: HP Model 1200A/B, $990; HP Model 1205A/B, $875.

OSCILLOSCOPES 1200 SERIES *continued*

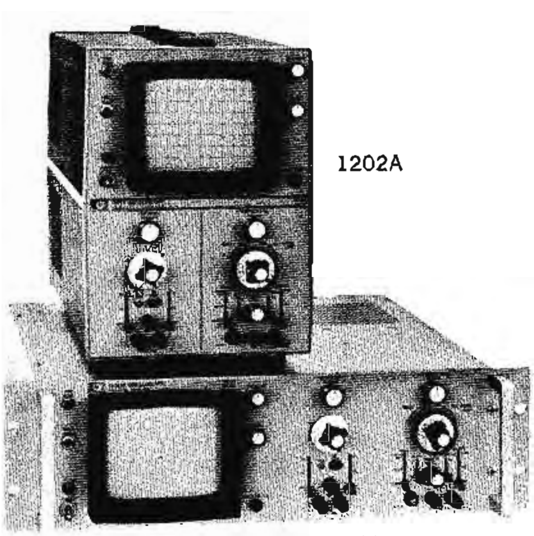
Single channel, solid-state, low power

Models 1202A/B, 1206A/B

Single trace Models 1202A/B and 1206A/B include all the 1200-series improved performance features, but differ in basic deflection factor and related common-mode and noise characteristics.

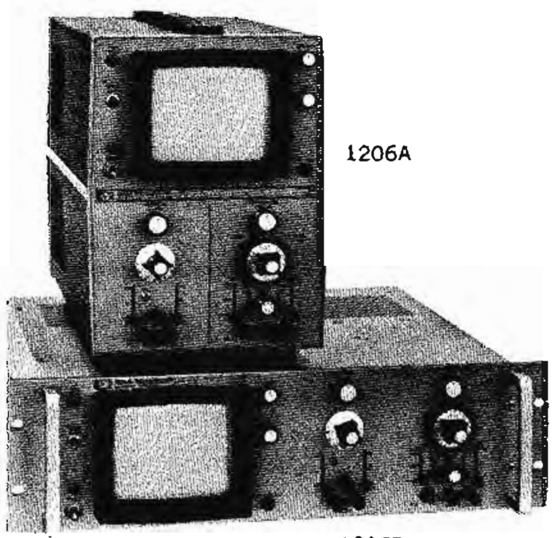
Models 1202A/B and 1206A/B have 500 kHz bandwidth, all-range differential input, dc-coupled Z-axis, single sweep, auto and amplitude selection triggering, external horizontal input, and all solid-state circuitry.

X-Y displays of two variables can be obtained by use of the external horizontal input. Bandwidth for the horizontal amplifier is 300 kHz. There are four horizontal deflection factors: .1 V/div, .2 V/div, .5 V/div, and 1 V/div. A vernier extends the maximum deflection factor to 2.5 V/div.



1202A

1202B



1206A

1206B

Rack version Models 1202B and 1206B are only 5¼" high, saving valuable space and allowing addition of other instruments to provide a more complete, more versatile system.

The horizontal deflection system time base provides a wide range of sweep speeds from 1 μsec/div to 5 sec/div. The vernier provides continuous coverage between ranges and extends the slowest sweep speed to 12.5 sec/div.

With solid-state portability, reliability, and stability, Models 1202A/B and 1206A/B can fulfill any low frequency measurement application requiring only single trace capability.

Model 1202A/B

Model 1202A/B provides the capability to accurately measure and analyze low level signals. Its 100 μV/div vertical amplifier has very low drift of typically less than 50 μV per hour and low noise of less than 50 μV pk-pk.

The low drift, very stable characteristics of the Model 1202A/B result in simpler operation and in less frequent circuit calibration. Operation is so stable that the balance control requires only infrequent adjustment and hence is now a front panel screwdriver control. With this high degree of stability, ac-coupling in the amplifier is no longer necessary as a means of eliminating drift, again simplifying operating controls.

Model 1202A/B has a common-mode rejection ratio of 100,000 to 1 (100 dB) on the lowest deflection factor of .1 mV/div, over a dc to 10 kHz frequency range. This high CMRR is made even more useful by the ±10 volts common-mode signal maximum on the lower deflection factors, a combination not previously available in low frequency oscilloscopes. High CMRR eliminates concern about inaccuracies caused by voltages induced in differential signal leads.

Measurement areas for which the Model 1202A/B is well-suited include: audio systems, biological research, circuit design, drift measurement, remote indicator, servo design, strain gage and transducer monitoring, tuner alignment, and ultrasonic systems.

Model 1206A/B

Model 1206A/B is a highly portable, reliable general purpose oscilloscope. It is a versatile instrument for single channel applications not requiring the lower deflection factor and common-mode characteristics of the Model 1202A/B.

Many systems applications are met satisfactorily by the size, economy and versatility offered in the Model 1206A/B.

Deflection factors are provided from 5 mV/div to 20 V/div with a vernier extending maximum deflection factor to 50 V/div. At least 50 dB common-mode rejection ratio with a ±3 volt common-mode signal maximum is specified for the six lowest deflection factors.

Measurement applications for the Model 1206A/B include: audio systems, circuit design, component testing, computer information display, system monitoring, research and educational laboratories, timing measurements, and ultrasonic systems.

Specifications, 1202A/B

Vertical amplifier

Deflection factor

Ranges: from 0.1 mV/div to 20 V/div (17 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position.

Vernier: continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Bandwidth: dc to 500 kHz with a maximum risetime of 0.7 μsec. 2 Hz to 500 kHz when ac-coupled. Front panel control provided to reduce upper frequency limit to approx. 50 kHz.

Noise: less than 50 μV peak-to-peak at full bandwidth.

Input: differential or single-ended on all ranges, selectable by front panel control.

Common-mode:

Frequency: dc to 10 kHz on all ranges.

Rejection: ratio at least 100 dB (100,000 to 1) on 0.1 mV/div range, decreasing by less than 20 dB per decade of deflection factor to at least 40 dB on the 0.2 V/div range; CMRR at least 30 dB on 0.5 V/div to 20 V/div ranges.

Signal maximum: ±10 V (dc + peak ac) on 0.1 mV/div to 0.2 V/div ranges; ±400 V (dc + peak ac) other ranges.

Specifications, 1206A/B

Vertical amplifier

Deflection factor

Ranges: from 5 mV/div to 20 V/div (12 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position.

Vernier: continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Bandwidth: dc to 500 kHz with a maximum risetime of 0.7 μsec. 2 Hz to 500 kHz when ac-coupled.

Input: differential or single-ended on all ranges, selectable by front panel control.

Common-mode

Frequency: dc to 10 kHz on all ranges.

Rejection ratio: at least 50 dB on 5 mV/div to 0.2 V/div ranges; CMRR is at least 30 dB on 0.5 V/div to 20 V/div ranges.

Signal maximum: ±3 V (dc + peak ac) on 5 mV/div to 0.2 V/div ranges; ±300 V (dc + peak ac) on all other ranges.

Following specifications apply to both Model 1202A/B and Model 1206A/B

Vertical amplifier (continued)

Input coupling: front panel selection of dc, ac, or off for both + and − inputs.

Input RC: 1 megohm shunted by 45 pF; constant on all ranges.

Maximum input: ±400 volts (dc + peak ac).

Time base

Sweep

Ranges: from 1 μsec/div to 5 sec/div (21 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: continuously variable between ranges; extends slowest sweep to at least 12.5 sec/div.

X10 magnifier: indicates magnified sweep directly with ±5% accuracy.

Automatic triggering: baseline is displayed in absence of an input signal.

Internal: 50 Hz to above 500 kHz on most signals causing 0.5 division or more vertical deflection. Triggering on line frequency also selectable.

External: 50 Hz to above 1 MHz on most signals at least 0.2 volt peak-to-peak.

Trigger slope: positive or negative slope on internal, external or line trigger signals.

Amplitude selection triggering

Internal: dc to above 500 kHz on signals causing 0.5 division or more vertical deflection.

External: dc to 1 MHz on signals at least 0.2 volt peak-to-peak. Input impedance is 1 megohm shunted by approx. 20 pF.

Trigger level and slope: internal, at any point on vertical waveform displayed; or continuously variable from +100 V to −100 V on either slope of the external trigger signal.

Trigger coupling: dc or ac for external, line, or internal triggering. Lower ac cut-off is 1.6 Hz for external; 5 Hz for internal.

Single sweep: selectable by front panel switch. Reset push button with armed indicator light.

Free run: selectable by front panel switch.

Maximum input: ±350 volts (dc + peak ac).

Horizontal amplifier

Bandwidth: dc to 300 kHz. With input ac-coupled, low frequency cut-off is 1.6 Hz.

Deflection factor

Ranges: 0.1 V/div, 0.2 V/div, 0.5 V/div, and 1 V/div.

Vernier: continuously variable between ranges; extends maximum deflection factor to at least 2.5 V/div.

Input: single-ended.

Input RC: 1 megohm shunted by approx. 20 pF.

Maximum input: ±350 volts (dc + peak ac).

General

Cathode-ray tube

Type: mono-accelerator, 3,000-volt accelerating potential; P31 phosphor standard (see Modifications for other phosphors); etched safety glass faceplate reduces glare.

Graticule: 8 x 10 divisions; parallax-free internal graticule; 0.2-div subdivision markings on horizontal and vertical major axes. 1 div = 1 cm. Front panel screwdriver adjust aligns trace with gratcule.

Intensity modulation: +2-volt signal blanks trace of normal intensity; +8-volt signal blanks any intensity. DC-coupled input on rear panel; amplifier risetime approx. 200 ns; input resistance is 5 k ohms.

Calibrator

Type: line frequency square wave.

Output: 1 volt ±1.5%, front panel connector.

Beam finder: push button to locate beam on CRT screen regardless of setting of vertical, horizontal, and intensity controls.

Dimensions

Cabinet: 8-5/16" wide x 11¾" high x 18-11/16" deep (211,1 x 298,5 x 474,4 mm).

Rack: 19" wide x 5¼" high x 15⅜" deep behind panel (483 x 132,5 x 390,5 mm).

Weight

Cabinet: net, 23½ lbs (10,6 kg); shipping, 33 lbs (15,0 kg).

Rack: net, 21 lbs (9,5 kg); shipping 33½ lbs (15,2 kg).

Power: 115 or 230 volts ±10%; 50 to 400 Hz; approx. 33 watts.

Modifications

CRT phosphors (specify by phosphor number): P31 standard. P2, P7 (with amber filter), and P11 available at no extra cost.

Options and specials: check with Hewlett-Packard Sales Office for latest information.

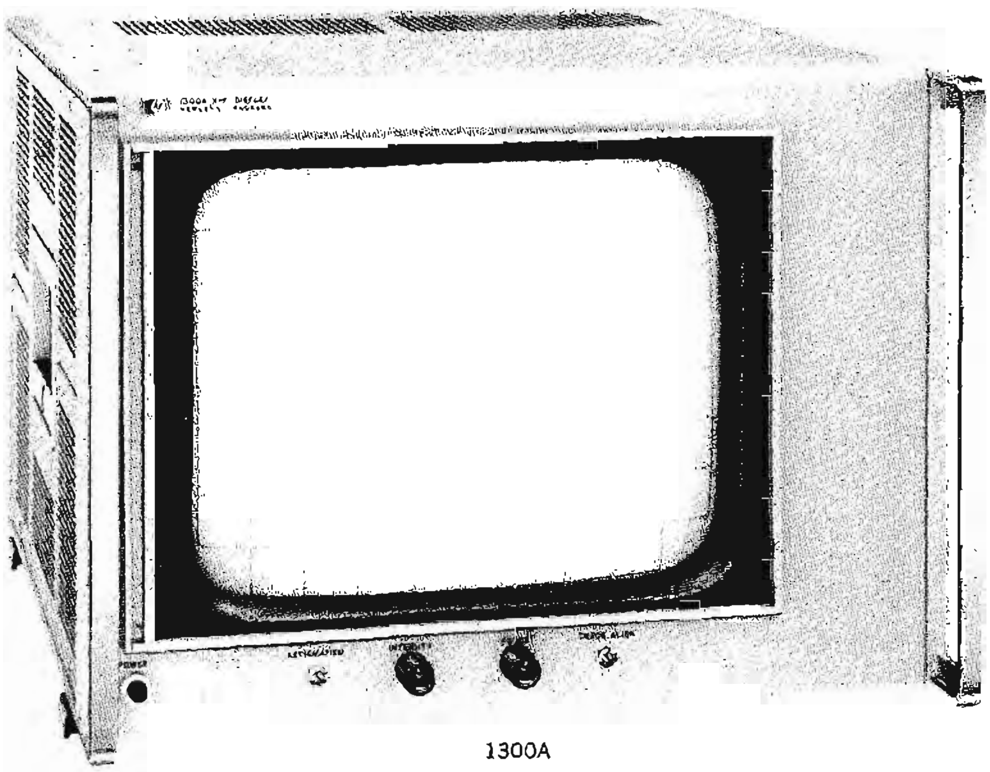
Accessories available: for testmobiles, probes, cameras, and other accessories for use with Models 1202A/B and 1206A/B, refer to pages 548 through 553.

Price: HP Model 1202A/B, $790; HP Model 1206A/B, $715.

X-Y DISPLAY

20 MHz Monitor with 8 inch by 10 inch screen

Model 1300A



1300A

The extremely wide dc-20 MHz bandwidth of the Model 1300A X-Y Display provides capabilities not found in any other large screen display. The fast 20 nanoseconds rise time and 200 nanoseconds settling time allow rapid switching between several input waveforms without flicker. The 1300A CRT writes at better than 20 inches/μs for bright displays of low rep rate signals. The 8 inch x 10 inch viewing area provides the high resolution readout needed for many measurements. Some of these include swept frequency, spectrum analysis and time domain reflectometry. The 1300A's 20 kV display is easy to see even from long distances making it especially suited for system applications as well as production testing or classroom demonstrations. Added versatility in a large screen display is also available in the HP Model 143A which is a plug-in type oscilloscope. Model 143A accepts all standard HP Model 1400-series plug-ins. Control and amplifier options are available for increased versatility. Contact your local HP field engineer for your special requirements.

Applications

Swept frequency measurements are especially suited for a large screen readout. The H09-1300A is a special model of the 1300A X-Y Display that has been modified to be directly compatible with the Model 674A Sweeping Signal Generator. These two instruments when used together, provide an easy to read, easy to use, high resolution display of swept frequency measurements. Extended vertical dynamic range in the H09-1300A allows high sensitivity measurements at any point on the 1.5 volt output of the Model 675A Sweeping Signal Generator. The H09-1300A vertical position control provides the dc offset required to look at any point on the incoming signal while at deflection factors as low as 10 mV/in.

Another important application for the 1300A is analog computer readout. The 1300A provides a significant increase in useful resolution over the conventional 5 inch oscilloscope, without sacrificing useful bandwidth for displays such as analog computers, bar graphs, and the like. Increased resolution coupled with 1% linearity provides an accurate display of even high frequency phenomena and stable dc amplifiers provide excellent repeatability. The all solid state circuits of the Model 1300A provide a very reliable instrument that will be free from maintenance and service requirements.

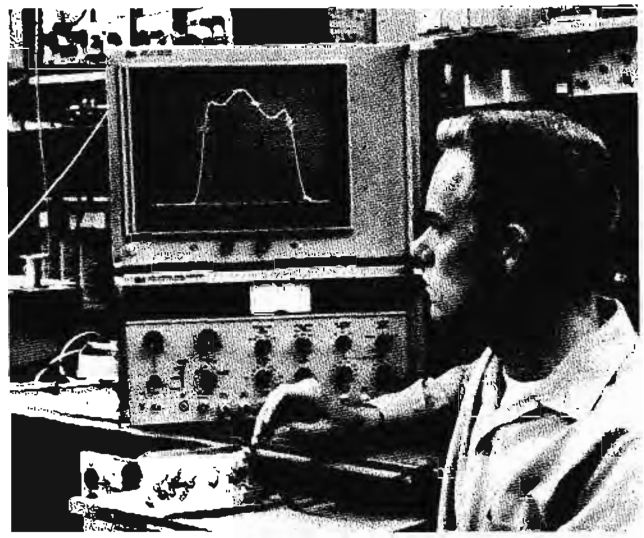
Specifications

X-Y amplifiers

Deflection factor: at least 0.1 V/inch; vernier provides 2.5:1 reduction.

Drift: <0.1 inch/hr after ½-hr warmup; <0.2 inch/8 hr.

Model 1300A displaying a computer readout. X-Y-Z information provides an easy to read three dimensional display.



Model 1300A displaying filter response in conjunction with Model 675A Sweeping Signal Generator.

Bandwidth: dc coupled, dc to 20 MHz; ac coupled 2 Hz to 20 MHz (8-inch reference at 50 kHz).

Rise time: <20 ns (10% to 90% points).

Settling time: <200 ns to within a trace width of final value.

Repeatability: less than 0.15% error for re-addressing a point from any direction; source impedance <4 kΩ.

Input RC: 1 megohm shunted by approximately 20 pF.

Input: single ended; BNC connector, maximum input ±500 V (dc + peak ac).

Linearity: over 8 x 10-inch screen ±1% of full screen; any inch with respect to any other inch, within 10%.

Phase shift: 0.1° to 50 kHz, up to 100-inch signal; 1° to 1 MHz, up to 10-inch signal.

Z amplifier

Analog input: dc to 20 MHz bandwidth over the 0 to +1 V range; +1 V gives full blanking, −1 V gives full intensity; vernier gives 2.5:1 reduction, balance allows intensity adjustment of ±1 V, maximum input ±500 V (dc + peak ac).

Rise time: <20 ns (10% to 90% points).

Sweep blank input: digital dc blanking with <1 KΩ and −0.7 V to +5 V; unblanking with >20 KΩ and 0 V to −5 V. Repetition rates to 1 MHz.

Chop blank input: ac coupled blanking, +50 V blanks CRT. Input grounded when not in use.

Calibrator

0.5 V ±2%, line frequency square wave.

CRT

Accelerating potential: 20 kV.

Writing rate: >20 inches/μs.

Spot size: less than 30 mils throughout 8 x 10-inch screen at 100 ft. lamberts light output; nominally 20 mils at center screen (shrinking raster).

Phosphor and graticule: aluminized P31 phosphor with 1-inch grid and 0.2-inch subdivisions on major axis. P2, P4, P7, P11 and other phosphors available; other graticules available on special order. Amber face plate filter supplied with P7 phosphor instead of standard blue-green.

Controls: X-Y-Z inputs, ac-dc input switches, calibrator, X-Y gain verniers and position, Z axis vernier and balance on rear panel. Intensity, astigmatism, trace align, and focus on front panel.

General

Size: 12¼" high, 16¾" wide, 19⅞" deep, 18½" behind front panel (310 x 425 x 470 mm). Rack mount hardware supplied.

Weight: net 47 lbs (21,4 kg); shipping 64 lbs (29,1 kg).

Power: 115 or 230 volts ±10%; 50 to 400 Hz; approximately 175 W.

Price: Model 1300A, $1900.

Special order: a number of special modifications are available. They include: front panel X and Y inputs and controls, X10 pre-amplifier for 10 mV/in X and Y deflection factor, Z axis to provide eight gray scales, attenuators for X and Y amplifiers. Contact your local HP Field Engineer for details on these and other special requirements.

Model H09-1300A: specially modified 1300A to be directly compatible with Model 675A Sweeping Signal Generator. Includes 10 mV/inch vertical deflection factor and attenuator. All X and Y inputs and controls on front panel. Price, $2100.

Option 14: no graticule in lieu of standard internal graticule. No additional charge.

Accessories available

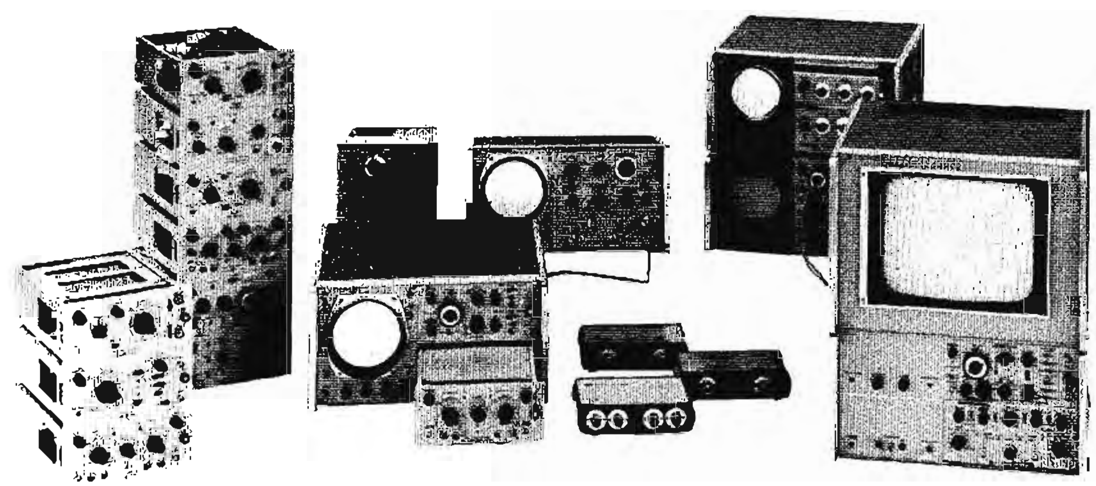
Anti-reflection filter: nylon mesh attached to contrast filter to reduce reflections; Model 10181A amber filter for P7 phosphor. Model 10182A green filter for standard phosphors. Price, Model 10181A, $25; Model 10182A, $25.

Chassis slides and adapters: fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides, order HP Part No. 1490-0721, $40. Note: One adapter kit required for mounting one pair of chassis slides.

PLUG-IN OCILLOSCOPE

One scope to do nearly any measurement task

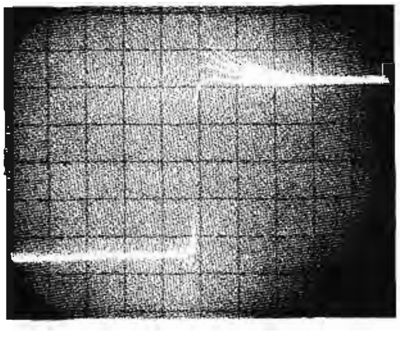
Model 140 System



140 System

The Hewlett-Packard 140 Oscilloscope System, which consists of either the 140A, 141A, or 143A mainframe and the 1400-series or 8550-series plug-ins, provides the versatility you need to get step-ahead measurements over the entire oscilloscope spectrum. With 19 high performance vertical and horizontal plug-ins to choose from, you can head in any measurement direction: wide-band sampling, high-sensitivity, delayed sweep, or measurements such as time domain reflectometry, swept frequency, or spectrum analysis . . . all with variable persistence and storage or large screen display if you like.

Hewlett-Packard's 140 system offers these capabilities: an oscilloscope system that gives you sampling bandwidth to 12.4 GHz . . . sampling delayed sweep time base . . . 50 μV/cm sensitivity with no dc drift . . . versatile single or double-size plug-in capability . . . plug-ins for direct readout TDR . . . swept frequency and spectrum analyzer plug-ins to convert the 140 system to a truly general purpose frequency-domain oscilloscope. In addition, it is the only oscilloscope system to offer standard CRT persistence in either the 140A mainframe or the 8 in x 10 in 143A mainframe; or variable persistence and storage in the 141A mainframe. Select from these unique measurement capabilities, or choose from the general purpose plug-ins available.



See signal trends while making circuit adjustments by simply making persistence long enough so that several traces appear on screen simultaneously.

12.4 GHz Sampling with Delayed Sweep

Exceedingly fast HP switching diodes have opened a true breakthrough in sampling scope capabilities.

For the first time, you can see through X band, observe CW signals to 12.4 GHz and beyond, and see fast pulses with a 28 ps rise time capability. You can also use TDR measurements to resolve discontinuities down to less than 1 cm in the design of cables, coaxial components, connectors and strip lines. In addition, you can utilize delayed sweep through the full bandwidth to get displays of pulse segments that leave conventional sampling scopes blurred. You also get less than 20 ps jitter to ensure steady, clear displays.

Two vertical amplifiers are available. Model 1411A provides dc to 12.4 GHz at 1 mV/cm, dual-channel performance with remote samplers featuring feed-through inputs for minimum signal disturbance. The other sampling vertical amplifier, Model 1410A, gives performance to 1 GHz, with both high-Z probes and 50 ohm inputs—and internal triggering. Model 1425A Sampling Time Base plug-in provides delayed sweep, automatic triggering and a movable intensified dot that makes it easy to set up the point of magnification.

50 μV/CM Zero Drift

The versatile HP 140 Scope System gives you five high-sensitivity plug-ins specifically designed for measurement of low-level signals. For example, the 1406A vertical plug-in offers high 50 μV/cm sensitivity with no dc drift—plus precision calibrated dc offset for extreme magnification.

With the HP calibrated offset feature, the 1406A gives you the advantages of a dc and ac voltmteer—four-digit readout, auto decimal placement, better than 0.5% measurement accuracy. As a dc voltmeter, the 1406A offers you the additional advantages of no drift in the measurement instrument, and the ability to observe and measure any ac riding on the dc voltage. With these capabilities you can make measurements never before possible. For example, you can simultaneously display a 10 V dc signal at 50 μV/cm (giving a magnification of 200,000), measure dc level accurately to four digits, see short term dc drift with microvolt resolution, and view and measure all ac ripple—an impossible measurement with a meter. The HP 1406A plug-in also operates as a dc coupled, no drift differential amplifier with 80 dB common mode rejection.

Get 20 MHz Bandwidth and Delayed Sweep Readability

If you need wideband performance, for example, you can use the dual-trace 1402A vertical amplifier and get dc to 20 MHz (15 MHz with Model 143A) at 5 mV/cm, algebraic addition, built-in delay line for viewing the leading edge of fast-rise pulses, full 6 cm deflection and a wide dynamic range. An internal sync amplifier triggers on Channel A in dual trace mode of operation—gives stable traces and accurate time measurements without external triggering.

For easy readability of complex waveforms and accurate time interval measurements, Model 1421A Time Base & Delay Generator provides extreme magnification—calibrated time delays from 10 seconds to 0.5 μs, calibrated sweep speeds from 1 s/cm to 20 ns/cm. The 1421A also offers the additional advantage of exclusive HP mixed sweep. This feature combines display of the first portion of a trace at normal sweep speeds, and simultaneously expands the trailing portion of the trace at faster delayed sweep speeds to allow step-by-step magnified examination.

Spectrum analyzer plug-ins for measurement in the frequency domain

The usefulness of the 140 system in the time domain can also be extended into the frequency domain. By a simple addition of Spectrum Analyzer plug-ins, you can convert your time-domain oscilloscope into a truly general purpose frequency-domain instrument. This spectrum analyzer has a frequency range of 1 kHz-110 MHz, absolute amplitude calibration, high sensitivity, low distortion, wide dynamic range, and flat frequency response.

Choose from three HP high-performance mainframes

The advanced HP 140A, 141A, and 143A mainframes give you a choice between conventional (fixed) CRT persistence, variable persistence and storage, and 8" x 10" CRT display. As a result, the 140 system gives you not only an extensive plug-in capability, but also, the CRT versatility you need to meet the requirements of any measurement problem today—six months from now—or at any future time.

These HP 140 system mainframes are specifically designed to give you both high-frequency and high-sensitivity performance. They consist of the essential functional blocks for low and high frequency applications—plus sampling. Included are a post-accelerator CRT, associated control circuitry, power supplies, and the dc supplies required to power the HP 1400 Series plug-ins which contain CRT drive circuitry.

This true building-block arrangement assures that you can use existing and future plug-ins without modification to the mainframe. You pay only for the circuitry you actually need to make your particular measurements.

Because all deflection circuitry is contained in the plug-ins, you get exclusive capabilities in mixing plug-ins. You can not only select the amplifier you need for the vertical axis, but also, you can select the particular time base generator needed for the horizontal axis.

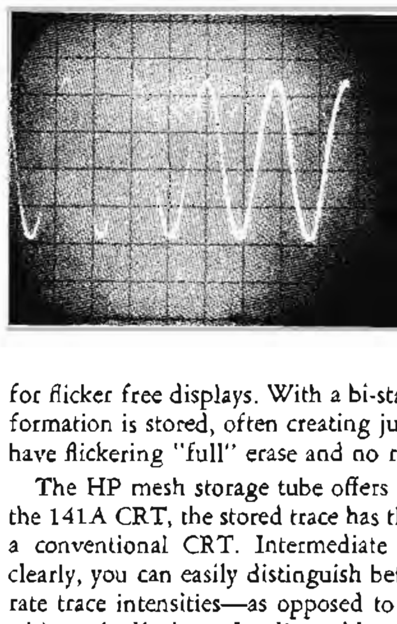
Further, since the 140 system CRT's have identical horizontal and vertical deflection sensitivities, you can use two vertical amplifiers for an X-Y display . . . or one single-channel amplifier and one dual-channel amplifier to plot two variables against a third . . . or two identical dual-channel amplifiers for a pair of simultaneous X-Y displays.

All 140 series mainframes are equipped with a convenient beam finder which quickly locates a trace and puts it on screen for fast trouble-free set-up.

Variable persistence and storage

The 141A mainframe gives you all the advantages of the 140A mainframe—plus the exclusive benefits of HP variable persistence and storage.

The HP 141A has a 7.3 kV, post accelerator CRT—with unique mesh storage. At the twist of a knob, you can adjust the 141A's memory span (trace persistence) from 0.2 seconds to a minute . . . to hours . . . to days. This exclusive HP variable persistence allows you to adjust the CRT persistence to match the changing characteristics of a signal—any necessary number of traces can be held for trend comparisons, or



Exclusive HP variable persistence enables you to match the persistence of your CRT screen to any signal—eliminating annoying flicker on slow signals such as swept frequency and sampling waveforms, transducer signals and low-frequency displays

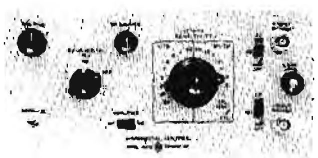
for flicker free displays. With a bi-stable storage tube, all information is stored, often creating jumbled displays—or you have flickering "full" erase and no retained information.

The HP mesh storage tube offers many advantages. With the 141A CRT, the stored trace has the same high contrast as a conventional CRT. Intermediate trace values stand out clearly, you can easily distinguish between four or five separate trace intensities—as opposed to the limiting black-and-white-only displays of ordinary bi-stable storage. Intensity of the 141A CRT can be varied by a front panel control, or modulated externally for X-Y-Z presentations. Maximum viewing intensity in store/view mode is 200 foot lamberts—25 times brighter than bi-stable tubes. With the HP storage mesh CRT, trace brightness and writing speed are maintained over the entire life of the tube—specified performance is warranted for one year.

Utilize the HP 141A scope for variable persistence, conventional persistence, and storage—it's like having three scopes in one! Also, you have the advantage of choosing from any of the HP high-performance 1400 Series plug-ins.

Selection chart
1400 Series plug-ins

Capabilities	Vertical plug-ins											
	1400A	1401A	1402A	1403A	1405A	1406A	1407A	1410A	1411A	1430A	1431A	1432A
1. Wide band			•		•							
2. Sampling								•	•	•	•	•
3. High grain differential	•			•		•	•					
4. Dual trace		•	•		•			•	•			
5. X-Y	•	•	•	•	•	•	•	•	•			
6. Delayed sweep			1421A for real time					1425A for sampling				
7. No drift						•	•					
8. High common mode rejection				•		•	•					
9. Algebraic addition		•	•		•			•	•			
10. Time domain reflectometry												
11. Wide band TDR									•	•		
12. Swept frequency									•	•		
13. Spectrum analyzer												



Price: $250.

1400A
- 100 μV/cm
- dc to 400 kHz
- Differential on all ranges

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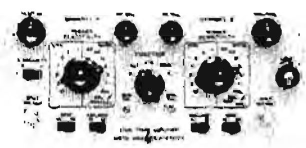

Price: $425.

1401A
- 1 mV/cm-dual trace
- dc to 450 kHz
- Convenient dual trace triggering

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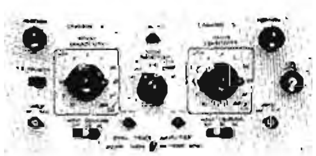

Price: $575.

1402A
- 5 mV/cm
- dc to 20 MHz-dual trace
- Signal delay for fast rise viewing

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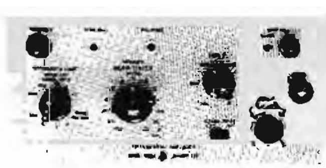

Price: $475.

1403A
- 10 μV/cm
- 0.1 Hz to 400 kHz
- 106 dB common mode rejection

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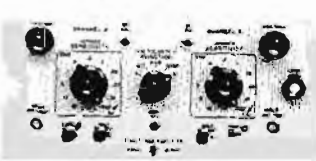

Price: $325.

1405A
- 5 mV/cm-dual trace
- dc to 5 MHz
- Algebraic addition

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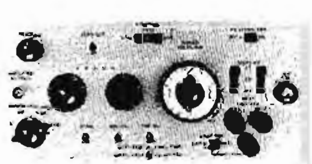

Price: $850.

1406A
- 50 μV/cm-dc to 400 kHz
- No drift
- Calibrated offset for accurate ac and dc measurements

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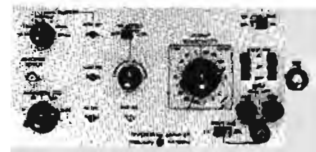

Price: $625.

1407A
- 50 μV/cm
- No drift
- 80 dB common mode rejection

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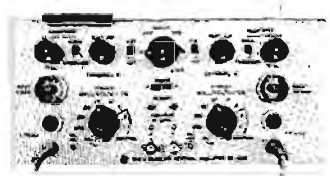

Price: $1600.

1410A
- 1 mV/cm at 1 GHz-dual trace
- Internal triggering
- High impedance probes and 50Ω inputs

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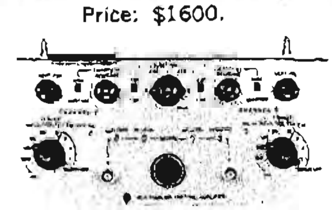

Price: $700.

1411A
- 1 mV/cm-dual trace
- Bandwidths to 12.4 GHz
- Remote samplers

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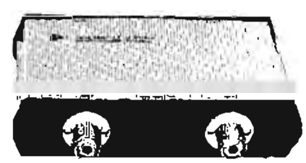

Price: $3000.

1430A
- 28 ps rise time—

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Price: $3000.

1431A
- 12.4 GHz bandwidth·

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Price: $1000.

1432A
- 90 ps rise time—

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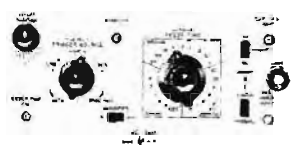
Capabilities	Compatible time bases						Double size plug-ins		Spectrum Analyzer	
	1420A	1421A	1422A	1423A	1424A	1425A	1415A	1416A	8552A	8533A
1. Wide band	•	•		•						
2. Sampling					•	•				
3. High gain differential	•	•	•	•						
4. Dual trace	•	•	•	•	•	•				
5. X-Y	Use 2 vertical or ext. horizontal									
6. Delayed sweep		•				•				
7. No drift	•	•	•	•						
8. High common mode rejection	•	•	•	•						
9. Algebraic addition	•	•	•	•	•	•				
10. Time domain reflectometry							•			
11. Wide band TDR					•	•				
12. Swept frequency								•		
13. Spectrum analyzer									•	•

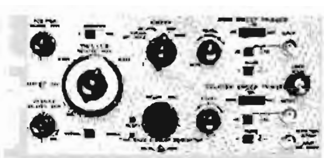


Price: $325.

1420A

- 10 MHz triggering
- Sweeps to 50 ns/cm
- Auto triggering

Page 520



Price: $625.

1421A

- 20 MHz triggering
- Delayed sweep
- Sweeps to 20 ns/cm

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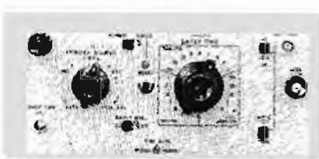

Price: $250.

1422A

- 500 kHz triggering
- Sweeps to 200 ns/cm
- Auto triggering

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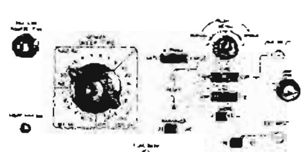
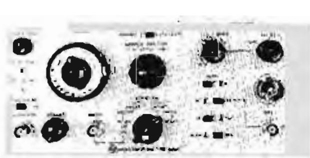


Price: $450.

1423A

- 20 MHz triggering
- Sweeps to 20 ns/cm
- Trigger hold-off

Page 520

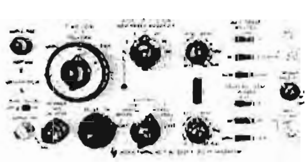


Price: $1325.

1424A

- Triggering to 5 GHz
- Sweeps to 10 ps/cm
- Direct readout on all sweeps

Page 526



Price: $1800.

1425A

- Delayed sweep
- Sweeps to 10 ps/cm
- Triggering to 1 GHz

Page 527

Price: $1050.

1415A

- Complete TDR system for testing cables, connectors, striplines
- Determines location, meaning, and nature of each discontinuity
- Resolves discontinuities—an inch apart
- Easy to operate

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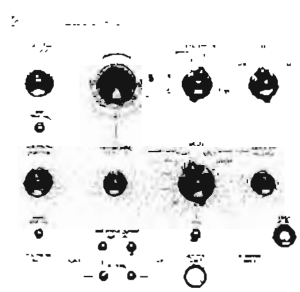
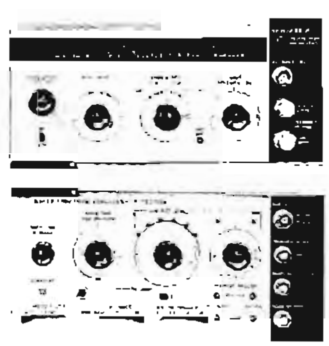


Price: $675.

1416A

- Speeds and simplifies swept frequency measurements
- High resolution readout directly in dB

Page 529



Price: 8552A, $1900
85532, $1800

8552A/8553L

- IF and RF plug-ins needed to form spectrum analyzer covering 1kHz to 110 MHz
- Presents amplitude as f (frequency) over > 70 dB dynamic range
- Absolute amplitude measurement from −130 dBm to +10 dBb (0.07 μV to 0.8 V)

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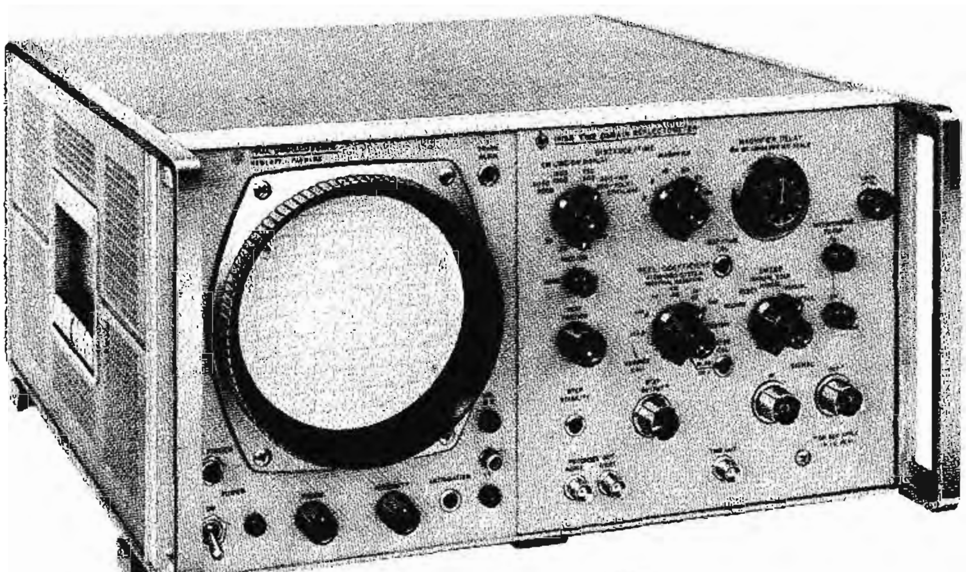
Accepts all 1400-Series Plug-Ins
Mainframe Model 140A

The Model 140A is a mainframe which contains the basic functional circuitry for both low and high frequency applications, as well as those for sampling. It contains a post-accelerator CRT with its associated power supplies and control circuitry, and the dc supplies required to power the Model 1400-series plug-ins. The plug-ins contain all of the circuitry necessary to produce beam deflection, and work directly into the CRT of the Model 140A mainframe.



140A

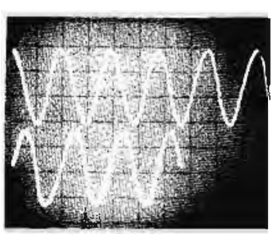
Specifications

Plug-ins: accepts Model 1400-series plug-ins; upper compartment for horizontal axis and lower compartment for vertical axis; center shield may be removed to accommodate a single dual-axis Model 1400-series unit.

Cathode-ray tube:

Type: post-accelerator, 7300-volt accelerating potential; aluminized P31 phosphor (other phosphors available, see modifications); etched safety glass face plate reduces glare.

Graticule: 10 cm x 10 cm parallax-free internal graticule marked in cm squares; major horizontal and vertical axes, and second and tenth horizontal graticule lines have 2 mm subdivisions.



In the HP 140A CRT, you get high 7.3 kV electron beam acceleration for bright, easy-to-see traces . . . internal graticule eliminates parallax . . . carefully shaped post accelerator field gives full 10 cm x 10 cm display area without distortion.

Intensity modulation: ac coupled, +20 volt pulse will blank trace of normal intensity; input terminals on rear panel.

Warranty: CRT warranted for one year.

Writing rate: (using HP Model 197A Camera with f/1.9 lens and Polaroid® 3000 speed film).

P31 Phosphor: 300 cm/μsec.

P11 Phosphor: 430 cm/μsec.

Calibrator:

Type: line-frequency rectangular signal, approximately 0.5 μsec risetime.

Voltage: two outputs: 1 volt and 10 volts peak-to-peak, $\pm 1\%$ from 15°C to 35°C, $\pm 3\%$ from 0°C to 55°C.

Beam finder: pressing beam finder control brings trace on CRT screen regardless of settings of horizontal, vertical or intensity controls.

Power requirements: 115 or 230 volts $\pm 10\%$, 50 to 60 Hz, normally less than 285 watts (varies with plug-in units used).

Dimensions: 16¾" wide, 9" high, 18⅜" deep overall (426 x 229 x 466 mm); hardware furnished for quick conversion to 19" x 8¾" x 16⅜" (483 x 222 x 416 mm) behind panel rack mount.

Weight: net, 37 lbs. (16,7 kg); shipping, 45 lbs (20 kg).

Price: HP Model 140A (without plug-ins), $595.00.

Modifications: CRT phosphors (specify by phosphor number); P31 standard; P2, P7 (with amber filter), P11 available at no charge.

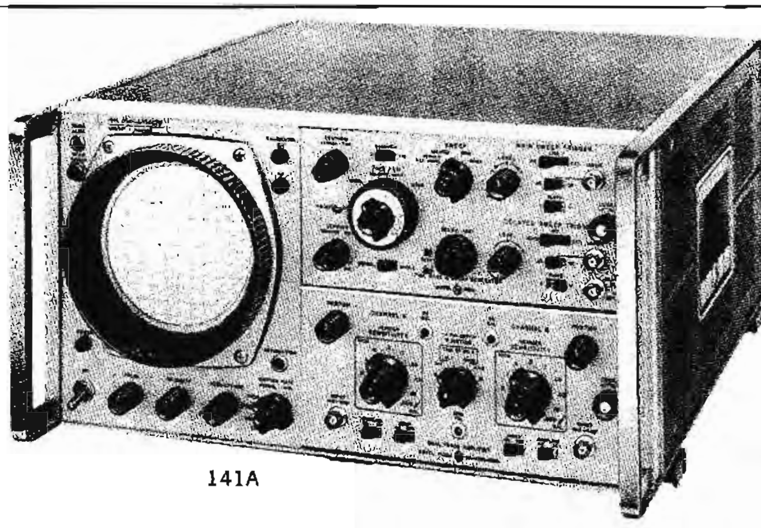
Special order: chassis slides and adapter kits. Fixed slides, order HP Part No. 1490-0714, $32.50. Pivot slides, order HP Part No. 1490-0718, $40.00. Slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40.00.

"Polaroid"® by Polaroid Corporation

Variable Persistence and Storage
Mainframe Model 141A

The Model 141A mainframe contains the same basic circuitry for low-frequency, high frequency and sampling applications as the 140A mainframe. It also accepts all of the 1400—series plug-ins. In addition the 141A mainframe contains the cathode-ray-tube and associated circuitry for the unique variable persistence and storage capabilities.

The 141A gives you storage for side-by-side comparison of waveforms. In this mode, traces can be held intact for more than an hour (days, in fact, with the scope turned off). Fast 1 cm/μsec storage writing rate enables you to capture single-shot transients. Variable persistence allows adjustments to match changing signal characteristics.



141A

Specifications

Plug-ins: same as Model 140A.

Cathode-ray tube:

Type: post-accelerator storage tube, 7300-volt accelerating potential; aluminized P31 phosphor; etched safety glass face plate reduces glare.

Graticule: 10 x 10 divisions (approximately 9.4 x 9.4 cm) parallax-free internal graticule; 5 subdivisions per major division on major horizontal and vertical axes, and on second and tenth horizontal graticule lines.

Intensity modulation: ac coupled, +20 volt pulse will blank trace of normal intensity; input terminals on rear panel.

Warranty: CRT specifications (persistence, writing rate, brightness, storage time) warranted for one year.

Persistence:

Normal: natural persistence of P31 phosphor (approximately 40 microseconds).

Variable:

Normal writing rate mode: continuously variable from less than 0.2 second to more than one minute (typically to two or three minutes).

Max writing rate mode: typically variable from 0.2 second to 15 seconds.

Erase: manual; erasure takes approximately 200 msec; scope ready to record immediately after erasure (see options for remote erase).

Writing rate (conventional operation): (using HP Model 197A Camera with f/1.9 lens and Polaroid® 3000 speed film): 100 cm/μsec.

"Polaroid"® by Polaroid Corporation

Writing rate (storage):

Normal mode: greater than 20 cm/msec.

Max. mode: greater than 1 cm/μsec.

Storage time: from Normal Writing Rate mode to Store, traces may be stored for 1 hour. To View mode, traces may be viewed at normal intensity for up to 1 minute. From Max. Writing Rate mode to Store, traces may be stored at reduced intensity for more than 15 minutes. To View mode, traces may be stored at normal intensity for more than 15 seconds.

Brightness: greater than 100 foot-lamberts in Normal or view modes; typically 5 foot-lamberts in Store mode.

Calibrator:
Beam finder:
Power requirements:
Dimensions:
} same as Model 140A

Weight: net, 40 lbs (18 kg); shipping, 51 lbs (23 kg).

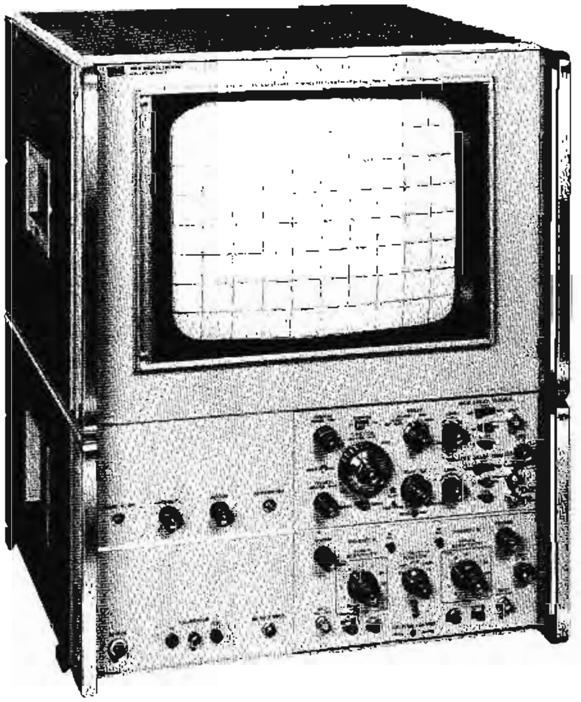
Price: HP Model 141A (without plug-ins), $1395.00.

Options: (specify by option number).

09: Remote erase. BNC input on rear panel; shorting to ground for at least 50 ms; erases screen, with scope ready for use 200 msec after ground is removed; input draws 20 mA from ground through a 600-ohm impedance to a —12 volt supply. Add $25.

Special order: chassis slides and adapter kit; fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides on scope, order HP Part No. 1490-0721, $40 New-fast writing rate CRT option for HP 141A, 5 cm/μsec. Order Model C05-141A, $1495.

8" x 10" CRT display
Mainframe Model 143A



- 8" x 10" CRT display
- Accepts HP 1400 Series plug-ins
- Parallax-free internal graticule

The HP Model 143A Oscilloscope mainframe provides the extreme versatility of a dual-axis plug-in oscilloscope, and in addition has a very large 8-inch by 10-inch viewing area. The large display is useful wherever the readout is to be viewed from a distance or by several people at one time.

The Model 143A provides higher resolution displays throughout the oscilloscope measuring spectrum with the same accuracy and linearity normally associated with a conventional 5" display.

This large-screen oscilloscope is specifically designed to give you both high-frequency and high-sensitivity performance. It consists of the essential functional blocks for low and high frequency applications—plus sampling. Included are an advanced-design post accelerator CRT, associated control circuitry, and the power supplies required for the HP 1400-series plug-ins.

Specifications, 143A

Plug-ins: accepts standard Model 1400-series plug-ins; upper compartment for horizontal axis and lower compartment for vertical axis (all plug-in specifications are same except bandwidth is 15 MHz with Model 1402A); center shield may be removed to accommodate a single dual axis Model 1400-series unit. Plug-in panel nomenclature of centimeter divisions translates directly to inch divisions on the Model 143A display. For example, 5 V/cm deflection factor is displayed as 5 V/inch on the Model 143A.

Cathode-ray tube

Type: post-accelerator, 20 kV accelerating potential; aluminized P31 phosphor (other phosphors available on order).

Graticule: 8-inch by 10-inch parallax-free internal graticule marked in one inch squares; major vertical and horizontal axes have 0.2-inch subdivisions (other graticules available on order).

Intensity modulation: ac-coupled (down 3 dB at 4 kHz), +20 volt pulse will blank trace of normal intensity; input on rear panel.

Warranty: CRT warranted for one year.

Calibrator

Type: line-frequency rectangular signal, approximately 0.5 μsec risetime.

Voltage: two outputs; 1 volt and 10 volts peak-to-peak ±1% from 15°C to 35°C, ±3% from 0° to +55°C.

Beam finder: pressing beam finder control brings trace on CRT screen regardless of vertical, horizontal or intensity control settings.

Power requirements: 115 or 230 volts ±10%, 50 to 60 Hz, normally less than 235 watts (varies with plug-in units used).

Weight: without plug-ins, net 63 lbs (28,6 kg); shipping 80 lbs (36,3 kg).

Dimensions: 16¾" wide, 21" high, 18⅜" deep over-all (426 x 533 x 466 mm); hardware furnished for quick conversion to 19" x 20¾" x 16⅜" (483 x 527 x 416 mm) behind panel rack mount.

Accessories furnished: rack mounting hardware for conversion to a standard EIA rack configuration.

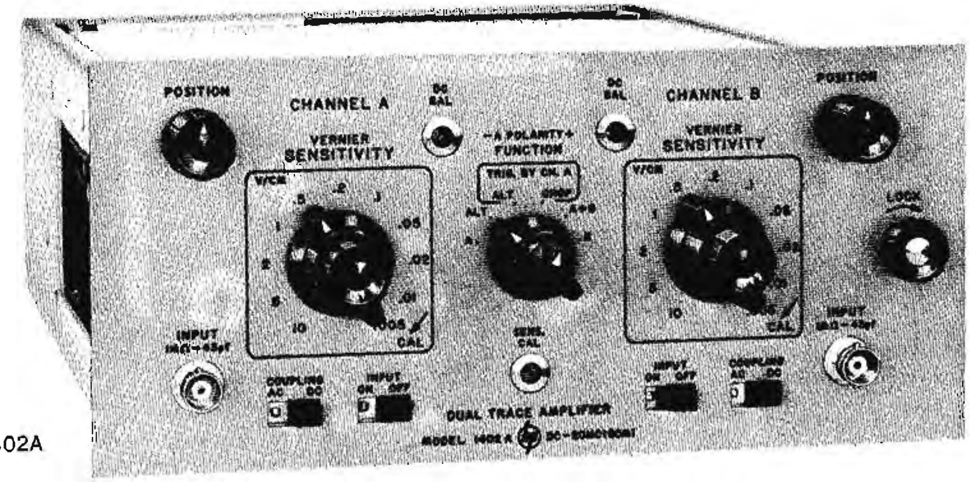
Price: HP Model 143A, $1400.

Accessories available

Anti-reflection filter: nylon mesh attached to contrast filter to reduce reflections. Model 10181A, amber for P7 phosphor; Model 10182A, green for standard phosphors. Price: Model 10181A, $30; Model 10182A, $30.

Chassis slides and adapters: fixed slides, order HP Part No. 1490-0714, $32.50; pivot slides, order HP Part No. 1490-0718, $40; slide adapter kit for mounting slides, order HP Part No. 1490-0721, $40. Note: one adapter kit required for mounting one pair of chassis slides.

20 MHz With Signal Delay
Dual Trace Amplifier Model 1402A



1402A

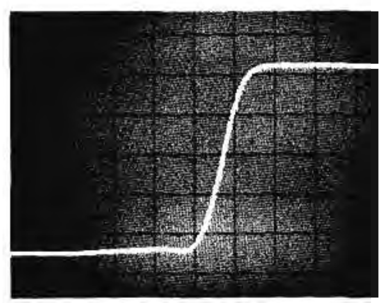
The 1402A Dual Trace Amplifier provides greater than 20 MHz bandwidth plus 5 mV/cm sensitivity on each channel for accurate analysis of high frequency low level signals. Rise times of signals can be easily measured because the 1402A has a built-in delay line in the vertical amplifier following the trigger take-off.

Two signals can be displayed with the 1402A in each of two modes. Slow signals can be viewed in the chopped mode, since the input to the CRT is switched between Channel A and Channel B at a high rate during each sweep. Fast signals can be viewed in the alternate mode since the input to the CRT is switched at the end of each sweep, with Channel A displayed during one sweep and Channel B on the following sweep.

Accurate time difference measurements are possible because the sync amplifier in the 1402A can be switched to Channel A alone. This feature is useful when dual traces are displayed on alternate sweeps; switching the sync to Channel A preserves the time relationship between the two signals, because the sweep always triggers on the same point on Channel A. Also, syncing to Channel A when in the chopped dual trace mode assures triggering on the displayed waveform rather than the chopper. Two unrelated signals can be displayed by triggering on the composite waveform. This feature avoids resorting to external triggering for either of these dual trace presentations.

Single-channel displays are also possible for either input A or B. The two channels may also be displayed algebraically added, and a polarity reversal switch on Channel A allows the differential signal, B — A, to be displayed.

Although maximum bandwidth is obtained from the 1402A with 6 cm or less deflection, larger amplitude signals can be displayed without distortion and with only a small sacrifice in bandwidth. For example, the bandwidth when using a full 10-cm deflection is greater than 15 MHz.



Above photo demonstrates bandwidth and excellent transient response of 1402A Dual Trace Amplier. Sweep time is 20 ns/cm; sensitivity is 5 mV/cm.

Specifications

Mode of operation: (1) Channel A alone, (2) Channel B alone, (3) Channel A and Channel B displayed on alternate sweeps, (4) Channel A and Channel B displayed by switching at approx. 100 kHz, with trace blanking during switching, (5) Channel A and Channel B added algebraically, polarity of Channel A may be inverted to obtain differential operation.

Bandwidth: (6 cm reference signal) dc coupled, dc to 20 MHz; ac coupled, 2 Hz to 20 MHz.

Risetime: less than 20 ns with 6 cm step input.

Deflection factor (sensitivity): each channel; 5 mV/cm to 10 V/cm, 11 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 25 V/cm.

Signal delay: signal is delayed so that leading edge of fast-rise signals is visible at start of sweep.

Common mode rejection: (in B-A mode) at least 40 dB on 5, 10 and 20 mV/cm ranges, at least 30 dB on 50 mV/cm to 10 V/cm ranges; common mode signal not to exceed 150 cm (e.g., 150 volts on 1 V/cm range) or a frequency of 500 kHz.

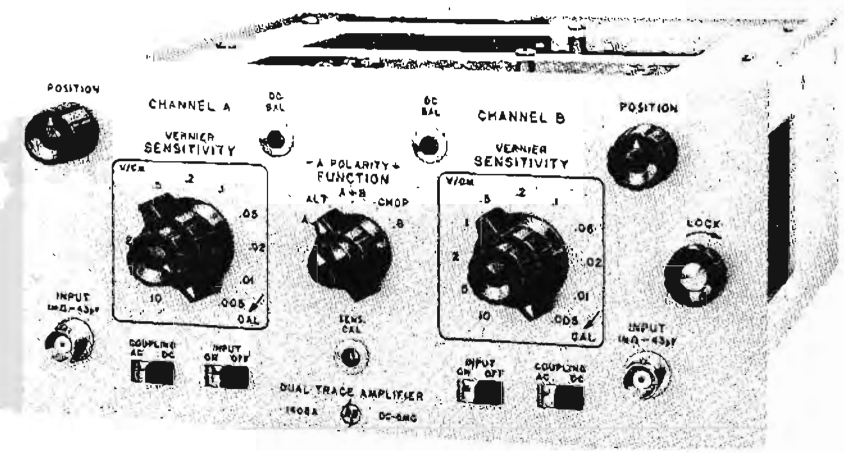
Input RC: 1 megohm shunted by 43 pF.

Maximum input: 600 volts peak (dc + ac).

Weight: net, 6 lbs (2,7 kg); shipping, 8 lbs (3,6 kg).

Price: HP Model 1402A, $575.

5 MHz with 5 mV/cm Deflection Factor
Dual Trace Amplifier Model 1405A

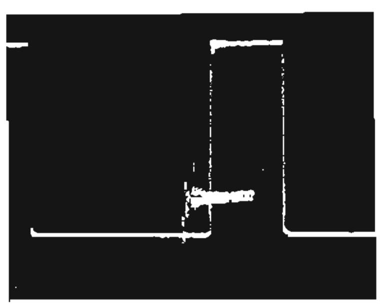


1405A

The wide dynamic range of the 1405A permits a 50 cm width at 5 mV/cm sensitivity. Dual trace presentations can be displayed on alternate sweeps or by chopping between the two input signals on the same sweep at a 100 kHz rate. In addition to single-trace presentations of Channel A or B, the two channels may be algebraically added or, by a reversal of the Channel A polarity switch, the differential signal may be viewed. The full 5 MHz frequency response is achieved in every operating mode, and when operating in any sensitivity position.

In all operating modes each channel has independent positioning and sensitivity controls, permitting the comparison of signals with widely differing amplitudes. When used as a differential amplifier, a common-mode rejection of better than 40 dB in the higher sensitivity positions permits the display of low-level signals while attenuating undesirable components such as hum.

The 1405A Dual Trace Amplifier provides 5 MHz band-peak-to-peak signal to be displayed without significant distortion. Using A + B mode and a variable dc voltage source such as the 723A power supply applied to the second channel, any 10-cm segment of the 50-cm trace can be positioned on screen and analyzed. The 1405A is an ideal tool for video waveforms when used with the 1421A Time Base and Delay Generator, since any single line of a television frame may be isolated and displayed. The 5 mV/cm sensitivity permits the display of signals in low-level stages, or permits the use of attenuator probes to prevent circuit loading. For X-Y measurements, such as phase shift or Lissajous patterns, the 1405A may be used with any other 1400 series plug-in (including another 1405A) for either vertical or horizontal deflection.



Double exposure showing 5-cm pulse on upper waveform, and the same pulse expanded 10 X to view small perturbation on the top.

Specifications

Mode of operation: (1) Channel A alone, (2) Channel B alone, (3) Channel A and Channel B displayed in alternate sweeps (4) Channel A and Channel B displayed by switching at approx. 100 kHz, with trace blanking during switching, (5) Channel A and Channel B added algebraically, polarity of Channel A may be inverted to obtain differential operation.

Bandwidth: dc coupled, dc to 5 MHz (70 nsec rise time; ac coupled, 2 Hz to 5 MHz (the lower limit is extended to approx. 0.2 Hz with a X10 probe).

Deflection factor (sensitivity): each channel; 5 mV/cm to 10 V/cm, 11 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 25 V/cm.

Common mode rejection: at least 40 dB on 5, 10, and 20 mV/cm ranges, at least 30 dB on 50 mV/cm to 10 V/cm ranges; common mode signal not to exceed 50 cm (e.g., 0.5 volt on 10 mV/cm range) or a frequency of 50 kHz.

Input RC: 1 megohm shunted by 43 pF.

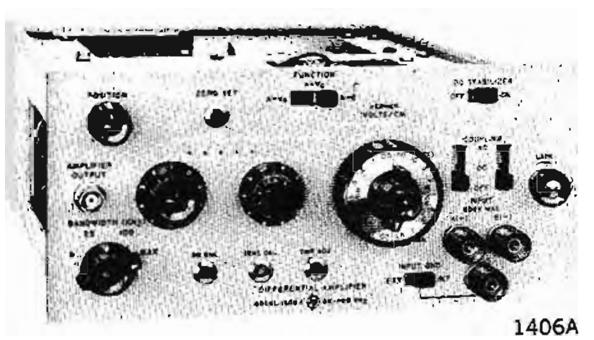
Maximum input: 600 volts peak (dc + ac).

Weight: net, 4 lbs (1,8 kg); shipping, 7 lbs (3,2 kg).

Price: HP Model 1405A, $325.

Special order: double-size, single-channel, X-Y only version of Model 1405A; order H20-1405A; price, $450.

Differential amplifier with calibrated offset
Precision amplifiers Model 1406A



In addition to 50 μV/cm deflection factor, no drift dc stabilization, and wide dynamic range, the 1406A offers a calibrated dc offset for better than 0.5% accurate ac and dc voltage measurements.

Accurate measurements are accomplished by inserting the test signal into one side of a high common mode rejection differential amplifier and a very accurate (0.15%) dc level into the other side. The top of the waveform is then positioned to center screen with the offset controls and the offset reading noted. This is then repeated for the bottom of the waveform. The difference between the two offset readings is the ac amplitude.

The same technique is used when measuring a dc level except only one reading is required; zero volts is already established because the stabilizer eliminates drift.

The range switching is interlocked with the deflection factor switching so that the direct reading offset does not change when changing the deflection factor. There are ten offset ranges providing ±0.1 V to ±1000 V in decade steps.

The 1406A can also be used as a differential amplifier. The high common mode rejection and no drift features provide for accurate differential measurements. An external ground is also provided to eliminate ground loops.

The adjustable bandwidth control of the 1406A allows the user to reduce bandwidth from the maximum of 400 kHz down to 100, 25, 5 kHz, eliminating noise present in the unused part of the bandwidth. The front panel amplifier output permits driving external equipment such as X-Y Recorders or tape recorders.

Specifications

Deflection factor: 50 μV/cm to 20 V/cm in a 1, 2, 5 sequence; vernier provides continuous adjustment between ranges and extends highest deflection factor to at least 50 V/cm; attenuator accuracy is ±3%.

Amplifier output: approx 1 V/cm, dc coupled, single ended, dc level approx 0 volts, output impedance less than 100 ohms, dynamic range ±5 V.

Bandwidth

Upper limit:

20 V/cm to 100 μV/cm - 400 kHz (0.9 μs rise time); or 50 μV/cm - 300 kHz.

Upper limits of max, 100, 25, and 5 kHz selectable with front panel switch on all deflection factors.

Lower limit: dc with input dc coupled, 2 Hz with input ac coupled.

Drift

Long-term drift: less than ±0.2 cm or less than ±20 μV per 200 hrs, whichever is greater.

Temperature drift: less than ±0.2 cm or less than ±50 μV, whichever is greater over a temperature range of 0°C to 55°C.

Drift correction occurs at 3 Hz for 50 ms/cm sweeps and faster, and 1.5 Hz on 0.1 s/cm sweeps and slower.

Range to range shift: dc stabilization maintains a fixed baseline reference within ±1 cm on crt over entire range of deflection factors after a 3-minute warmup.

Positioning: baseline can be positioned ±10 cm by continuous position.

DC offset: offset is applied to the B (—) input.

Readout: 4-digit resolution, with lighted decimal indicators.

Ranges: ±0.1 V, ±1 V, ±10 V, ±100 V, ±1000 V Up to ±10 V offset can be used on all deflection factor ranges; an equivalent ±100 V range can be used from 0.5 mV/cm through 20 V/cm, and an equivalent ±1000 V range from 5 mV/cm through 20 V/cm.

Accuracy: ±0.15% of indicated value plus 0.05% of full scale offset range, on ±0.1 V, ±1 V, and ±10 V ranges. ±0.4% of indicated value plus 0.05% of full scale offset range, on ±100 V and ±1000 V ranges.

Differential input: may be selected on all deflection factor ranges. Single-ended operation is used when employing offset.

Common mode rejection: ±5 V (dc + pk ac) or ±10 V dc, dc coupled, 50 μV/cm to 20 mV/cm; dc to 60 Hz, 80 dB; 60 Hz to 10 kHz, 60 dB.

Maximum input without overload

50 μV/cm to 20 mV/cm — ±10 V pk-pk.
50 mV/cm to 2 V/cm — ±100 V pk-pk.
5 V/cm to 20 V/cm — ±600 V pk-pk.

Dynamic range: dynamic signals of at least ±50 cm of deflection can be displayed without distortion.

Input impedance: 1 megohm shunted by 100 pF, constant on all attenuator ranges.

Max input

V_o range: 0.1 to 10.

15 V (dc + peak ac), 0.05 mV/cm to 20 mV/cm; 150, 50 mV/cm to 0.2 V/cm; 600 V, 0.5 V/cm to 20 V/cm.

V_o range: 100.

150 V (dc + peak ac).

V_o range: 1000.

600 V (dc + peak ac).

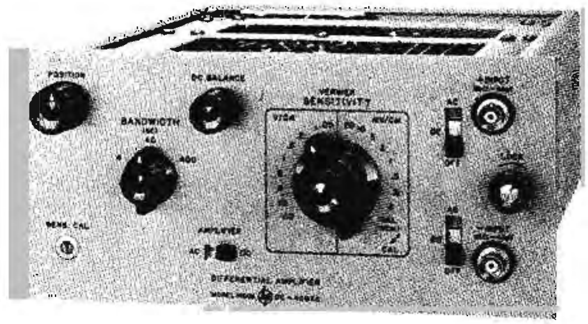
X-Y operation: two 1406A's or 1406A and a 1407A can be used to give stabilized X-Y presentation. Models 1406A and 1407A are not compatible with other 1400-series vertical plug-ins for X-Y displays.

Time base compatibility: the 1406A and 1407A can be used directly with the 1422A and 1423A; 1420A's below serial 441-01326 and 1421A's below serial 545-00651 must be modified. (Order kits 01420-69502 for the 1420A, 01421-69501 for the 1421A.)

Weight: net 5 lbs (1,8 kg); shipping 7 lbs (3,2 kg).

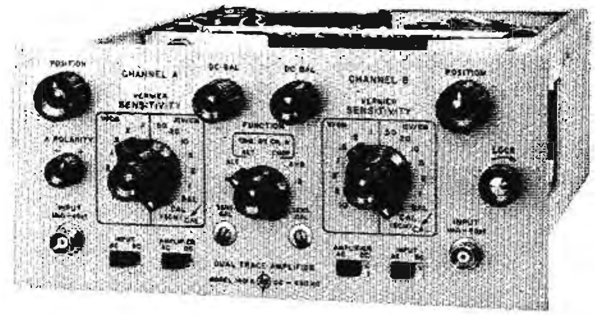
Price: HP Model 1406A, $850.

Measure microvolt signals
High sensitivity amplifiers Models 1400A, 1401A



1400A

Get 100 μV/cm sensitivity and selectable bandwidth from dc to 400 kHz with low drift differential amplifiers in the 1400A.



1401A

The 1401A is a dual trace amplifier with 1 mV/cm sensitivity and a 450 kHz bandwidth.

Specifications, 1400A

Bandwidth

Upper limit: 400 (0.9 μs rise time), 40 or 4 kHz.

Lower limit: input and amplifier coupling set to dc: dc; input set to dc and amplifier set to ac: dc from 20 V/cm to 50 mV/cm, approx 0.1 Hz on 20 mV/cm increasing with deflection factor to approx 20 Hz at 0.1 mV/cm; input set to ac and amplifier set to dc: 2 Hz.

Deflection factor (sensitivity): 100 μV/cm to 20 V/cm, 17 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 20 V/cm step to at least 50 V/cm.

Phase shift: when used with another Model 1400A, less than 2° relative phase shift up to 50 kHz with X and Y deflection factors the same, and verniers in Cal.

Common mode rejection: differential input may be selected on all ranges; cmr at least 40 dB on 0.1 mV/cm to 0.2 V/cm ranges, signal not to exceed 4 V pk-pk; at least 30 dB on 0.5 V/cm to 20 V/cm ranges, signal not to exceed 40 V pk-pk on 0.5, 1, and 2 V/cm ranges or 400 V pk-pk on 5, 10, and 20 V/cm ranges, measured with 1 kHz sine wave.

Input RC: 1 megohm shunted by 45 pF.

Maximum input: 600 volts peak (dc + ac).

Internal calibrator: line frequency square wave, 6 cm pk-pk; displayed when vernier is set to Cal; accuracy ±3%.

Weight: net 4 lbs (1,8 kg); shipping 7 lbs (3,2 kg).

Price: HP Model 1400A, $250.

Specifications, 1401A

Bandwidth: input and amplifier coupling set to dc, dc to 450 kHz (0.8 μs rise time); input set to dc and amplifier set to ac, dc to 450 kHz for deflection factors from 50 mV/cm to 10 V/cm; from 1 mV/cm to 20 V/cm, lower cutoff depends on the deflection factor: approx 0.5 Hz (to 450 kHz) at 20 mV/cm and 10 Hz (to 450 kHz) at 1 mV/cm; input set to ac and amplifier set to dc, 2 Hz to 450 kHz.

Deflection factor (sensitivity): each channel; 1 mV/cm to 10 V/cm, 14 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 10 V/cm step to at least 25 V/cm.

Phase shift: when used with another Model 1401A, less than 2° relative phase shift up to 50 kHz with X and Y deflection factors the same, and verniers in Cal.

Common mode rejection: both inputs may be switched to one channel to give differential input; cmr at least 40 dB on 1 mV/cm to 0.1 V/cm ranges, signal not to exceed 4 V pk-pk; at least 30 dB on 0.2 V/cm to 10 V/cm ranges, signal not to exceed 40 V pk-pk on 0.2, 0.5, and 1 V/cm ranges or 400 V pk-pk on 2, 5 and 10 V/cm ranges; measured with 1 kHz sine wave.

Input RC: 1 megohm shunted by 45 pF.

Maximum input: 60 volts peak (dc + ac).

Internal calibrator: line frequency square wave, 6 cm pk-pk; displayed when vernier is set to Cal; accuracy ±3%.

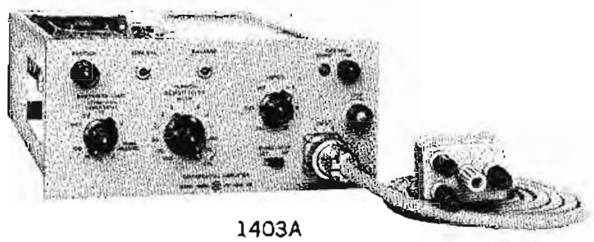
Mode of operation: (1) channel A alone, (2) channel B alone, (3) channel A and channel B displayed on alternate sweeps, (4) channel A and channel B displayed by switching at approx 100 kHz, with trace blanking during switching, (5) channel A minus channel B.

Display polarity: + up or − up, selectable, 7 lbs (3,2 kg).

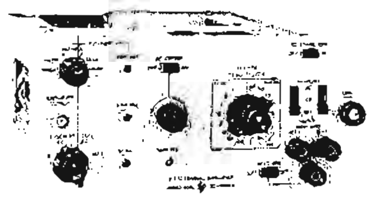
Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: HP Model 1401A, $425.

High common mode rejection
High sensitivity amplifiers Models 1403A, 1407A



The Model 1403A Amplifier features 106 dB of common mode rejection with guarded input and 10 μV/cm sensitivity.



The Model 1407A has 50 μV/cm sensitivity, 80 dB of common mode rejection, and no dc drift.

Specifications, 1403A

Input modes: (1) input A single-ended, (2) input B single-ended and inverted, (3) A-B differential, (4) off disconnects inputs and grounds input amplifier, (5) cmr, and (6) Cal for calibrating the instrument; A and B inputs, guard, and chassis ground are brought out through a special guarded connector; guard is normally driven by internal common mode signal amplifier; with unbalanced source impedances, the guard may be driven externally, preserving high cmr.

Bandwidth: 0.1 Hz to 400 kHz (0.9 μs rise time) (to 200 kHz at 10 μV/cm and to 300 kHz at 20 μV/cm); upper and lower limits may be independently selected; lower: 0.1, 1, 10, and 100 Hz; upper: max (greater than 400 kHz), 100, 10, 1, and 0.1 kHz.

Deflection factor (sensitivity): 0.01 mV/cm to 100 mV/cm, 13 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 100 mV/cm step to at least 125 mV/cm.

Phase shift: when used with another Model 1403A, less than 2° relative phase shift up to 50 kHz with X and Y deflection factors the same, and verniers in Cal.

Common mode rejection: differential input may be selected on all ranges; with a balanced input impedance and the guard drive in external, cmr may be adjusted to the values below for up to 5 V pk-pk, 45 Hz to 3 kHz (for internal, cmr is 6 dB less than shown below).

Deflection factor (mV/cm)	Common mode rejection (dB)
0.01 to 0.2	106
0.5, 1, 2	86
5, 10, 20	66
50, 100	46

Typical CMR with an unbalanced source impedance when using Guard Drive Ext on most sensitive ranges:

Unbalance	60 Hz	120 Hz	1 kHz	10 kHz
100 ohms	100 dB	100 dB	100 dB	90 dB
1 k ohms	100 dB	100 dB	90 dB	70 dB
10 k ohms	80 dB	80 dB	70 dB	50 dB

Input RC: 10 megohms shunted by approx. 60 pF.

Maximum input: 600 volts peak (dc + ac) on A and B inputs, 10 volts on Guard input.

Noise: 20 μV pk-pk at 100 kHz, noise is reduced as bandwidth is reduced.

Internal calibrator: line frequency square wave, 100 mV pk-pk; displayed when input selector is set to Cal; accuracy ±3%.

Weight: net 4 lbs (1,8 kg); shipping 7 lbs (3,2 kg).

Accessories furnished: 6-ft double-shielded extension cable, and a 4-terminal binding post adapter.

Price: HP Model 1403A, $475.

Specifications, 1407A

Bandwidth

Upper limit: selectable; 5, 25, 100 kHz, and max (400 kHz for 20 V/cm to 100 μV/cm ranges, 0.9 μs rise time; or 300 kHz for 50 μV/cm range).

Lower limit: dc coupled input, dc; ac coupled input, 2 Hz.

Deflection factor (sensitivity): 50 μV/cm to 20 V/cm, 17 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 20 V/cm step to at least 50 V/cm.

Amplifier output: approx 1 V/cm, dc coupled, single-ended, dc level approx 0 V, output impedance ≤100 ohms, dynamic range ±5 V.

Drift: drift correction occurs at 3 Hz for 50 ms/cm speeds and faster, 1.5 Hz on 0.1 s/cm speeds and slower.

Long term drift: less than ±0.2 cm or ≤ ±20 μV/200 hours, whichever is greater.

Temperature drift: less than ±0.2 cm or ≤ ±50 μV, whichever is greater, over a temperature range of 0°C to 55°C.

Range to range shift: dc stabilization maintains a fixed baseline reference within ±1 cm on crt over entire deflection factor range, after a 3-minute warmup.

Positioning: baseline can be positioned continuously or in calibrated steps of 0, ±5 cm, and ±10 cm; accuracy ±3%.

DC offset: uncalibrated dc offset is provided in both single-ended and differential operation; the max amount of offset obtainable, referenced to the input, varies with deflection factor approx as follows: 0.2 V at 50 μV/cm, increasing to 0.5 V at 10 mV/cm, 5 V at 100 mV/cm, 50 V at 1 V/cm, and 600 V at 20 V/cm; offset dc drift is ≤ 20 μV/hr at constant ambient temperature, or ≤ ±100 μV for ambient temperature change of 0°C to 50°C.

Differential input: may be selected on all ranges; offset capability is maintained in differential operation.

Common mode rejection: ±5 V (dc + pk ac) or ±10 V dc, dc coupled, 50 μV/cm to 20 mV/cm; dc to 60 Hz, 80 dB; 60 Hz to 10 kHz, 60 dB; max input without overload: 50 μV/cm to 20 mV/cm, ±10 V pk-pk; 50 mV/cm to 2 V/cm, ±100 V pk-pk; 5 V/cm to 20 V/cm, ±600 V pk-pk.

Dynamic range: dynamic signals of less than ±50 cm of deflection can be displayed without distortion.

Input RC: 1 megohm shunted by 90 pF.

Maximum input: 100 volts peak (dc + ac) for 0.05 mV/cm to 20 mV/cm ranges, 600 volts peak (dc + ac) for 50 mV/cm to 20 V/cm ranges.

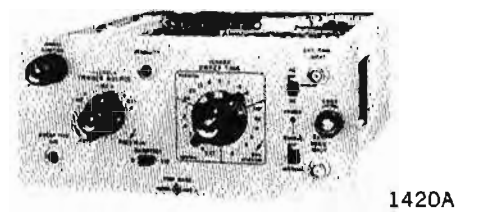
X-Y operation: two 1407A's or 1407A and a 1406A can be used to provide stabilized X-Y presentations. Models 1406A and 1407A are not compatible with other 1400-series vertical plug-ins for X-Y displays.

Time base compatibility: the Model 1407A may be used directly with Models 1422A and 1423A; Model 1420A's below serial 441-01326, and Model 1421A's below serial 545-00651 must be modified for use with the Model 1407A (order kits 01420-69502 for the Model 1420A, $12.50; or 01421-69501 for the Model 1421A, $20).

Weight: net 5 lbs (1,8 kg); shipping 7 lbs (3,2 kg).

Price: HP Model 1407A, $625.

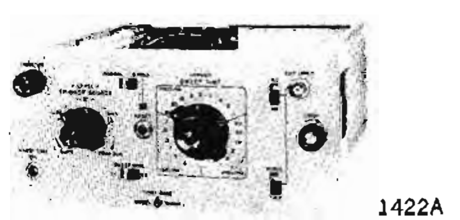
Sweeps to 20 ns/cm
Time bases Models 1420A, 1422A, 1423A



5 MHz triggering with sweeps to 50 ns/cm and automatic triggering.

Specifications, 1420A

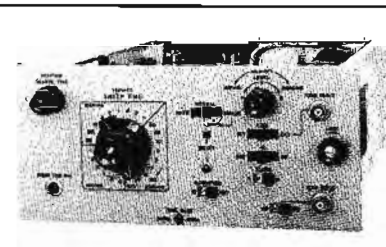
Range: 0.5 μs/cm to 5 s/cm, 22 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends the 5 s/cm step to at least 12.5 s/cm.
Magnifier: X10, overall accuracy ±5%; expands 0.5 μs/cm speed to 50 ns/cm.
Automatic triggering: (baseline displayed in the absence of an input signal).
 Internal: 40 Hz to 500 kHz for signals causing 0.5 cm or more vertical deflection; also from line signal.
 External: 40 Hz to 500 kHz for signals at least 0.5 V pk-pk.
 Trigger slope: positive or negative slope of external sync signal or internal vertical deflection signal.
Amplitude selection triggering
 Internal: 10 Hz to 5 MHz for signals causing 0.5 cm or more vertical deflection.
 External: for signals at least 0.5 V pk-pk; dc coupled, dc to 5 MHz; ac coupled, 10 Hz to 5 MHz; max input, 600 V pk (dc + ac).
 Trigger point and slope: from any point on the vertical waveform presented on crt; or continuously variable from −7 to +7 volts on external sync signal; positive or negative slope.
Single sweep: front panel switch permits single sweep operation.
Horizontal input
 Bandwidth: dc to better than 1.5 MHz (typically).
 Deflection factor: vernier permits continuous adjustment from approx 50 mV/cm to 5 V/cm.
 Input RC: 1 megohm shunted by approximately 50 pF.
Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).
Price: HP Model 1420A, $325.



500 kHz triggering with sweeps to 200 ns/cm and automatic triggering.

Specifications, 1422A

Range: 1 μs/cm to 5 s/cm, 21 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends the 5 s/cm step to at least 12.5 s/cm.
Magnifier: X5, overall accuracy ±5%; expands 1 μs/cm speed to 200 ns/cm.
Automatic triggering: (baseline displayed in the absence of an input signal).
 Internal: 50 Hz to 500 kHz for signals causing 0.5 cm or more vertical deflection; also from line signal.
 External: 50 Hz to 500 kHz for signals at least 0.5 V pk-pk.
 Trigger slope: positive or negative slope of external sync signal or internal vertical deflection signal.
Amplitude selection triggering
 Internal: dc or 10 Hz to 500 kHz (depending on vertical system) for signals causing 0.5 cm or more vertical deflection.
 External: for signals at least 0.5 V pk-pk; dc coupled, dc to 500 kHz; ac coupled, 10 Hz to 500 kHz; max input, 600 V pk (dc + ac).
 Trigger point and slope: from any point on the vertical waveform presented on crt; or continuously variable from −10 to +10 volts on external sync signal; positive or negative slope.
Single sweep: front panel switch permits single sweep operation.
Horizontal input
 Bandwidth: dc coupled, dc to 400 kHz; ac coupled, 20 Hz to 400 kHz.
 Deflection factor: vernier permits continuous adjustment from approx 0.8 V/cm to 2.5 V/cm.
 Input RC: 1 megohm shunted by approx 150 pF.
Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg)
Price: HP Model 1422A, $250.

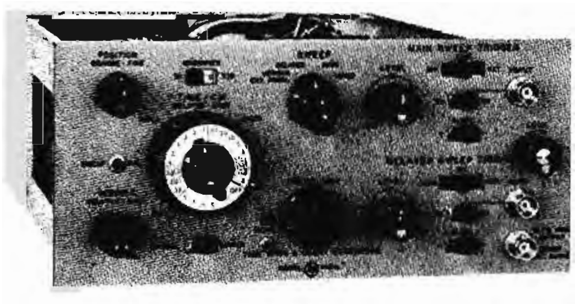


20 MHz triggering with sweeps to 20 ns/cm and trigger hold-off.

Specifications, 1423A

Range: 0.2 μs/cm to 5 s/cm, 23 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends the 5 s/cm step to at least 12.5 s/cm.
Magnifier: X10, overall accuracy ±5%; expands 0.2 μs/cm speed to 20 ns/cm.
Automatic triggering: (baseline displayed in the absence of an input signal) same as normal, except lower limit is 40 Hz for both ac and dc coupling.
Normal triggering
 Internal: dc coupled: dc (with Models 1406A/1407A) to 15 MHz for signals causing 0.5 cm or more vertical deflection, to 20 MHz for 1 cm signals; ac coupled: 10 Hz to 15 MHz for 0.5 cm signals, to 20 MHz for 1 cm signals; ACF: approx 2 kHz to 15 MHz for 0.5 cm signals, to 20 MHz for 1 cm signals.
 External: for signals at least 0.5 V pk-pk; dc coupled, dc to 20 MHz; ac coupled, 10 Hz to 20 MHz; ACF, approx 2 kHz to 20 MHz; max input, 600 V pk (dc + ac).
 Line: triggering from line frequency also selectable.
Trigger point and slope: selectable in both normal and automatic: from any point on the vertical waveform presented on crt, or continuously variable from −5 to +5 volts on external sync signal; positive or negative slope.
Trigger hold-off: time continuously variable, exceeding one full sweep at 50 ms/cm and faster, prevents multiple triggering on signals that have desired triggering level and slope appearing more than once per cycle.
Trigger input RC: dc and ac, approx 1 megohm shunted by 50 pF; acf, approx 120 k ohms shunted by 50 pF.
Single sweep: front panel switch permits single sweep operation.
Horizontal input
 Bandwidth: dc to 500 kHz.
 Deflection factor: vernier and X10 magnifier permit continuous adjustment from approx 300 mV/cm to 30 V/cm.
 Input RC: 1 megohm shunted by approx 50 pF.
Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).
Price: HP Model 1423A, $450.

Delayed sweep to 20 MHz
Time base Model 1421A



1421A

The 1421A Time Base and Delay Generator provides sweep speeds to 20 ns/cm with stable triggering to 20 MHz and beyond.

The delayed sweep feature of the 1421A permits detailed examination of any portion of a complex signal or pulse train by generating an accurately controlled delay time, at the end of which, a second sweep in the 1421A provides the deflection signal to the crt. The 1421A has provision to trigger the deflection sweep at the end of the delay interval either automatically, on the vertical deflection signal (internal), or on an external signal. In the automatic mode, the delayed sweep is immediately triggered at the end of the delay interval, thereby permitting accurate measurements of the time jitter in the input waveform. In the internal and external modes, the delayed sweep is armed at the end of the delay interval and the signal triggers the delayed sweep. Thus the rise time and amplitude can be accurately measured without jitter.

Specifications

Main sweep: for displaying signals vs time where sweep delay is not required; employs the main time base only.

Range: 0.2 μs/cm to 1 s/cm, 21 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 1 s/cm step to at least 2.5 s/cm.

Triggering: (when used with Model 1402A).

Amplitude selection:

Internal: approx 10 Hz to 15 MHz for signals causing 0.5 cm or more vertical deflection, to 20 MHz for 1 cm signals; also from line signal.

External: for signals at least 0.5 V pk-pk; dc coupled, dc to 20 MHz; ac coupled, approx 5 Hz to 20 MHz.

Trigger point and slope: controls allow selection of level and positive or negative slope; trigger level of external sync signal is continuously variable from −5 to +5 volts.

Automatic: baseline displayed in the absence of an input signal; internally down to 40 Hz on signals causing 1 cm or more vertical deflection, also on line signal; externally down to 40 Hz on signals at least 1 V pk-pk; trigger slope, positive or negative.

Trace intensification: used for setting up delayed or mixed sweep modes by increasing brightness of portion of main sweep which will be expanded to full screen in delayed sweep, or magnified portion of display in mixed sweep; rotating delayed sweep time switch out of off position activates intensified mode.

Delayed sweep: delayed time base sweeps after a time delay set by main sweep and delay controls.

Range: 0.2 μs/cm to 50 ms/cm, 17 ranges in a 1, 2, 5 sequence; accuracy ±3%; vernier provides continuous adjustment between steps and extends 50 ms/cm step to at least 125 ms/cm.

Delay (before start of delayed sweep):

Time: continuously variable from 0.5 μs to 10 s.

Accuracy: ±1%; linearity, ±0.2%; time jitter less than 0.005% of max delay of each range (1 part in 20,000).

Trigger output: (at end of delay time) approx +4 V with less than 150 ns risetime, from 1 k ohms output impedance.

Triggering: (applies to intensified main, delayed, and mixed sweep modes).

Automatic: delayed sweep starts precisely at end of delay period.

Internal: delayed sweep triggered by vertical waveform presented on crt after end of delay period; approx 10 Hz to 15 MHz for signals causing 0.5 cm or more vertical deflection, or to 20 MHz for 1 cm signals.

External: delayed sweep triggered by external signal after end of delay period; for signals at least 0.5 V pk-pk; dc coupled, dc to 20 MHz; ac coupled, approx 5 Hz to 20 MHz.

Trigger point and slope: (internal and external) same as main sweep.

Mixed sweep: dual sweep-speed display in which main sweep drives first portion of display, and delayed sweep completes the display at sweep speeds up to 100 times faster; changeover point determined approx by delay setting.

Triggering: same as for delayed sweep.

Magnifier: X10, any display; overall accuracy ±5%; expands 0.2 μs/cm speed to 20 ns/cm.

Single sweep: any display can be operated in single sweep.

Horizontal input

Bandwidth: dc to typically better than 500 kHz.

Deflection factor: vernier and X10 magnifier permit continuous adjustment from approx 0.3 V/cm to 30 V/cm.

Input RC: 1 megohm shunted by less than 20 pF.

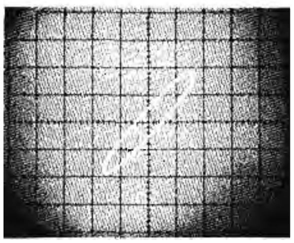
Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: HP Model 1421A, $625.

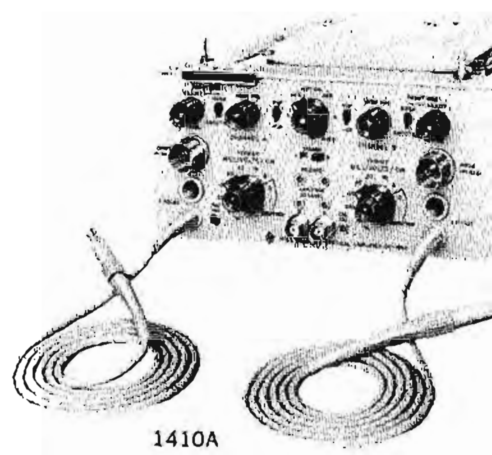
1 GHz sampling
Sampling vertical amplifier Model 1410A

The versatile 1410A Sampling Vertical Amplifier provides 1 mV/cm deflection factor at 1 GHz. Optimum compromise among risetime, overshoot, and noise can be easily and quickly made with the front-panel risetime and smoothing controls.

Front-panel recorder outputs with both dc level and amplitude adjustments simplify your X-Y or strip chart recorder setup and enable permanent recording of crt traces.



The A vs B mode of the 1410A permits X-Y measurements to 1 GHz and above.



1410A

Specifications

Mode of operation

1. channel A only.
2. channel B only.
3. channel A and channel B.
4. channel A and channel B added algebraically.
5. channel A vs channel B.

Polarity: either channel may be displayed either positive or negative up in any mode.

Risetime: less than 350 ps.

Bandwidth: dc to 1 GHz.

Overshoot: less than 5%.

Deflection factor: calibrated ranges from 1 mV/cm to 200 mV/cm in a 1, 2, 5 sequence; vernier control provides continuous adjustment between ranges and extends deflection factor to less than 0.4 mV/cm.

Attenuator accuracy: ±3%.

Isolation between channels: greater than 40 dB to 1 GHz.

Input impedance

Probes: 100 K ohms shunted by 2 pF nominal.

GR type 874 inputs: 50 ohms ±2% with 57 ns internal delay lines for viewing leading edge of fast rise signals. Reflection from input connector is approx 10%, using a 150 ps TDR system.

Noise: approximately 1 mV observed noise on crt excluding 10% of random dots; noise decreases on automatically smoothed ranges and 2 and 1 mV/cm; smoothed position of smoothing switch reduces noise and jitter approximately 4:1; vernier control provides continuous adjustment between the normal and smoothed modes.

Dynamic range: ±2 volts.

Drift: less than 3 mV/hr after warmup.

Maximum safe input

Probes: ±50 volts.

50Ω inputs: ±5 volts.

Triggering: internal or external when using 50Ω inputs; internal triggering selectable from channels A or B; external triggering necessary when using probes.

Time difference between channels (for probes or 50Ω inputs): less than 100 ps.

Recorder outputs: front panel outputs provide 0.1 V/cm from a 500Ω source; gain adjustable from approximately 0.05 V/cm to 0.2 V/cm; dc level adjustable from approx −1.5 V to +0.5 V.

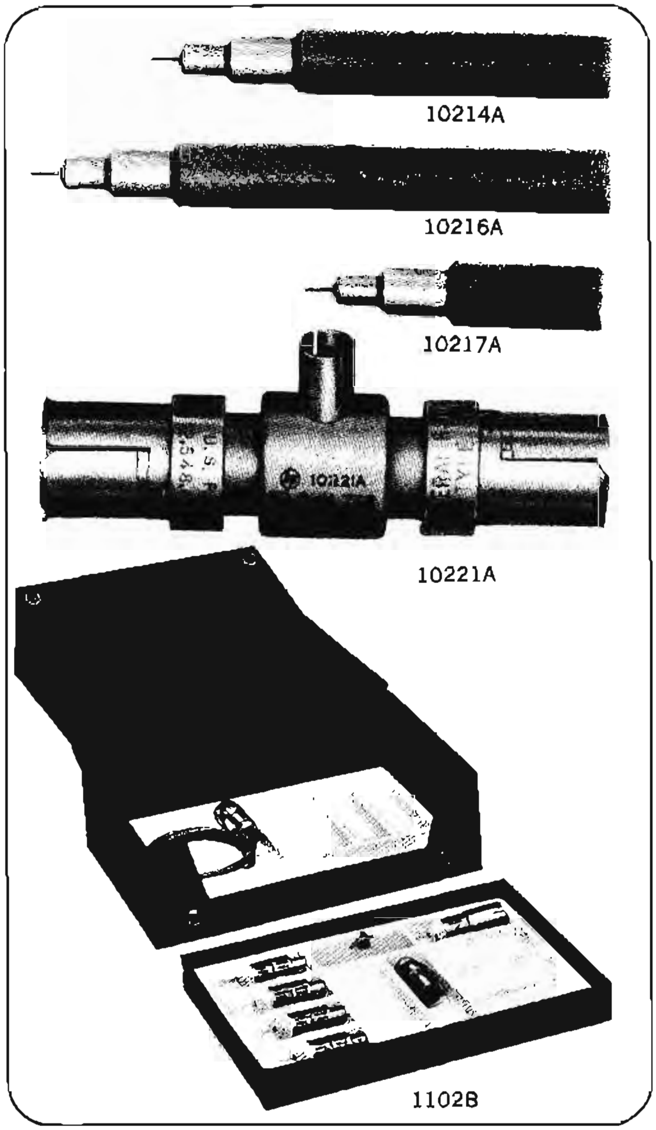
Accessories provided

HP Model	Quantity	Description
10214A	2	10:1 divider
10216A	2	Isolator
10217A	2	0.001 μF blocking capacitor
10218A	2	BNC adapter
10219A	1	GR adapter
10220A	2	Microdot adapter
10221A	1	50-ohm T-connector
10213-62102	6	Ground clip
5020-0457	6	Probe tip
—	1	Accessory box

Weight: net 10 lbs (4,5 kg); shipping 15 lbs (6,8 kg).

Price: HP Model 1410A, $1600.

Accessories for 1 GHz Sampling
Sampling Accessories for 1410A



Specifications

1410A ACCESSORIES (Separately Available)

10214A 10:1 divider: permits accurate measurement of signals as large as 20 volts peak-to-peak and increases the impedance of the probe to 1 megohm shunted by 2.5 pF. **Price,** $30.

10216A isolator: increases convenience and accuracy when probing by reducing base line shift and transient response changes caused by changes in the circuit source impedance. 1410A rise time is increased to approximately 0.6 nsec and probe input capacitance is increased by less than 3 pF. **Price,** $25.

10217A blocking capacitor: this blocking capacitor (0.001 μF) permits measurements of signals that are ±50 volts from ground (to ±200 V when used with 10214A 10:1 Divider). The blocking capacitor contributes only 1% sag when used with the 10:1 divider. No more than 2.5 pF shunt capacitance is added to the input by the blocking capacitor. **Price,** $20.

10218A BNC adapter: converts probe tip into a male BNC connector. **Price,** $6.

10219A GR adapter: converts probe tip into a GR type 874 connector. **Price,** $15.

10220A microdot screw-on adapter and 10223A microdot slide-on adapter: allows easy connection to coaxial connectors and also provides a solid ground reference. 10220A adapts to connectors similar to Microdot series 31-50. 10223A adapts to connectors similar to Microdot series SOS-50. **Price:** 10222A, $4; 10223A, $5.

10221A 50-ohm T connector: permits monitoring of signals in 50 ohm transmission lines with the 1410A without terminating the line or disturbing the signal. Mismatch is low; the reflection from a step input is no greater than 20% of the input step height. **Price,** $40.

ADDITIONAL ACCESSORIES
(Not supplied with 1410A)

10203A 100:1 divider: this 100:1 divider may be used to reduce levels as high as 200 V to the ±2 V dynamic range of the 1410A. The 10203A offers less than 1 pF shunt capacity and 10 megohms shunt resistance to the circuit under test. (The K01-10203A Divider Adapter must be used to adapt the 10203A to the 1410A probe). **Price,** $60.

K01-10230A divider adapter: adapts the 10203A 100:1 divider to the 1410A probe. **Price,** $30.

1102B ACCESSORY KIT
The Model 1102B Accessory Kit permits convenient circuit probing and reduced circuit loading with oscilloscopes that have 50-ohm input impedances. Thus it allows probing with the 1410A where the 50 ohm inputs are used in order to get internal triggering. The kit is also ideal for the 1432A where a high input impedance is needed to prevent loading of the test circuit. Kit includes following:

10201A to D resistive divider probes and 10122A cable: the dividers should always be terminated with 50 ohms to provide the correct voltage division. They should not be attached directly to the 1410A probe.

Model	Input Resistance (ohms)*	Division Ratio	Division Ratio with 10205A Sync Take-off	Max Input (V rms)†	μs for 1% Sag with 10209A
10201A	250	5:1	10:1	10	0.25
10201B	500	10:1	20:1	15	0.5
10201C	2500	50:1	100:1	35	2.5
10201D	5000	100:1	200:1	50	5.0

Input capacitance: 0:4 pF.

Price, as sold separately, $40.00 each.

10208A blocking capacitor: this blocking capacitor (0.001 μf) permits measurements of signals that are ±600 volts from ground. No more than 0.5 pF shunt capacitance is added to the input by the blocking capacitor. **Price,** as sold separately, $5.

10209A blocking capacitor: this blocking capacitor (0.1 μF) may be used to observe relatively long pulses or signals ±200 volts from ground. Signals which have rise times slower than 1 nsec may be displayed without distortion. No more than 3.5 pF shunt capacitance is added to the input. **Price,** as sold separately, $35.

The kit also includes: 1 ea HP Model 10122A, Cable. Coaxial, Type N to BNC Female; 1 ea GR Type 874, Type N Female to GR Adapter; 2 ea HP Part Number 5060-0415, Ground Clip; and 1 ea Accessory Box.

Weight: net, 3 lbs (1,4 kg); shipping: 4 lbs (1,8 kg).

Price: Model 1102B Accessory Kit, $160.

*When terminated in 50 ohms.
†Limited by the power dissipation of the resistive element.

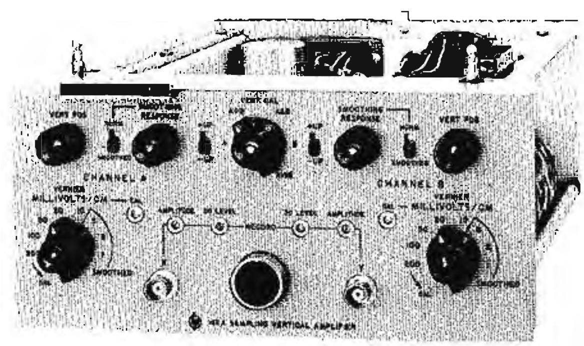
Bandwidth to 12.4 GHz at 1 mV/cm
Amplifier and sampler Models 1411A, 1432A

1411A Sampling Amplifier, 12.4 GHz

The 1411A Sampling Vertical Amplifier is a basic vertical plug-in that accepts a series of wide band samplers. All three samplers have 1 mV/cm deflection factor. Feedthrough inputs are also featured, for monitoring signals without terminating them and for precise Time Domain Reflectometry measurements.

The remote samplers, connected to the oscilloscope by a five-foot cable, can be placed right at the signal source, eliminating lossy lines.

Risetime is set with a front panel knob, allowing convenient adjustment of risetime and bandwidth to the ultimate when needed, at the sacrifice of increased noise. Front panel recorder outputs and an X-Y mode for wideband phase measurements add to the 1411A's measurement capability.



1411A

Specifications, 1411A
(When used with 1430A, 1431A, or 1432A)

Mode of operation
1. channel A only.
2. channel B only.
3. channel A and channel B.
4. channel A and channel B added algebraically.
5. channel A vs channel B.

Polarity: either channel may be displayed either positive or negative up in any mode.

Deflection factor: calibrated ranges from 1 mV/cm to 200 mV/cm in a 1, 2, 5 sequence; vernier control provides continuous adjustment between ranges and extends deflection factor to less than 0.4 mV/cm.

Attenuator accuracy: ±3%.

Isolation between channels: greater than 40 dB over bandwidth of sampler.

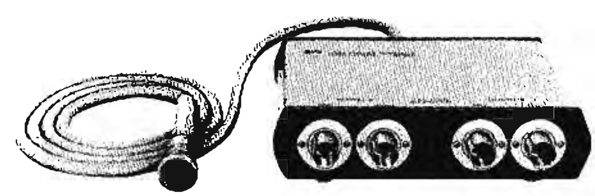
Recorder outputs: front panel outputs provide 0.1 V/cm from a 500 ohm source; gain adjustable from approximately 0.05 V/cm to 0.2 V/cm; dc level adjustable from approximately −1.5 V to +0.5 V.

Weight: net 10 lbs (4,5 kg); shipping 15 lbs (6,8 kg)

Price: HP Model 1411A, $700.

1432A Sampler, 90 ps

The 1432A is a lower-priced version of the 1430A and 1431A. Its 90 ps risetime (dc to 4 GHz bandwidth), 1 mV/cm deflection factor and feedthrough inputs permit many accurate measurements involving CW, fast pulses, and TDR.



1432A

Specifications, 1432A
(When used with 1411A)

Risetime: less than 90 ps.

Bandwidth: dc to 4 GHz.

Overshoot: less than ±5%.

Noise: same as 1340A, except approx 3 mV observed noise.

Dynamic range: ±1 volt.

Low frequency distortion: less than ±3%.

Maximum safe input: ±5 volts.

Input characteristics

Mechanical: GR type 874 connectors used on input and output.

Electrical: 50 ohm feedthrough, dc coupled; reflection from sampler is approximately 15% using a 90 ps TDR system; pulses emitted from sampler input are approx 50 mV in amplitude and 10 ns wide.

Time difference between channels: less than 25 ps.

Connecting cable length: 5 ft (for longer cable, see special order below).

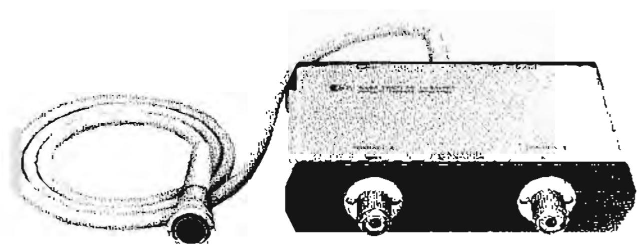
Weight: net 4 lbs (1,8 kg); shipping 9 lbs (4,1 kg).

Accessories provided: two GR Model 874-W50 50 ohm loads.

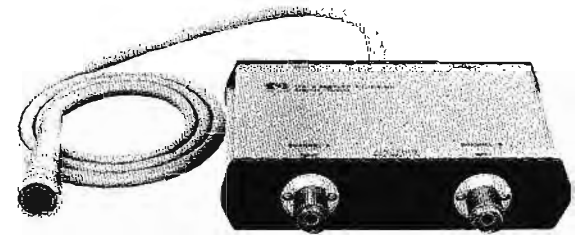
Price: HP Model 1432A, $1000.

Special order: 10-ft connecting cable (5-ft is standard), order C01-1432A. Price, $1035.

Sampler with 28 psec risetime
12.4 GHz samplers Models 1430A, 1431A



1430A



1431A

Model 1430A provides 28 ps risetime with minimal overshoot for accurate measurements on fast-rise pulses. Used with the 1105A/1106A 20 ps pulse generator, its response and feedthrough inputs make it ideal for TDR measurements.

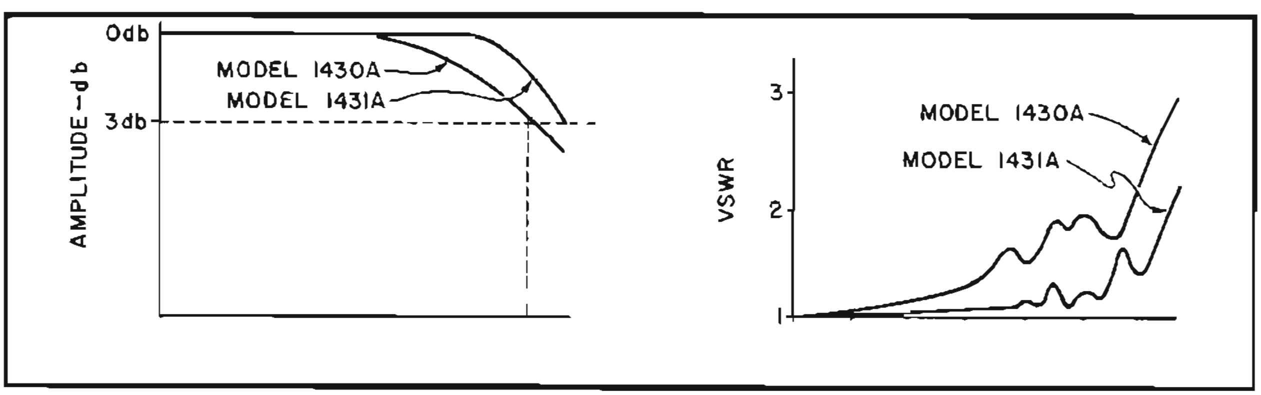
Specifications, 1430A
(When used with 1411A)

Risetime: approx. 28 ps (less than 35 ps observed with 1105A/1106A pulser and 909A 50-ohm load).
Bandwidth: dc to approx 12.4 GHz.
Overshoot: Less than ±5%.
Noise: approximately 8 mV observed noise on crt excluding 10% of random dots. Noise decreases on automatically smoothed ranges 5, 2, and 1 mV/cm. Smoothed position of smoothing switch reduces noise and jitter approximately 4:1. Vernier control provides continuous adjustment between the normal and smoothed modes.
Dynamic range: ±1 volt.
Low frequency distortion: less than ±3%.
Maximum safe input: ±3 volts.
Input characteristics
Mechanical: Amphenol APC-7 precision 7 mm connectors on input and output.
Electrical: 50 ohm feedthrough, dc coupled. Reflection from sampler is approx 10%, using a 40 ps TDR system. Pulses emitted from sampler input are approximately 10 mV in amplitude and 5 ns in duration. Vswr less than 3:1 at 12.4 GHz.
Time difference between channels: less than 5 ps.
Connecting cable length: 5 ft.
Weight: net 4 lbs (1,8 kg); shipping 9 lbs (4,1 kg).
Accessories provided: two Amphenol APC-7 to female Type N adapters (HP 11524A); two 50-ohm loads (HP 909A).
Price: HP Model 1430A, $3000.
Special order: 10-ft connecting cable (5-ft is standard), order C01-1430A. Price, $3035.

The 1431A allows viewing of CW signals from dc to beyond 12.4 GHz at 1 mV/cm deflection factor. It differs slightly from the 1430A, having a very flat bandwidth and low vswr at the sacrifice of increased overshoot.

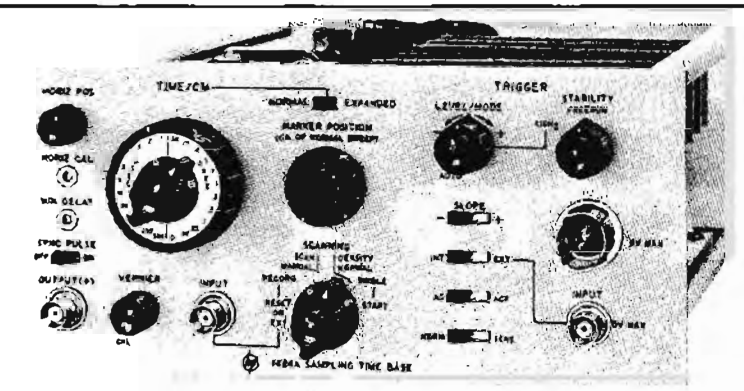
Specifications, 1431A
(When used with 1411A)

Bandwidth: dc to greater than 12.4 GHz (less than 3 dB down from a 10 cm dc reference).
Risetime: approx 28 ps.
Vswr: dc to 8 GHz, 1.4:1
8 to 10 GHz, 1.6:1
10 to 12.4 GHz, 2.0:1
Noise: same as 1430A.
Dynamic range: ±1 volt.
Low frequency distortion: less than ±3%.
Maximum safe input: ±3 volts.
Input characteristics
Mechanical: Amphenol APC-7 precision 7 mm connector used on input and output.
Electrical: 50-ohm feedthrough, dc coupled. Reflection from sampler is approx 5%, using a 40 ps TDR system. Pulses emitted from sampler input are approx 10 mV in amplitude and 5 ns in duration.
Phase shift between channels: less than 10° at 5 GHz, typically less than 2° at 1 GHz.
Connecting cable length: 5 ft.
Weight: net 4 lbs (1,8 kg); shipping 9 lbs (4,1 kg).
Accessories provided: two Amphenol APC-7 to female Type N adapters (HP 11524A); two 50-ohm loads (HP 909A).
Price: HP Model 1431A, $3000.
Special order: 10-ft connecting cable (5-ft is standard), order C01-1431A. **Price,** $3035.



Solid triggering to 5 GHz

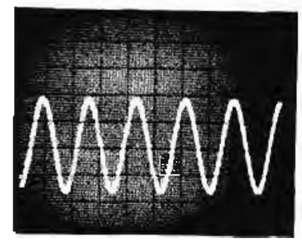
Sampling time base Model 1424A



1424A

Model 1424A is an easy-to-operate time base for use with the 1410A and 1411A plug-ins. Convenient and more meaningful measurements are made possible through features such as: direct sweep readout, calibrated marker position control (which positions an intensified marker), and automatic triggering (which locks in on a wide range of signals). A single scan feature helps provide clearer photos and stored traces of drifting or changing signals.

Solid triggering to 5 GHz without external count down box.



Specifications, 1424A

Sweep range: 24 ranges, 10 ps/cm to 500 μs/cm in a 1, 2, 5 sequence. Sweeps from 1 ns/cm to 500 μs/cm may be expanded up to 100 times and read out directly. Sweeps from 10 ps/cm to 500 ps/cm are obtained by expansion and also read out directly. Accuracy ±3% except for time represented by approx first ¼ cm of unexpanded sweep. Vernier provides continuous adjustment between ranges and increases max sweep speed to faster than 4 ps/cm.

Marker position: intensified marker indicates point about which sweep is expanded; 10-turn calibrated control. Accuracy, ±1.5 mm.

Minimum delay: less than 55 ns.

Triggering (less than 1 GHz)

Internal (with Model 1410A)

Automatic: baseline displayed in the absence of an input signal.

Pulses: at least 50 mV amplitude required of pulses 2 ns or wider for jitter less than 30 ps.

Sine waves: signals from 200 Hz to 150 MHz require 25 mV amplitude for jitter less than 10% of input signal period (usable to 1 GHz with increased jitter).

Level select

Pulses: at least 50 mV amplitude required for pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals require from 200 Hz to 150 MHz 25 mV amplitude (increasing to 400 mV at 1 GHz) for jitter less than 1.5% of input signal period +10 ps.

External

Automatic: baseline displayed in the absence of an input signal.

Pulses: at least 100 mV amplitude required of fast rise pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals from 200 Hz to 500 MHz require 50 mV for jitter less than 10% of input signal period (usable to 1 GHz with increased jitter).

Level select

Pulses: at least 50 mV amplitude required of fast rise pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals from 200 Hz to 1 GHz require 50 mV for jitter less than 1.5% of input signal period +10 ps; jitter is less than 50 ps for signals of 10 mV at 1 GHz.

Dynamic range: 100 mV in sensitive; 1.0 V in normal.

Trigger input: 50-ohm, ac, or ac fast; signal output, <10 mV in sensitive and <5 mV in normal.

Maximum safe input: sensitive, 5 V rms or peak transient; normal, 5 V rms (50 V peak transient); internal, 5 V rms or peak transient.

Jitter (with 500 mV pulses having 1 ns or faster risetimes): less than 10 ps plus 0.2% of unexpanded sweep time per cm.

Slope: positive or negative.

Sensitivity: jitter specifications above are for sensitive mode; normal mode reduces sensitivity by approx. 10:1.

Triggering (greater than 1 GHz): jitter is less than 30 ps for 25 mV input from 1 GHz to 4 GHz, and for 50 mV input from 4 to 5 GHz.

Scanning

Internal: X axis driven from internal source; scan density continuously variable.

Manual: X axis driven by manual scan control knob.

Record: X axis driven by internal slow ramp; approx 60 seconds for one scan.

External: 0 to +15 V required for scan; input impedance, 10 k ohms.

Single scan: one scan per actuation; scan density continuously variable.

Sync pulse output

Amplitude: greater than 1.5 V into 50 ohm

Risetime: approx 1 ns.

Overshoot: less than 5%.

Width: approx 1 μs.

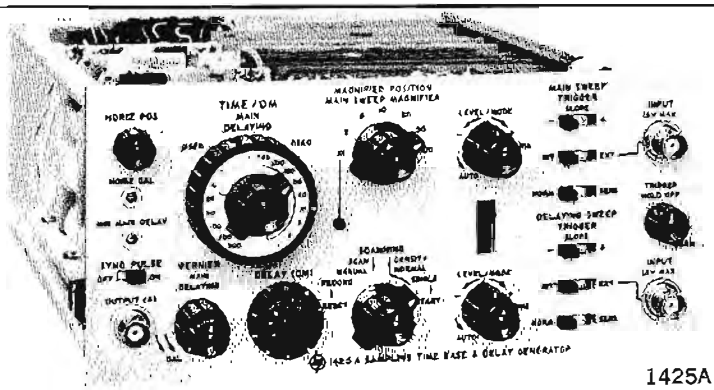
Relative jitter: less than 10 ps.

Repetition rate: one pulse per sample.

Weight: net 5 lbs (2,3 kg); shipping 9 lbs (4,1 kg)

Price: HP Model 1424A, $1325.

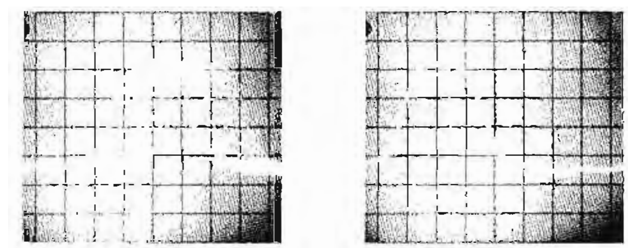
Triggering to 1 GHz with delayed sweep
Sampling time base Model 1425A



1425A

Model 1425A's delayed sweep feature allows detailed examination (magnification as great as 10,000:1) of any portion of complex signals and pulse trains for the first time in the GHz region. And accurate time jitter measurements in the input waveform can be measured when in the automatic triggering mode. This same automatic triggering mode provides a baseline in the absence of an input signal aiding in getting a trace displayed sooner.

When you want to set up a magnified trace, an intensified marker dot locates the expansion point for you. You also get pushbutton return to X1 magnification for fast reference or relocation of the expansion point.



Jitter on delayed pulse in left photo eliminated at right by retriggering the delayed sweep. Sweep speed, 1 ns/cm; delay, 5 μs.

Specifications, 1425A

Main Sweep

Range: 1 ns/cm to 10 μs/cm, 13 ranges in a 1, 2, 5 sequence; accuracy ±3%, except for time represented by approx first ¼ cm of unexpanded sweep. Vernier provides continuous adjustment between steps and extends max magnified speed to at least 4 ps/cm.

Magnifier: X1 to X100 in 7 calibrated steps; increases 1 ns/cm sweep to 10 ps/cm; pushbutton returns magnifier to X1.

Marker position: intensified marker indicates point about which sweep is expanded; 10-turn control.

Minimum delay: main sweep, less than 55 ns; main delayed sweep, less than 105 ns.

Triggering (for both main and delaying sweeps)

Internal (with Model 1410A)

Automatic: baseline displayed in the absence of an input signal.

Pulses: at least 75 mV amplitude required of pulses 2 ns or wider for jitter less than 30 ps.

Sine waves: signals from 200 Hz to 150 MHz require 50 mV amplitude for jitter less than 10% of input signal period (usable to 1 GHz with increased jitter).

Level select

Pulses: at least 100 mV amplitude required for fast rise pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals from 200 Hz to 150 MHz require 50 mV amplitude (increasing to 400 mV at 1 GHz) for jitter less than than 1.5% of input signal period +10 ps.

External

Automatic: baseline displayed in the absence of an input signal.

Pulses: at least 100 mV amplitude required of fast-rise pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals from 200 Hz to 500 MHz require 50 mV amplitude for jitter less than 10% of input signal period (usable to 1 GHz with increased jitter).

Level select

Pulses: at least 50 mV amplitude required for fast-rise pulses 2 ns or wider for jitter less than 20 ps.

Sine waves: signals from 200 Hz to 1 GHz require 50 mV for jitter less than 1.5% of input signal period +10 ps; jitter is less than 50 ps for signals of 10 mV amplitude at 1 GHz.

Dynamic range: 100 mV in sensitive, 1.0 V in normal.

Trigger input: 50 ohms, ac-coupled (2.2 μF); signal output, <10 mV in sensitive and <5 mV in normal.

Maximum safe input: sensitive, 5 V rms or peak transient; normal, 5 V rms (50 V peak transient); internal, 5 V rms or peak transient.

Jitter (with 500 mV pulses having 1 ns or faster risetimes): less than 10 ps on 1 ns/cm range and less than 20 ps (or 0.2% of unexpanded sweep time per cm, whichever is larger) at 2 ns/cm and slower.

Slope: positive or negative.

Sensitivity: jitter specifications above are for sensitive mode; normal mode reduces sensitivity by approx. 10:1.

Delaying sweep

Range: 10 ns/cm to 500 μs/cm, 15 ranges in a 1, 2, 5 sequence; accuracy ±3%, except for slight nonlinearity at start of sweep, ±5%, on 200 μs/cm and 500 μs/cm ranges; vernier provides continuous adjustment between steps and increases 10 ns/cm step to at least 4 ns/cm.

Delay time: continuously variable from 50 ns to 5 ms.

Accuracy: ±3%; linearity 0.5%; jitter time is less than 1 part in 20,000 or 20 ps, whichever is greater.

Sweep functions: main, delaying, and main delayed.

Scanning: same as 1424A except no external scan input.

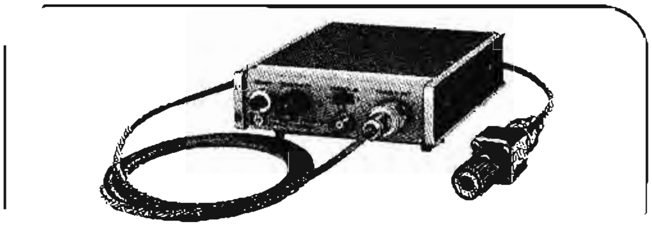
Sync pulse output: same as 1424A. Pulse always synchronized to main sweep trigger circuit; pulse delay and rate are variable.

Weight: net 7 lbs (3,2 kg); shipping 11 lbs (5 kg).

Price: HP Model 1425A, $1800.

Sampling accessories

1105A/1106A 20 ps pulse generator



Specifications, 1105A/1106A

Output

Rise time: approximately 20 ps. Less than 35 ps observed with HP Model 1411A/1430A 28 ps Sampler and HP Model 909A 50 ohm termination.

Overshoot: less than ±5% as observed on 1411A/1430A with 909A.

Droop: less than 3% in first 100 ns.

Width: approximately 3 μs.

Amplitude: greater than +200 mV into 50 ohms.

Output characteristics (1106A):

Mechanical: Amphenol APC-7 connector.

Electrical: dc resistance —50 ohm ±2%. Source reflection—less than 10%, using a 40 ps TDR system. DC offset voltage —approximately 0.1 V.

Triggering

Amplitude: at least ±0.5 V peak required.

Rise time: less than 20 ns required. Jitter less than 15 ps when triggered by 1 ns rise time sync pulse from 1424A or 1425A Sampling Time Base.

Width: greater than 2 ns.

Maximum safe input: 10 volts.

Input impedance: 200 ohms, ac coupled through 20 pF.

Repetition rate: 0 to 100 kHz; free runs at 100 kHz.

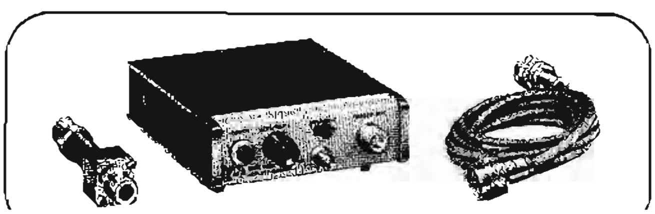
Accessories provided (with Model 1105A): one 6-ft 50 ohm cable with Type N connectors, HP Model No. 10132A.

Weight

1105A: net 3 lbs (1,4 kg); shipping 8 lbs (3,6 kg).
1106A: net 1 lb (0,5 kg); shipping 3 lbs (1,4 kg).

Price: HP Model 1105A, $200. HP Model 1106A, $550.

1105A/1108A 60 ps pulse generator



Specifications, 1105A/1108A

Same as 1105A/1106A except as follows:

Output

Risetime: less than 60 ps.

Overshoot: less than ±5%.

Output characteristics (1108A)

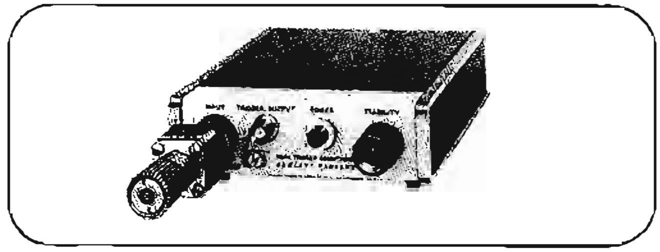
Mechanical: GR-874 connector.

Weight

Model 1108A: net, 1 lb (0,5 kg); shipping, 3 lbs (1,4 kg)

Price: HP Model 1108A, $175

1104A/1106A 18 GHz trigger countdown



Specifications, 1104A/1106A

Input

Frequency range: 1 GHz to 18 GHz.

Sensitivity: signals 100 mV or larger, and up to 12.4 GHz, produce less than 20 ps of jitter (200 mV required to 18 GHz).

Maximum safe input: ±1 V.

Input impedance (1106A): 50-ohm Amphenol APC-7 input connector. Reflection from input connector is less than 10%, using a 40 ps TDR system.

Signal appearing at input connector: approximately 250 mV.

Output

Center frequency: approximately 100 MHz.

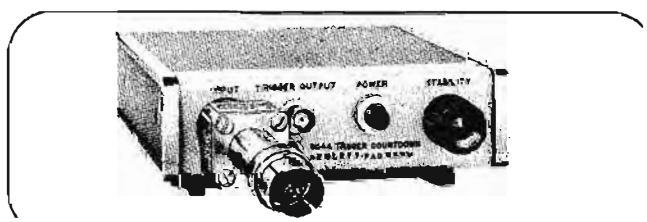
Amplitude: typically 150 mV.

Weight

1104A: net 2 lbs (0,9 kg); shipping 4 lbs (1,8 kg).
1106A: net 1 lb (0,5 kg); shipping 3 lbs (1,4 kg).

Price: HP Model 1104A, $200. HP Model 1106A, $550.

1104A/1108A 10 GHz trigger countdown



Specifications, 1104A/1108A

Same as 1104A/1106A except as follows:

Input

Frequency range: 1 GHz to 10 GHz.

Sensitivity: signals up to 50 mV or larger, and up to 10 GHz, produce less than 20 ps of jitter.

Input impedance: 50-ohm GR-874 input connector.

Weight

Model 1108A: net, 1 lb (0,5 kg); shipping, 3 lbs (1,4 kg).

Price: HP Model 1108A, $175.

Other sampling accessories

50-ohm loads: Models 908A and 909A. See index.

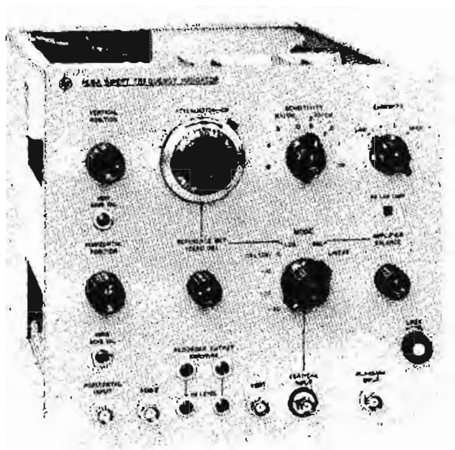
Sync probe: Model 10200B; for trigger input. Price, $51.

50-ohm adapter: Model 11524A; has type N female and APC-7 connectors. Price, $55.

Air line extensions: Model 11566A; 10 cm, APC-7 connector. Model 11567A; 20 cm, APC-7 connector. Price, $100 each.

High pass filters: Models 1109A and 1129A reduce trigger "kick out." Model 1109A has APC-7 connector; Model 1129A has GR-874 connector. Price, HP Model 1109A, $250; HP Model 1129A, $150.

Make microwave swept frequency measurements
Swept frequency indicator Model 1416A



1416A

Model 1416A Swept Frequency Indicator transforms Model 140-series into an X-Y oscilloscope which speeds and simplifies microwave swept frequency measurements. Insertion loss vs frequency measurements on attenuators, filters, ferrite isolators, and return loss measurements on all types of loads can be made with ease and accuracy.

Model 1416A incorporates a number of features which provide convenience and accuracy not available with the usually used conventional X-Y scope. Readouts directly in dB are provided by Model 1416A's logarithmic amplifier. The attenuation-dB control allows a calibrated dB offset to be applied to an offscreen trace, providing high resolution readings when trace returns to reference. A linear mode of operation is also provided. A chopper stabilized input amplifier minimizes drift, and a front-panel adjustable bandwidth switch allows the operator to select a bandwidth just wide enough to present the signal with a minimum amount of noise. An internal dB calibrator, accurate to 3%, allows a quick check of amplifier accuracy. Also provided on the front panel are outputs for driving an X-Y recorder. Thus, you can now achieve speed, convenience, and accuracy with all types of swept frequency measurements by using the Model 140-series/1416A combination and appropriate auxiliary equipment. Sweep oscillators and associated instruments are available for testing both coaxial and waveguide microwave components from 1 to 40 GHz. Such items as adapters, impedance transformers, tuners, loads, filters, detectors, couplers, and attenuators can be measured or adjusted. Swept frequency techniques are also useful for overall system analysis.

Swept frequency techniques are not only helpful design aids, but can be used as maintenance tools as well. They provide fast routine maintenance checks on laboratory instruments. Hours and sometimes days of tedious precise measurements can often be completed within minutes.

Specifications, 1416A

Mode of operation: linear or logarithmic.

Bandwidth

Linear: variable from approx. 1 kHz to 30 kHz in four steps.

Logarithmic: varies with input level.

Deflection factor (sensitivity):

Linear: 50 μV/cm to 10 mV/cm, 8 ranges in a 1, 2, 5 sequence; accuracy ±3%.

Logarithmic: 0.5 dB/cm to 10 dB/cm (referred to RF input into crystal detector) in 5 ranges; accuracy (after 30-min warmup), ±0.02 dB/dB (0 to −25 dB) and ±0.03 dB/dB (−25 to −30 dB).

Noise: typical observed values on crt:

Mode	Noise at low bandwidth	Noise at high bandwidth
Linear	40 μV pk-pk	200 μV pk-pk
Logarithmic: input signal level		
0 dB	0.05 dB	0.1 dB
−10 dB	0.05 dB	0.2 dB
−20 dB	0.3 dB	0.4 dB
−25 dB	1 dB	1 dB
−30 dB	4 dB	4 dB

Linear: less than 120 mV; Model 1416A deflection factor set to 0.05 mV/cm and input shorted.

Logarithmic: less than 50 mV/cm; Model 1416A deflection factor set to 5 dB/cm and input signal of −30 μV (−30 dB).

Internal calibrator: four positions: 0, 10, 20, and 30 dB below approx. 50 mV; accuracy ±0.01 dB/dB.

Sweep and blanking: supplied by Model 690 Series Sweep Oscillator.

Recorder outputs:

Vertical: gain adjustable from 0 to approx. 200 mV/cm; dc level adjustable over approx. ±1.5 volts.

Horizontal: gain adjustable from 0 to approx. 100 mV/cm; dc level adjustable over approx. ±1 volt.

Inputs

Vertical: input impedance, 75 k ohms; dynamic range: logarithmic, −50 μV to −100mV; linear 0 to −100 mV; BNC connector receives output from Models 423A or 424A Crystal Detectors, or Models 786D or 787D Directional Detectors (all Option 02).

Horizontal: ramp required: amplitude between 7.5 and 20 volts; some part of ramp must be at 0 volts.

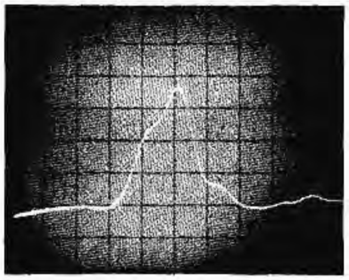
Blanking: 0 to −5 V gate (supplied by Model 690 Series Sweep Oscillator; early models require slight modification).

Power: supplied by oscilloscope.

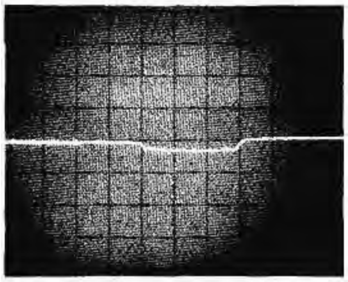
Weight: net 7 lbs (3,2 kg); shipping 14 lbs (6,3 kg).

Price: HP Model 1416A, $675.

Complete cable testing system
Time domain reflectometer Model 1415A



Magnified display of a BNC connector joining two 50-ohm cables. The horizontal axis is set at 2 cm/cm. Multiplying the 3.5 cm deflection by the reflection coefficient sensitivity of 0.01/cm, one can determine the connector has a ρ of 0.035.



TDR display of a section of unknown cable spliced into a length of 50-ohm cable. Noting the distance setting of 40 cm/cm, and reflection coefficient sensitivity of 0.2/cm, one can determine the unknown cable is 120 cm long and has a Z_0 of 44 ohms.

1415A

The Model 1415A Time Domain Reflectometer in a 140 system Oscilloscope represents a completely integrated broadband system for testing cables, transmission lines, strip lines, connectors, and other types of high frequency devices.

You can quickly determine the magnitude and nature of each resistive or reactive discontinuity in coaxial components such as attenuators, cables, connectors and delay lines used in microwave and pulse circuit design. Or you can locate and identify cable faults such as shorts, opens, loose connectors, defective tap offs, splices, and mismatches in signal transmission cables. Whatever your application the 1415A can save you time and money by minimizing guesswork and indecision.

Model H08-1415A is a 3000-foot version of Model 1415A, with the horizontal scale calibrated in ft/div and vertical scale calibrated in % reflection. H08-1415A specifications follow 1415A specifications below.

Also available is a complete 75-ohm, factory-calibrated TDR system, E75-140A. This system includes: H08-1415A Time Domain Reflectometer plug-in; a standard Model 140A Oscilloscope with P7 phosphor CRT; a Model 10458A 50-ohm to 75-ohm adapter (includes operating instructions and 75-ohm impedance overlays for CRT); Application Note 67 on cable testing (contains TDR slide rule for quick conversion to different dielectrics). Price of E75-140A is $1900.

Specifications, 1415A

System (in reflectometer configuration)
- **Risetime:** less than 150 ps.
- **Overshoot:** 5% or less overshoot and ringing (½% in 2 ns).
- **Internal reflections:** less than 10% (does not limit resolution).
- **Reflectometer sensitivity:** reflection coefficients as small as 0.001 can be observed.
- **Rep. rate:** 150 kc nominal.

Signal channel
- **Risetime:** approximately 110 ps.
- **Reflection coefficient:** 0.5/cm to 0.005/cm in 1, 2, 5 sequence.
- **Input:** 50 ohms, feedthrough type.
- **Noise and internal pickup, peak:** less than 0.2 cm on 0.005/cm range, with step disconnected and input terminated in 50 ohms.
- **Dynamic range:** ±0.5 volt.
- **External signal level:** up to 1 V p-p may be safely applied to the signal out connector.
- **Attenuator accuracy:** ±3%.

Step generator
- **Amplitude:** approx. 0.25 V into 50 ohms (0.5 V open circuit).
- **Risetime:** approximately 50 ps.
- **Output impedance:** 50 ohms ±1 ohm.
- **Droop:** less than 1%.

Distance/time scale
- **Distance scale (cm line/cm display) accuracy:** 5%.
- **Polyethylene line (ϵ=2.25):** 200 to 2000 cm/cm.
- **Air line (ϵ=1):** 300 to 3000 cm/cm (0.19 mi.).
- **Time scale:** 20 to 200 ns/cm, ±5% accuracy.
- **Magnification:** X1 to X200 in 1, 2, 5 sequence; accuracy of basic sweep maintained at all magnifier settings with exception of time represented by first 0.1 cm of unmagnified step.
- **Delay control:** 0 to 10 cm of unmagnified sweep, calibrated.
- **Jitter:** less than 20 ps.

Power: supplied by oscilloscope.

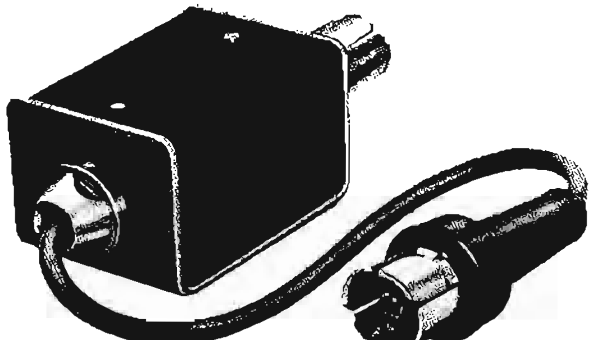
Weight: net 7 lbs (3,2 kg); shipping 11 lbs (5 kg).

Acessories furnished: 2 GR elbows (HP Part No. 1250-0239), 1 GR to Type N adapter (1250-0240), and 1 Type N to BNC adapter (1250-0067).

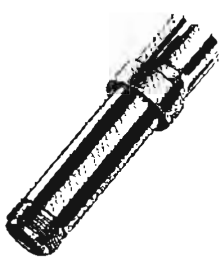
Price: HP Model 1415A, $1050.

Option 14: long-line TDR for cables up to 1500 meters (0.62 mile); P7 phosphor recommended for CRT, no extra charge; specifications same as for 1415A except as follows:
- **System risetime:** less than 200 ps.
- **Rep rate:** 30 kHz, nominal.
- **Noise and internal pickup:** 0.25% of step.
- **Droop:** 2%.
- **Time scale:** 20 ns/cm to 1 μs/cm.
- **Air line:** 300 cm/cm to 150 m/cm.
- **Polyethylene:** 200 cm/cm to 100 m/cm.
- **Price:** HP Model 1415A Option 14, $1150.

H08-1415A: calibrated to read distance in feet of polyethylene or polyfoam dielectric cables; vertical scale calibrated in % reflection. H08-1415A same as Option 14 except as follows:
- **Reflection coefficient:** 50, 20, 10, 5, 2, 1, and 0.5%/div.
- **Distance scale:** maximum range 3000 ft in 300, 100, 50, 20, and 10 ft/div for polyfoam and polyethylene dielectric cables.
- **Time scale:** 900, 300, 150, 60, and 30 ns/div.
- **Price:** HP Model H08-1415A, $1280.



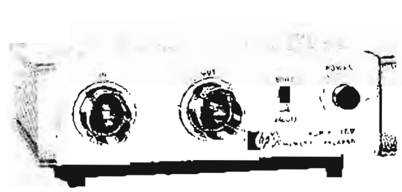
10452A



10457A

10458A

874A



K60-1415A

Models 10452A-10456A

Model 10452A through 10456A Rise Time Converters slow down the step from the 1415A in order to eliminate reflections caused by frequencies beyond the bandwidth of interest.

Specifications

Rise times: (10-90% points as measured in 150 ps rise time system.)
10452A: 0.5 ns. 10453A: 1 ns. 10454A: 2 ns. 10455A: 5 ns. 10456A: 10 ns.

Rise time accuracy: better than ±5%.

Overshoot: less than ±3%.

Output impedance (dc): 50 ohms (accuracy determined by output impedance of generator).

Output mismatch: less than ±5% reflection to output rise time.

Allowable input voltage: up to 50 volts, open circuit (from a 50-ohm source).

Connectors: GR Type 874.

Price: $75 each.

Models 10457A-10458A

Adapters convert 1415A 50 ohm output to 75 ohm systems.
Model 10457A: converts 50 ohm GR to 75 ohm Type N.

Price: $35.

Model 10458A: converts 50 ohm GR to 75 ohm Type F (CATV).

Price: $25.

Model 874A

The 874A is a calibrated TDR comparison device for simple, rapid, direct-reading evaluation of reactive discontinuities.

Specifications

Characteristic impedance: 50 ohms ±0.1 ohm.

Capacitance range: 0 to 1 pF.

Inductance range: 0 to 2 nH.

Accuracy: capacitance: ±0.005 pF or ±5%, whichever is greater, from 0 to 0.5 pF. Inductance: ±0.013 nH or ± 5%, whichever is greater, from 0 to 1.3 nH.

Line length: 17.4 cm.

Connectors: 874A, GR type 874.

Price: 874A, $250.

Model K60-1415A

Power line interference can be reduced with the K60-1415A Hum Filter when used with Time Domain Reflectometers such as the HP Model 1415A. A front panel switch allows you to select either 60 Hz or 400 Hz filtering.

Specifications

Hum rejection
In a 50 ohm hum source
50-120 Hz, 40 dB; 400 Hz, 35 dB.

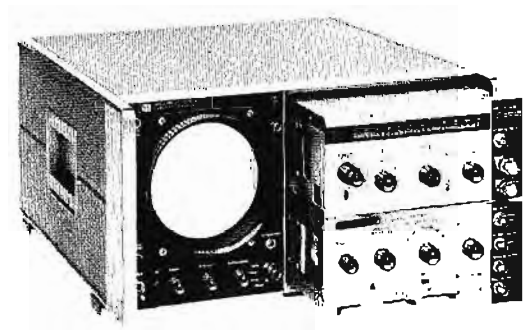
Introduced reflection: less than 5%.

Step distortion (droop): less than 3%.

Power
115-230 volts ac; 50-400 Hz; 1 watt.

Price: $325.

SPECTRUM ANALYZERS
An oscilloscope in the frequency domain
Models 8553L/8552A and 8551B/851B



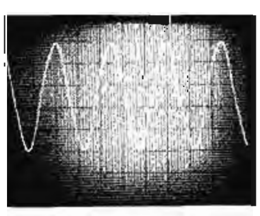
8553L/8552A Spectrum Analyzer Plug-ins in 141S Oscilloscope Mainframe

General

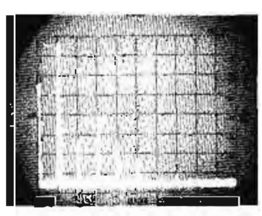
Oscilloscopes display the amplitude of electrical signals as a function of time, combining all frequency components into the composite time-domain waveform. Spectrum analyzers separate the frequency components, displaying the amplitude of each as a function of its frequency. Both time- and frequency-domain analysis are indispensable for the rapid analysis of signals in circuit characterization.

Common frequency domain applications

Many measurements commonly made on circuits such as oscillators, amplifiers, mixers, and filters must be made in the frequency domain. Such measurements include frequency response, harmonic and intermodulation distortion, spurious oscillations, frequency stability, spectral purity, modulation index, and attenuation. Each is a measurement of a phenomenon that has unmistakable and dramatic effects in the frequency domain—measurements ideally suited to this versatile new spectrum analyzer. For more complete information on spectrum analysis, see pages 450 through 460.



Harmonic Distortion in Time-Domain—Hardly Visible



Harmonic Distortion in Frequency Domain—Easily Seen

8553L/8552A spectrum analyzer

The 8553L/8552A Spectrum Analyzer brings the power of complete frequency domain analytical capabilities to the design engineer, the systems engineer, the maintenance engineer, and the EMC engineer. For the first time *absolute amplitude calibration* is combined with broad sweep capabilities, high sensitivity, low distortion, wide dynamic range, and flat frequency response (all calibrated), to produce a truly general-purpose frequency domain instrument.

The 8553L/8552A is invaluable, not only in basic circuit design, but also in system evaluation. The broad frequency range of 1 kHz to 110 MHz extends from audio through the FM broadcast band; this span includes audio, video, IF amplifiers, navigation aids, telemetry, most multiplex communications systems basebands, commercial AM, FM, TV, and land mobile communications. The combination of absolute amplitude calibration and full 100-MHz scan capability has already made and will continue to make a tremendous impact on measurement techniques in this frequency range.

The 8553L/8552A is designed for use with a 140S or a 141S Display Section. The 140S CRT is of the fixed-persistence/nonstorage type; the 141S offers the additional benefits of variable persistence and storage. The spectrum analyzer plug-ins work equally well in a 140A or a 141A oscilloscope mainframe.

70-dB Display Dynamic Range: free of analyzer distortion products.

High Sensitivity: to −130 dBm (0.07 μV).

50-Hz Resolution: to separate closely spaced signals.

High Stability: residual FM less than 20 Hz p-p when stabilized.

Automatic Stabilization for narrow scan widths: no complicated phase-locking procedure.

Flatness: ±0.5 dB.

Variable Persistence Display: a necessity for low-frequency, high-resolution, *flicker-free* displays. This is the breakthrough that makes low-frequency spectrum analysis *practical;* the *spectrum,* instead of a slowly moving CRT spot, can be seen.

For complete specifications and accessory information, refer to pages 450 through 454.

8551B/851B and 8551B/852A spectrum analyzer

The 8551B RF Section with either the 851B or 852A Display Section makes a spectrum analyzer that is a versatile, fully calibrated instrument over the 10.1-MHz to 40-GHz frequency range. Accuracy and flexibility of the 8551B make it suitable for many applications, such as rapid, wideband EMC measurements, spectrum surveillance, spectrum signature recording, and microwave semiconductor evaluations — all in the frequency domain.

Complete specifications and accessory information for this instrument are given on pages 455 through 458.

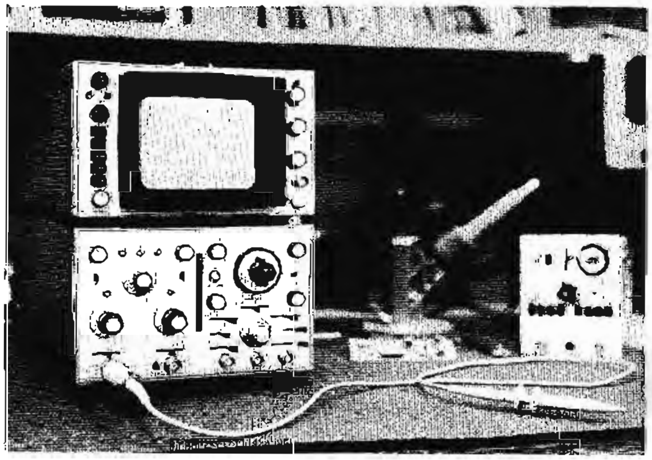
SOLID-STATE OSCILLOSCOPES

Large display, lower power, light weight

Models 180A, 181A

NEW STANDARD FOR OSCILLOSCOPE MEASUREMENTS

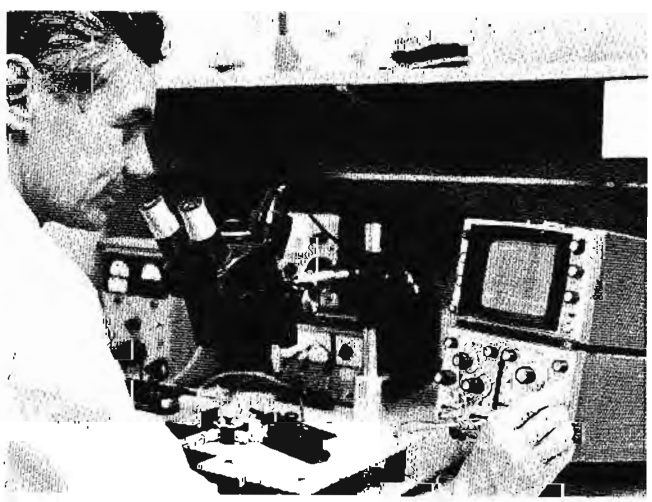
The growing 180 Oscilloscope system establishes a new standard for high-performance, general-purpose oscilloscope design. This modern plug-in system, consisting of six mainframes and twelve plug-ins, allows you to match your oscilloscope capability to your particular application. Small and lightweight, these all solid-state scopes are ideal for all types of high frequency measurements. This reliable, accurate performance has been proven in applications varying from shipboard testing, to flight-line checkout, to exacting measurements of computer memories. This system is designed to meet today's requirements and still provide capabilities for future growth.



COMPLETE SELECTION FOR ANY MEASUREMENT NEED

General-purpose engineering and development

For versatility combined with accuracy, choose the 50 MHz dual channel plug-in with either standard or delayed sweep time base. Plug these into the variable persistence and storage mainframe for a truly general-purpose scope. This mainframe features conventional oscilloscope operation with variable persistence and storage available at the push of a button. The cabinet version requires little of that valuable workbench space or, if you prefer, the rack version is a real space-saver (5¼" high) in a portable test console.



Precision measurements to 100 MHz

With the introduction of a new 100 MHz plug-in, high frequency measurements have reached a new level of quality. Utilizing transmission line techniques, this plug-in allows you to probe a wide variety of source resistances without introducing errors into the measurement and disturbing the circuit. The 50-ohm input also provides the ideal termination for measurements in a 50-ohm system, as well as providing the basis for impedance multiplication necessary for probing applications.

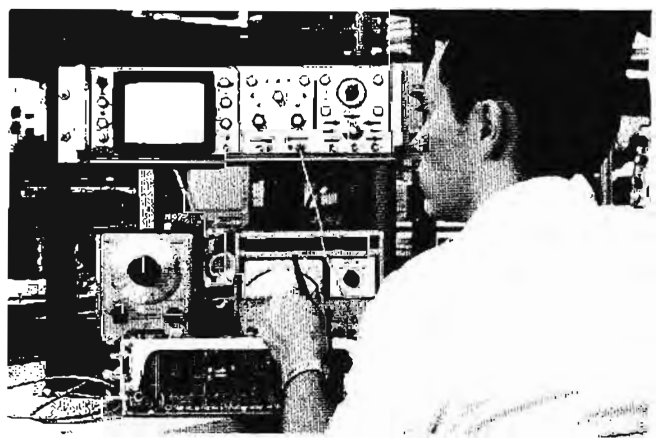
The differential/dc offset plug-in, coupled with system features such as low dc drift and large 8 x 10 cm CRT display area, allows easy and precise measurements. For example, offset voltages may be measured with a comparison accuracy of better than 0.5%.

Field and service

The over-all design concept of the 180 system results in features especially suited for field and service applications. All solid-state circuitry, small 30-pound package, with accessories such as front panel covers and portable testmobiles, make this system ideal for field location work. The plug-in design lets you take only those plug-ins necessary for the job. You take along another plug-in, not a second oscilloscope.

Systems and manufacturing

The design of the 180 system also makes it ideal for instrument systems and manufacturing applications. The rack-mount versions of the mainframes are only 5¼" high, saving valuable space. The wide selection of plug-ins allows you to easily tailor the system to fit the application. The human-engineered, logical arrangement of controls makes these instruments easy to operate even for those not familiar with an oscilloscope. The 180 Oscilloscope system requires only 115 watts of power with no fan, making operation more reliable and more economical. Displays on the big 8 x 10 cm graticule are easy to read and the internal graticule eliminates possible parallax errors.



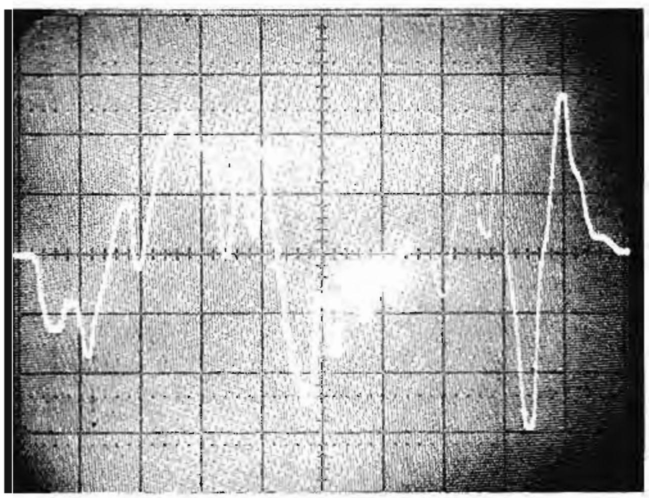
Operation in extreme environments

A version of the 180 system has been developed to meet the extreme environmental requirements of the military. This system (includes plug-ins) is available in the cabinet version as an AN/USM-281 or in the rack-mount configuration as an AN/USM-296. The same system can be obtained as an HP Model 180E or Model 180ER, with appropriate ruggedized plug-ins (Models 1801E, 1820E, etc.). Rigid military specifications met by this system are listed on page 547

ACCURACY, VERSATILITY, AND EASE OF OPERATION

PLUG-IN DESIGN lets you economically change the performance of your system to meet the changing measurement requirements. It also protects you from expensive obsolescence, since the system can be updated as new plug-ins are developed to meet your increased measurement needs.

ALL SOLID-STATE circuitry allows you to make accurate measurements after only 15 seconds warm-up. The low power consumption eliminates the need for a fan; heat-related component failures are minimized.



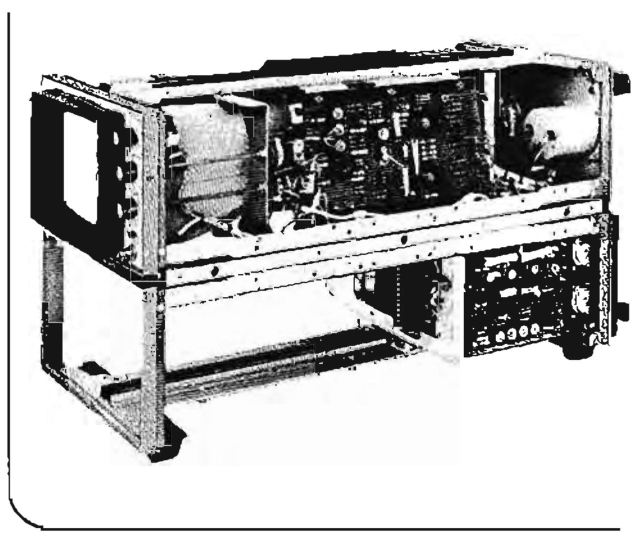
VARIABLE PERSISTENCE lets you control the CRT persistence to eliminate flicker or to integrate dim signals to a display at full brightness.

STORAGE is also available at the push of a button for side-by-side trace comparison or measurement of single-shot occurrences.

SMALL 30-LB PACKAGE is easily carried around the lab or to remote field sights. Also, the small cabinet size gives you more usable bench space.

8 x 10 CM CRT DISPLAY AREA features an internal graticule to increase accuracy by eliminating parallax errors. The large viewing area also makes measurements easier to read and easier to see from a distance.

AIRCRAFT TYPE MAINFRAME designed for maximum ruggedness and a minimum weight, makes this system ideal for field and service. It also allows easy access to all components to facilitate calibration and maintenance.



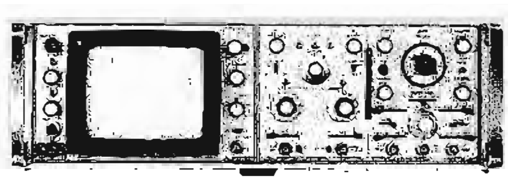
BROAD ENVIRONMENTAL SPECIFICATIONS give you laboratory performance in field applications. Specification over a wide range assures accurate measurements under different or changing conditions.

Mainframes			
Model	**Description of mainframes (accepts 1 vertical and 1 time base)**	**Price**	**Page**
180A	Cabinet configuration	$ 825	533, 535
180AR	5¼ in. high rack/bench configuration	900	533, 535
181A	Cabinet configuration with variable persistence and storage	1,850	533, 536
181AR	5¼ in. high rack/bench configuration with variable persistence and storage	1,925	533, 536
180E	Militarized cabinet configuration	1,215	546
180ER	Militarized rack/bench configuration	1,205	546

Vertical plug-ins					
Model No.	**1801A**	**1802A**	**1803A**	**1804A**	**1801E**
Bandwidth	50 MHz	100 MHz (75 MHz cascaded)	40 MHz (30 MHz)	50 MHz	50 MHz (20 MHz)
Min. deflection factor	5 mV/div	10 mV/div (1 mV/div)	5 mV/div (1 mV/div)	20 mV/div	5 mV/div (1 mV/div)
Channels	2	2 (1)	1	4	2
Differential input	●	●	● (with ac offset)		●
Price	$650	$1,200	$950	$975	$800
Page	537	540	537	538	546

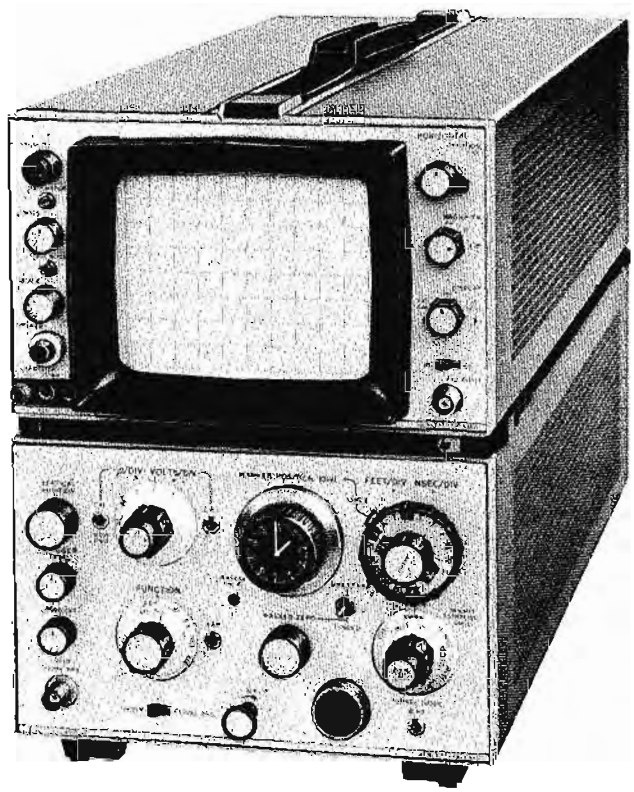
Time base plug-ins							Double
Model No.	**1820A**	**1820B**	**1821A**	**1822A**	**1820E**	**1821E**	**1816A**
Ext. trig.	100 MHz	150 MHz	100 MHz	150 MHz	100 MHz	100 MHz	35 ps calibrated TDR and 12.4 GHz Sampling
Int. trig.	75 MHz	120 MHz	75 MHz	120 MHz	75 MHz	75 MHz	
Sweep speeds	5 ns/div-2 s/div	5 ns/div-2 s/div	10 ns/div-1 s/div	5 ns/div-1 s/div	5 ns/div-2 s/div	10 ns/div-2 s/div	
Delayed and mixed sweep			●	●		●	
Price	$475	$525	$800	$900	$570	$920	$1900–3150
Page	539	541	539	541	546	546	542

8 x 10 cm display, solid-state, 30 pounds
Models 180A, 180AR mainframes



180AR

The 180AR is housed in the HP modular cabinet, suitable for either bench or rack mount. As a rackmounted unit, the 180AR requires only 5¼ inches of vertical rack space, with no clearance requirements at top or bottom of the unit. Fixed pivoted slides are described on page 545.



Specifications, 180A/180AR

Cathode-ray tube and controls

Type: post accelerator, 12 kV accelerating potential; aluminized P31 phosphor (other phosphors available, see Modifications); safety glass faceplate.

Graticule: 8 x 10 div parallax-free internal graticule, 0.2-div subdivisions on major axes. 1 div = 1 cm. Front panel recessed screwdriver adjust TRACE ALIGN aligns trace with graticule. Internal Y-align aligns Y-trace with X-trace. Scale control illuminates CRT phosphor for viewing with hood or taking photographs.

Beam finder: pressing Find Beam control brings trace on CRT screen regardless of setting of horizontal, vertical, or intensity controls.

Intensity modulation: approximately +2 V, dc to 15 MHz, will blank trace of normal intensity. Input R, 5100 ohms.

Calibrator

Type: approximately 1 kHz square wave, 3 μs risetime.

Voltage: two outputs, 250 mV pk-pk and 10 V pk-pk; accuracy, ±1%.

Horizontal amplifier

Bandwidth: dc to 5 MHz when dc-coupled; 5 Hz to 5 MHz when ac-coupled.

Deflection factor: 1 V/div, X1; 0.2 V/div, X5; 0.1 V/div, X10. Vernier provides continuous adjustment between ranges. Dynamic range, ±5 V.

Maximum input: 600 V dc (ac-coupled input).

Input RC: 1 megohm shunted by approximately 30 pF.

Sweep magnifier: X1, X5, X10; magnified sweep accuracy, ±5% (for ±3% accuracy time base plug-ins).

Outputs: four emitter follower outputs on rear for main and delayed gates, main and delayed sweeps; maximum current available, ±3 mA; outputs will drive impedances down to 1000 ohms without distortion.

General

Weight: (without plug-ins) Model 180A, net, 22 lb (9,9 kg); shipping, 30 lb (13,5 kg). Model 180AR (rack), net, 25 lb (11,3 kg); shipping, 33 lb (14,9 kg).

Environment: 180A/AR scope operates within specifications over the following ranges:

Temperature: −28°C to +65°C.

Humidity: to 95% relative humidity to 40°C.

Altitude: to 15,000 ft.

Vibration: vibrated in three planes for 15 min. each with 0.010-inch excursion, 10 to 55 Hz.

Active components: all solid-state (except CRT).

Power: 115 or 230 V ±10%, 50 to 400 Hz, less than 110 watts with plug-ins at normal line, convection cooled.

Dimensions

Cabinet: 7⅞" wide, 11⅜" high, 21¼" deep behind panel (200 x 289 x 540 mm).

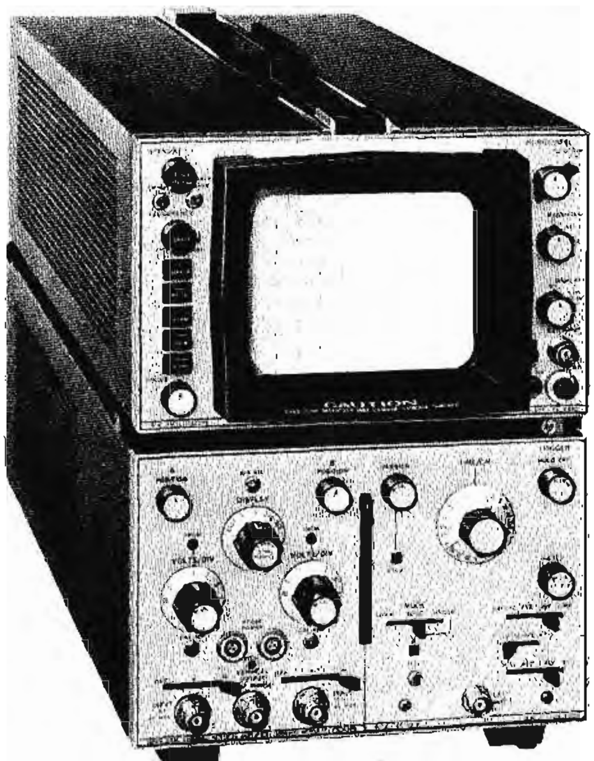
Rack: 19" wide, 5¼" high, 19½" deep behind panel (482 x 133 x 495 mm); 21⅜" deep over-all.

Accessories furnished: mesh contrast filter; rack mounting hardware (180AR only).

Modifications: CRT phosphor (specify by phosphor number); P31 standard; P2, P7, P11 available, no extra charge.

Price: HP Model 180A (cabinet), $825; HP Model 180AR (modular rack), $900.

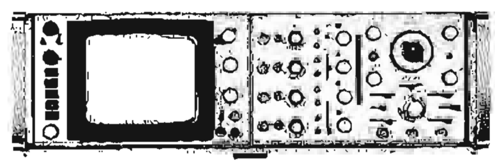
Storage, variable persistence, solid-state
Models 181A, 181AR mainframes



181A

Features:

- Vary persistence to view slow signals
- "Develop" fast, low repetition rate pulses
- Bright, high-contrast storage up to 1 hour
- Rugged construction for field use
- Scope with plug-ins weighs only 32 pounds
- Push-button erase and mode controls



181AR

The 181AR is housed in the HP modular cabinet, suitable for either bench or rack mount. As a rackmounted unit, the 181AR requires only 5¼ inches of vertical rack space, with no clearance requirements at top or bottom of the unit. Fixed pivoted slides are described on page 545.

Specifications, 181A/AR

Cathode-ray tube and controls

Type: post accelerator storage tube; 8.5 kV accelerating potential: aluminized P31 phosphor.

Graticule: 8 x 10 div parallax-free internal graticule. 0.2-div subdivisions on major axes. 1 div = 0.95 cm. Front panel recessed screwdriver adjust TRACE ALIGN aligns trace with graticule. Internal Y-align aligns Y-trace with X-trace.

Beam finder: pressing Find Beam control brings trace on CRT screen regardless of setting of horizontal or vertical controls.

Intensity modulation: approximately +2 V, dc to 15 MHz, will blank trace of normal intensity. Input R, 5100 ohms.

Persistence: normal, natural persistence of P31 phosphor (approx. 40 μs). Variable, continuously variable from less than 0.2 second to more than 1 minute.

Storage writing rate

Write mode: greater than 20 cm/ms.

Max. write mode: greater than 1 cm/μs.

Brightness: measured with entire screen faded positive, greater than 200 footlamberts.

Storage time: from Write mode to Store, traces may be stored at reduced intensity for more than one hour. To View mode, traces may be viewed at normal intensity for more than one minute. From Max. Write mode to Store, traces may be stored at reduced intensity for more than 5 minutes. To View mode, traces may be stored at normal intensity for more than 15 seconds.

Erase: manual, push-button erasure takes approximately 300 ms.

Calibrator

Type: approximately 1 kHz square wave, 3 μs risetime.

Voltage: 10 V pk-pk; accuracy, ±1%.

Horizontal amplifier

Bandwidth: dc to 5 MHz when ac-coupled.

Deflection factor: 1 V/div, X1; 0.2 V/div, X5; 0.1 V/div, X10. Vernier provides continuous adjustment between ranges. Dynamic range, ±5 V.

Maximum input: 600 V dc (ac-coupled input).

Input RC: 1 megohm shunted by approximately 30 pF.

Sweep magnifier: X1, X5, X10; magnified sweep accuracy, ±5% (for ±3% accuracy time base plug-ins).

Outputs: four emitter follower outputs on rear for main and delayed gates, main and delayed sweeps; maximum current available, ±3 mA; outputs will drive impedances down to 1000 ohms without distortion.

General

Weight: (without plug-ins) Model 181A, net, 24 lbs (10,9 kg); shipping, 32 lbs (14,5 kg). Model 181AR (rack), net, 26 lbs (11,8 kg); shipping, 35 lbs (15,9 kg).

Environment: same as Model 180A/AR except for temperature which is 0°C to +65°C.

Active components: all solid-state (except CRT).

Power: 115 or 230 volts ±10%, 50 to 400 Hz, less than 115 watts with plug-ins at normal line, convection cooled.

Dimensions

Cabinet: same as Model 180A.

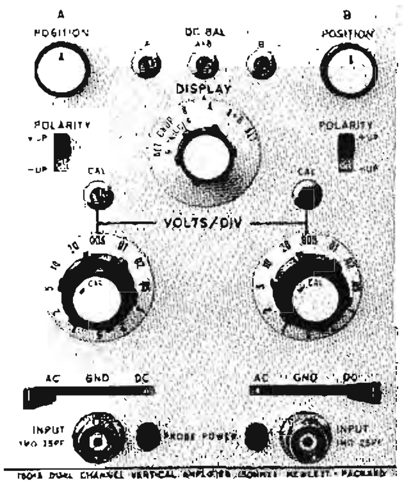
Rack: same as Model 180AR.

Accessories furnished: mesh contrast filter; rack mounting hardware (181AR only).

Special order: modified Model 181A/AR with remote programming capability for Write, Max Write, Normal, Store, View, and Erase functions. Programming accomplished through contact closures, DTL or TTL logic sources. Order as H49-181A (cabinet) or H49-181AR (modular rack).

Price: HP Model 181A (cabinet), $1,850; HP Model 181AR (modular rack), $1,925; H49-181A (cabinet), $2,350; H49-181AR (modular rack), $2425.

50 MHz amplifier, differential/dc offset amplifier
Models 1801A, 1803A



1801A

This dual channel amplifier is ideal for general-purpose use in the 180A or 181A. Its high sensitivity of 5 mV/div provides the extra gain needed when divider probes are used. (Also note 1 mV/div special order available; see Specifications.) The 1801A has FET inputs for low drift and instant warmup, plus a virtual absence of microphonics. All attenuation, which sets deflection factor, occurs prior to any active component—eliminating trace shift with range changes and also assuring constant bandwidth in excess of 50 MHz on all ranges. Internal triggering on the B channel signal assures time correlation between traces in either chopped or alternate operation.

Specifications, 1801A

Modes of operation: channel A alone; channel B alone; channels A and B displayed alternately on successive sweeps (ALT); channels A and B displayed by switching between channels at approx. 400 kHz rate (CHOP), with blanking during switching; channel A plus channel B (algebraic addition).

Each channel

Bandwidth: dc to 50 MHz when dc-coupled; 2 Hz to 50 MHz when ac-coupled. (Direct or with probe; 3 dB down from 8-div reference signal, 25-ohm source.)

Risetime: less than 7 ns. (Direct or with probe; 10% to 90% with 8-div input step, 25-ohm source.)

Deflection factor

Ranges: from 0.005 V/div to 20 V/div (12 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position; calibration adjustment provided on front panel.

Vernier: continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Polarity: +UP or −UP, selectable.

Signal delay: input signals are delayed sufficiently to view leading edge of input pulse without advance external trigger.

Input coupling: front panel selection of ac, dc, or Ground; Ground position disconnects signal input and grounds amplifier input for reference.

Input RC: 1 megohm shunted by approx. 25 pF.

Maximum input

AC-coupled: ±600 V (dc + peak ac).

DC-coupled: ±350 V (dc + peak ac) on 20 V/div deflection factor, decreasing to 150 V (dc + peak ac) on 5 mV/div.

A + B operation

Amplifier: bandwidth and deflection factor are unchanged; either channel may be inverted to give ±A±B operation.

Differential input (A-B) common mode: for frequencies from dc to 5 MHz, common mode rejection ratio is at least 40 dB on 5 mV/div deflection factor, at least 20 dB on other ranges; common mode signal, up to amplitude equivalent of 30-div deflection.

Triggering

Mode

A, B, A + B: on the signal displayed.

Chop: on channel B signal.

Alternate: on either channel B or on the signal displayed by each channel.

Frequency: dc to 50 MHz on signals causing 0.5 division or more vertical deflection in all display modes except Chop; dc to 100 kHz for Chop mode.

General

Weight: net, 4 pounds (1,8 kg); shipping, 6½ pounds (3,0 kg).

Environment: same as Model 180A/AR.

Active components: all solid-state.

Accessories furnished: two Model 10004A 10:1 Voltage Divider probes.

Special order: modified Model 1801A with switchable X5 magnifier, providing 1 mV/div deflection factor on both channels. Bandwidth is reduced to 20 MHz when using X5 magnifier, no change in standard specifications in X1. Order as H05-1801A.

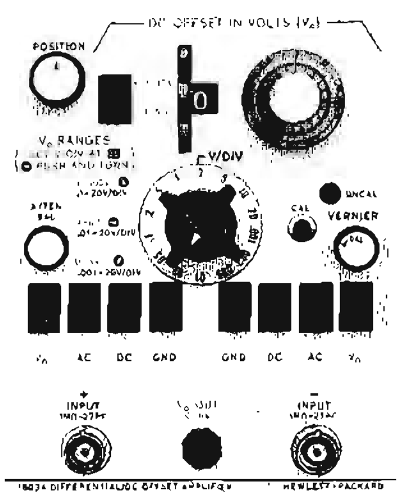
Options

Option 90: two 10006A probes (6-ft cable) instead of 10004A probes. Add $10.

Option 91: two 10005A probes (10-ft cable) instead of 10004A probes. Add $20.

Price: HP Model 1801A, $650; H05-1801A, $745.

Differential/DC Offset Amplifier



1803A

The Model 1803A Differential/DC Offset Amplifier uses the slide-back technique to achieve greater measurement accuracy. The plug-in generates a very stable, precise dc voltage which may be read to four-digit resolution. This voltage is then compared to the input signal. If the input signal is expanded to many screen diameters the dc offset permits any part of the input signal to be displayed on screen and measured accurately. Fool-proof, interlocked controls prevent unwanted offset changes as sensitivity is changed.

Used as a differential amplifier, the 1803A has high common-mode rejection and will withstand a 10 V common-mode signal on the most sensitive range of 1 mV/div. Even higher common-mode signals may be applied on the less sensitive ranges. Rugged construction and conservative design insures that full accuracy is maintained over the specified environmental extremes.

(Model 1803A specifications on following page.)

50 MHz 4-channel amplifier
Model 1804A

(Model 1803A photograph and description on preceding page).

Specifications, 1803A

Bandwidth: dc to 40 MHz on 0.005 V/div to 20 V/div deflection factors; dc to 30 MHz on 0.001 V/div and 0.002 V/div. Lower limit is 2 Hz with input ac-coupled. (Direct or with probe; 3 dB down from 8-div reference signal, 25-ohm source.)

Risetime: less than 10 ns on 0.005 V/div to 20 V/div deflection factors; less than 12 ns on 0.001 V/div and 0.002 V/div. (Direct or with probes; 10% to 90% with 8-div input step, 25-ohm source.)

Deflection factor

Ranges: from 0.001 V/div to 20 V/div (14 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position; calibration adjustment provided on front panel.

Vernier: with UNCAL (uncalibrated) light; continuously variable between all ranges; extends maximum deflection factor to at least 50 V/div.

Signal delay: input signals are delayed sufficiently to view leading edge of input pulse without advance external trigger.

Input RC: 1 megohm shunted by approx. 27 pF.

Input coupling: front panel selection of ac, dc, ground, or V_o for both + and − inputs. Ground push button disconnects signal input and substitutes internal calibrated dc offset voltage.

Maximum input

AC-coupled: ±600 V (dc + peak ac).

DC-coupled: ±600 V (dc + peak ac) on 0.1 V/div to 20 V/div deflection factors, decreasing to ±15 V (dc + peak ac) on 0.001 V/div.

Common-mode rejection ratio: greater than 86 dB (20,000:1) from dc to 100 kHz on 0.001 V/div deflection factor for common-mode signals up to 10 V pk-pk. CMRR decreases with increasing frequency or deflection factor.

Overload recovery

6 V overload: within ±10 mV of final signal value in 0.3 μs or less; within ±5 mV in 1 μs or less; and within ±1 mV in 1 ms or less.

60 V overload: within ±100 mV of final signal value in 0.3 μs or less; within ±50 mV in 1 μs or less; and within ±10 mV in 1 ms or less.

600 V overload: within ±1 V of final signal value in 0.3 μs or less; within ±0.5 V in 1 μs or less; and within ±100 mV in 1 ms or less.

DC offset:

Offset range	Deflection factor	Comparison accuracy
0 to ±6 V	0.001 V/div to 0.02 V/div	±(0.15% +8 mV)
	0.005 V/div to 0.2 V/div	±(0.75% +8 mV)
	0.5 V/div to 2 V/div	±1%
	5 V/div to 20 V/div	±3%
0 to ±60 V	0.01 V/div to 0.2 V/div	±(0.4% +80 mV)
	0.5 V/div to 2 V/div	±(0.75% +80 mV)
	5 V/div to 20 V/div	±3%
0 to ±600 V	0.1 V/div to 2 V/div	±(0.65% +0.8 V)
	5 V/div to 20 V/div	±3%

Triggering: dc to 40 MHz on signals causing 0.5 division or more vertical deflection.

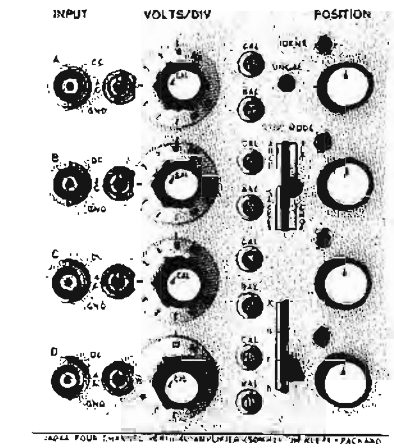
V_o output: dc offset voltage available at front panel connector, continuously variable from 0 to ±0.006 V, 0 to ±0.06 V, 0 to ±0.6 V or 0 to ±6 V. Accuracy of the ±6 V range is ±0.15% of reading ±8 mV, when loaded with 10 megohms or more.

Weight: net, 4 lbs (1,8 kg); shipping, 6½ lbs (3,0 kg).

Environment: same as Model 180A/AR except temperature which is 0°C to +55°C.

Active components: all solid-state.

Price: HP Model 1803A, $950.



1804A

The 1804A Four Channel Amplifier permits the direct comparison of four signals simultaneously. Each of the four channels features 50 MHz bandwidth, 20 mV/div sensitivity. Ideal for logic circuit testing, the 1804A may be operated to trigger on each channel individually for asynchronous signals or for direct comparison of input/output pulses in spite of time delays. Or, the triggering may be set for one channel only for time correlation measurements.

Specifications, 1804A

Modes of operation: channels A, B, C, and D or any combination displayed alternately on successive sweeps (ALT); channels A, B, C, and D or any combination displayed by switching between channels at approx. 1 MHz rate (CHOP), with blanking during switching.

Each channel (4)

Bandwidth: dc to 50 MHz when dc-coupled; 10 Hz to 50 MHz when ac-coupled. (Direct or with probe; 3 dB down from 8-div reference signal, 25-ohm source.)

Risetime: less than 7 ns. (Direct or with probe; 10% to 90% with 8-div input step, 25-ohm source.)

Deflection factor:

Ranges: from 0.02 V/div to 10 V/div (9 positions) in 1, 2, 5 sequence. ±3% accuracy with vernier in calibrated position; calibration adjustment provided on front panel.

Vernier: with UNCAL (uncalibrated) light; continuously variable between all ranges; extends maximum deflection factor to at least 25 V/div.

Signal delay: input signals are delayed sufficiently to view leading edge of input pulse without advance external trigger.

Input coupling: front panel selection of ac, dc, or ground; ground position disconnects signal input and grounds amplifier for reference.

Input RC: 1 megohm shunted by approximately 25 pF.

Maximum input

AC-coupled: ±400 V (dc + peak ac).

DC-coupled: ±350 V (dc + peak ac) on 50 mV/div deflection factors; ±150 V (dc + peak ac) on 20 mV/div.

Trace identification: push button displaces respective trace approx. 0.5 div.

Triggering

Mode

Chop: selectable on signal from any channel.

Alternate: on any channel selected, or by the signal displayed by each channel (any channel turned off will be skipped).

Frequency: dc to 50 MHz on signals causing 0.5 div or more vertical deflection in all display modes except Chop; dc to 200 kHz for Chop mode.

General

Weight: net, 4¾ lbs (2,1 kg); shipping, 7¼ pounds (3,2 kg).

Environment: same as Model 180A/AR except temperature which is 0°C to +55°C.

Active components: all solid-state.

Price: HP Model 1804A, $975.

General-purpose time bases
Models 1820A, 1821A

Time base plug-ins

The Model 1820A Time Base provides sweep speeds from 2 s/cm to 50 ns/cm, 5 ns/cm when using Model 180A/181A X10 horizontal amplifier magnifier. Positive triggering is assured to 100 MHz and a front panel trigger holdoff control locks in complex waveforms. Automatic triggering provides a bright baseline in the absence of an input signal, and syncs on the input waveform when a vertical input signal is applied.

Model 1821A Time Base and Delay Generator provides from 1 s/cm to 100 ns/cm, 10 ns/cm when using Model 180A/181A magnifier. It also features easy-to-use delayed sweeps. Exclusive Hewlett-Packard mixed sweep combines display of first portion of trace at normal sweep speeds, and simultaneously expands trailing portion of trace at faster delayed sweep speeds to allow magnified examination. Functional groupings of all controls simplifies operation. The internally generated delay trigger is available for external syncing.

Specifications, 1820A

Same as Model 1820B (see page 541) except for following:

Internal triggering: see Model 1802A Vertical Amplifier plug-in specifications for specific difference.

External triggering: dc to 50 MHz on signals 0.5 V pk-pk or more, increasing to 100 MHz on 1 V pk-pk or more.

Price: HP Model 1820A, $475.

Specifications, 1821A

Main time base

Sweep

Ranges: from 0.1 μs/div to 1 s/div (22 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: continuously variable between all ranges; extends slowest sweep to at least 2.5 s/div.

Magnifier: mainframe magnifier expands fastest sweep to 10 ns/div.

Sweep mode

Normal: sweep is triggered by an internal, external, or power line signal.

Automatic: bright baseline displayed in absence of input signal. Triggering same as Normal except low frequency limit is 40 Hz for internal and external.

Single: sweep occurs once with same triggering as Normal; reset push button with indicator light.

Triggering

Internal: see vertical amplifier plug-in specifications.

External: from dc to 50 MHz on signals 0.5 V pk-pk or more, increasing to 100 MHz on 1 V pk-pk or more.

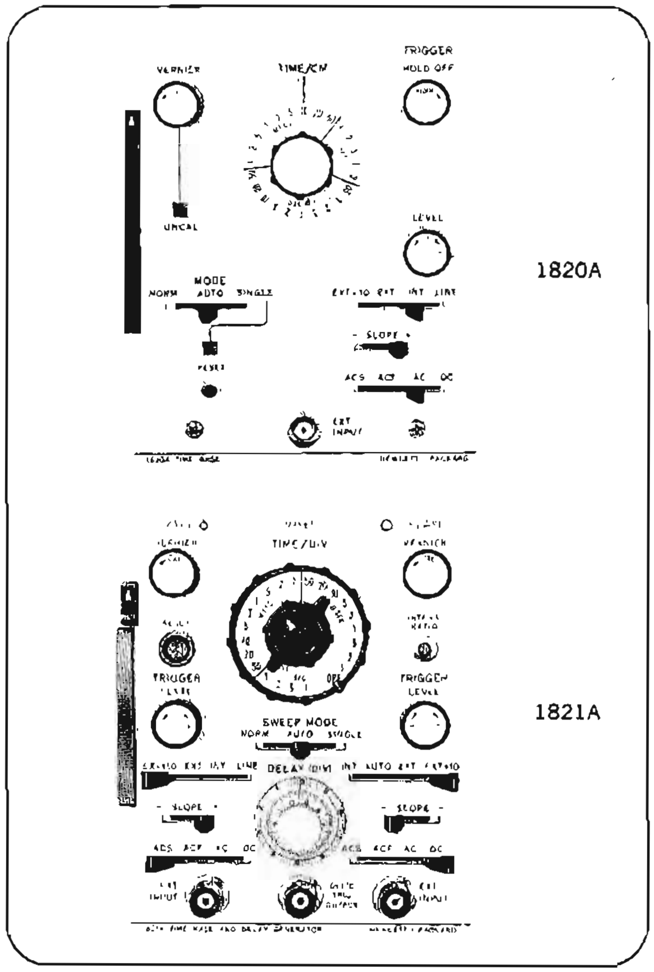
Line: selectable on power line frequency signal.

Level and slope: internal, at any point on the vertical waveform displayed. External, continuously variable from +3 V to −3 V on either slope of the sync signal; from +30 V to −30 V in ÷ 10 setting.

Coupling: front panel selection of ac, dc, ac fast (ACF), or ac slow (ACS). AC attenuates signals below approx. 20 Hz; ACF attenuates signals below approx. 15 kHz; ACS attenuates signals above approx. 30 kHz.

Trace intensification: used for setting up Delayed or Mixed time base. Intensifies that part of Main time base to be expanded to full screen on Delayed time base. Rotating Delayed time base sweep switch from Off position activates intensified mode. Front panel screwdriver adjust sets relative intensity of of brightened segment.

Delayed time base: delayed time base sweeps after a time delay set by Main time base and Delay controls.



Sweep

Ranges: from 0.1 μs/div to 50 ms/div (18 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: continuously variable between all ranges; extends slowest sweep to at least 125 ms/div.

Triggering: applies to intensified Main, Delayed, and Mixed time base triggering.

Internal: same as Main time base triggering.

Automatic: delayed sweep is automatically triggered at end of set delay time.

External: same as Main time base triggering.

Level and slope: same as Main time base triggering.

Coupling: same as Main time base triggering.

Delay (before start of Delayed time base)

Time: continuously variable from 0.1 μs to 10 s.

Accuracy: ±1%. Linearity, ±0.2%. Time jitter is less than 0.005% (1 part in 20,000) of maximum delay of each step.

Trigger output: (at end of Delay time) approximately 1.5 V with less than 50 ns risetime from 1000-ohm source resistance.

Mixed time base: dual time base in which Main time base drives first portion of display and delayed time base completes sweep at up to 1000 times faster. May be operated in single sweep mode.

General

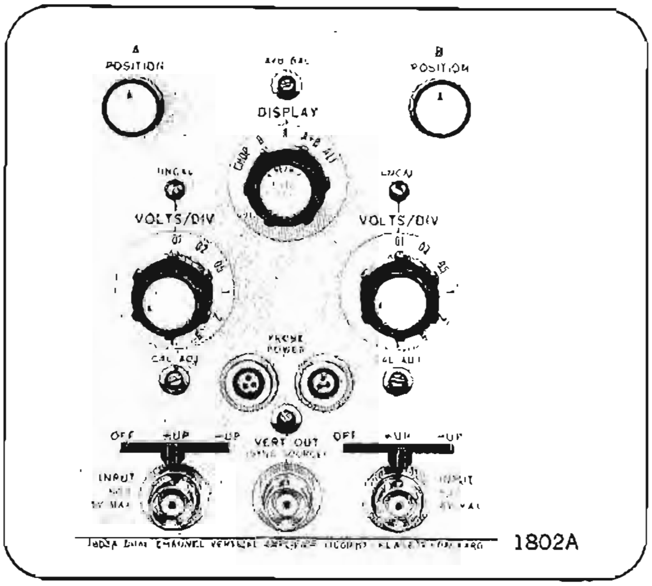
Weight: net, 3¾ lbs (1,7 kg); shipping, 6½ lbs (2,8 kg).

Environment: same as Model 180A/AR.

Active components: all solid-state.

Price: HP Model 1821A, $800.

Precision measurements to 100 MHz
Model 1802A



Model 1802A Dual Channel Vertical Amplifier extends precision high frequency measurements to greater than 100 MHz, demonstrating the versatility and improved performance of the plug-in 180 system.

Standard deflection factor for each channel is 10 mV/div. Channels may be cascaded to provide 1 mV/div deflection factor, single channel operation.

High frequency work with 50-ohm systems is simplified and accurate with the 1802A. The plug-in input has been designed to terminate a 50-ohm system. It is also ideal for probing applications since it minimizes capacitance, an obstacle to accuracy in most high frequency measurements. Capacitance reduces signal amplitude, introduces phase shift, limits risetime in circuit and in measurement, and causes a time delay.

Resistive divider probes(refer to page 544 for specifications) for Model 1802A add less than 0.7 pF. The basic 50-ohm input can be multiplied to 250, 500, 1k, 2.5k, or 5k ohms, to reduce the dc loading.

When a measurement requires a higher input resistance the Model 1123A Active Probe (powered by Model 1802A) can be used. It offers 100 k ohms with only 3.5 pF capacitance. (Refer to page 544 for specifications.)

Specifications, 1802A

Modes of operation: channel A alone; channel B alone; channels A and B displayed alternately on successive sweeps (ALT); channels A and B displayed by switching between channels at approx. 400 kHz rate (CHOP), with blanking during switching; channel A plus channel B (algebraic addition). Vertical output allows cascading of channels.

Each channel

Bandwidth

Direct: dc to greater than 100 MHz (3 dB down from 8-div reference signal); with channels cascaded, dc to greater than 75 MHz.

With Model 1123A active probe: same as Direct for source resistances from 0 to 150 ohms.

With Model 10020A resistive divider probes: same as Direct for source resistances from 0 to 750 ohms.

With Model 10201A-D resistive divider probes: same as Direct for source resistances from 0 to 1000 ohms.

Risetime

Direct: less than 3.5 ns (10% to 90% with 6-div input step); with channels cascaded, less than 4.5 ns.

With Model 1123A active probe: same as Direct for source resistances from 0 to 150 ohms.

With Model 10020A resistive divider probes: same as Direct for source resistances from 0 to 750 ohms.

With Models 10201A-D resistive divider probes: same as Direct for source resistances from 0 to 1000 ohms.

Pulse response: (6 div reference at 25°C) overshoot, <3%; perturbations, <3%; tilt, <2%. With channels cascaded: overshoot, <5%; perturbations, <5%; tilt, <3%.

Deflection factor

Ranges: from 0.01 V/div to 1 V/div (7 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position. calibration adjustment provided on front panel. Channels may be cascaded using vertical output to obtain 1, 2, or 5 mV/div.

Vernier: with UNCAL (uncalibrated) light; continuously variable between all ranges; extends maximum deflection factor to at least 2.5 V/div.

Polarity: +UP or −UP, selectable; OFF postiion disconnects signal input from amplifier, terminates input signal in 50 ohms and grounds amplifier input for reference.

Signal delay: input signals are delayed sufficiently to view leading edge of input pulse without advance external trigger.

Dynamic range: 6 divisions for signals to 100 MHz, increasing to 8 div at 50 MHz.

Positioning range: allows positioning top of a 6-div pulse to center graticule line.

Drift: less than ±1 div over environmental temperature range (except for cascaded operation).

Input impedance: 50 ohms ±2 ohms.

Maximum input: 6 V rms.

VSWR: less than 1.35:1 at 100 MHz on 0.01 V/div, less than 1.1:1 at 100 MHz on all other deflection factors.

Reflection coefficient: less than 15% at 100 MHz on 0.01 V/div; less than 5% at 100 MHz on all other deflection factors.

Probe power: provides power to operate Model 1123A Active Probe (one each channel).

A + B operation

Amplifier: bandwidth and deflection factor are unchanged, either channel may be inverted to give ±A±B operation.

Differential input (A - B) common mode: common mode rejection ratio greater than 40 dB for frequencies to 1 MHz, greater than 20 dB to 100 MHz; common mode signal, up to amplitude equivalent of 6-div deflection.

Triggering

Mode: normal, on the signal displayed as selected by DISPLAY switch; A, on channel A signal; B, on channel B signal.

Frequency: dc to greater than 120 MHz on 1 div pk-pk signal for Models 1820B or 1822A time base plug-ins; or from dc to greater than 75 MHz on 1 div pk-pk signal for Models 1820A or 1821A time base plug-ins.

Vertical signal output

Amplitude: 100 mV/div of displayed signal into 50-ohm load, adjustable with front panel control; usuable amplitude, 600 mV pk-pk.

Bandwidth: dc to greater than 100 MHz.

Risetime: less than 3.5 ns.

General

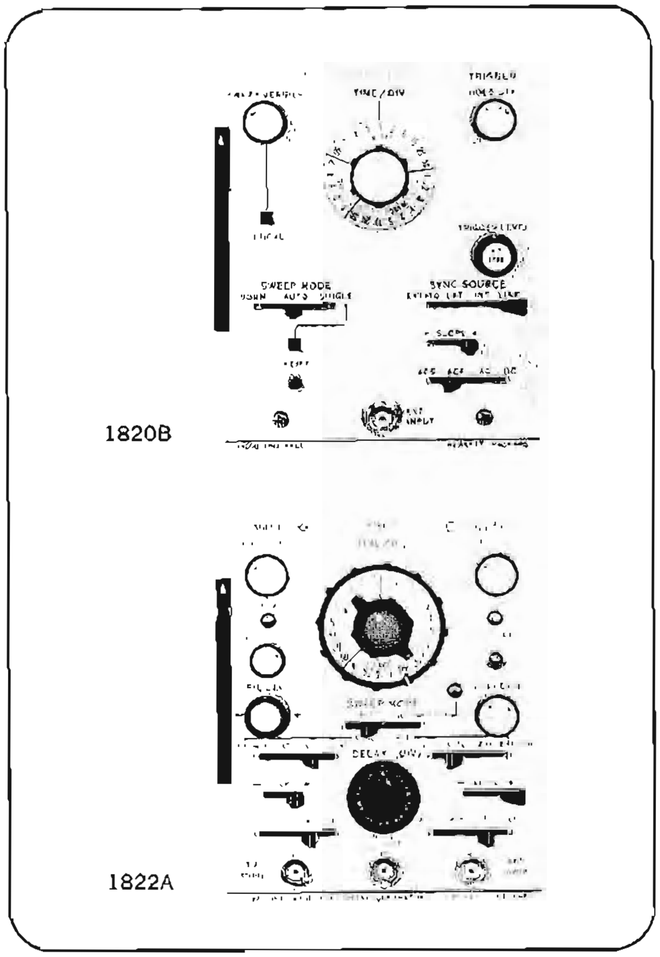
Weight: net, 4½ lbs (2,0 kg); shipping, 7 lbs (3,2 kg).

Environment: same as Model 180A/AR except temperature which is 0°C to +55°C.

Active components: all solid-state.

Accessories furnished: calibrator adapter (HP Part No. 01802-63201).

Price: HP Model 1802A, $1,200.



1820B

1822A

Model 1820B Time Base has sweep speeds to 5 ns/div (using mainframe magnifier) and triggering capability to 150 MHz. A trigger hold-off control allows easy triggering on complex waveforms.

Model 1822A has the same basic features as the 1820B, i.e., 5 ns sweep, 150 MHz triggering, and trigger hold off. In addition, it provides a delayed sweep to allow viewing of a waveform at a faster sweep speed.

Specifications, 1820B

Sweep

Ranges: 0.05 μs/div to 2 s/div (24 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: with uncalibrated light; continuously variable between ranges; extends slowest sweep to at least 5 s/div.

Magnifier: (on mainframe) expands fastest sweep to 5 ns/div.

Triggering

Normal

Internal: see vertical amplifier plug-in specifications.

External: dc to 100 MHz on signals 0.25 V pk-pk or more, increasing to 150 MHz on 1 V pk-pk or more.

Line: selectable, from line frequency.

Automatic: bright baseline displayed in absence of input signal. Same as Normal except low frequency limit is 40 Hz.

Single sweep: selectable by front panel switch; reset push button with armed indicator light.

Trigger level and slope

Internal: at any point on the vertical waveform displayed.

External: continuously variable from +3 V to −3 V on either slope of the sync signal; from +30 V to −30 V in ÷ 10 setting.

Coupling: front panel selection of ac, dc, ac fast (ACF), or ac slow (ACS). AC attenuates signals below approx. 20 Hz; ACF attenuates signals below approx. 15 kHz; ACS attenuates signals above approx. 30 kHz.

Variable hold off: time between sweeps continuously variable, exceeding one full sweep at 50 ms/div and faster. Prevents multiple triggering on signals that have desired triggering level and slope occurring more than once per cycle.

Weight: net, 2¾ lbs (1,3 kg); shipping, 5½ lbs (2,4 kg).

Price: HP Model 1820B, $525.

OSCILLOSCOPES 180 SYSTEM *continued*

Time base triggering to 150 MHz
Models 1820B, 1822A

Specifications, 1822A

Main time base

Sweep

Ranges: 0.05 μs/div to 1 s/div (23 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: with uncalibrated light; continuously variable between ranges; extends slowest sweep to at least 2.5 s/div.

Magnifier: (on mainframe) expands fastest sweep to 5 ns/div.

Sweep mode

Normal: sweep is triggered by an internal, external, or power line signal.

Automatic: bright baseline displayed in absence of input signal. Same as Normal except low frequency limit is 40 Hz.

Single: sweep occurs once with same triggering as Normal; reset spring-return switch with indicator light.

Triggering

Internal: see vertical amplifier plug-in specifications.

External: from dc to 100 MHz on signals 250 mV pk-pk or more, increasing to 150 MHz on 1 V pk-pk or more.

Line: selectable on power line frequency signal.

Level and slope: internal, at any point on the vertical waveform displayed. External, continuously variable from +3 V to −3 V on either slope of the sync signal; from +30 V to −30 V in ÷ 10 setting.

Coupling: front panel selection of ac, dc, ac fast (ACF), or ac slow (ACS). AC attenuates signals below approx. 20 Hz; ACF attenuates signals below approx. 15 kHz; ACS attenuates signals above approx. 30 kHz.

Variable hold off: time between sweeps continuously variable, exceeding one full sweep at 50 ms/div and faster. Prevents multiple triggering on signals that have desired triggering level and slope occurring more than once per cycle.

Trace intensification: used to set up Delayed or Mixed time base. Intensifies that part of Main time base to be expanded to full screen on Delayed time base. Moving Delayed sweep switch from Off position activates intensified mode. Front panel adjust sets relative intensity of brightened segment.

Delayed time base: delayed time base sweeps after a time delay set by Main time base and Delay controls.

Sweep

Ranges: 0.05 μs/div to 50 ms/div (19 positions) in 1, 2, 5 sequence. ±3% accuracy with Vernier in calibrated position.

Vernier: with uncalibrated light; continuously variable between ranges; extends slowest sweep to at least 125 ms/div.

Triggering: applies to intensified Main, Delayed, and Mixed time base triggering.

Internal: same as Main time base triggering.

Automatic: delayed sweep is automatically triggered at end of set delay time.

External: same as Main time base triggering.

Level and slope: same as Main time base triggering.

Coupling: same as Main time base triggering.

Delay (before start of Delayed time base)

Time: continuously variable from 0.05 μs to 10 s.

Accuracy: ±1%. Linearity, ±0.2%. Time jitter is less than 0.005% (1 part in 20,000) of maximum delay of each step.

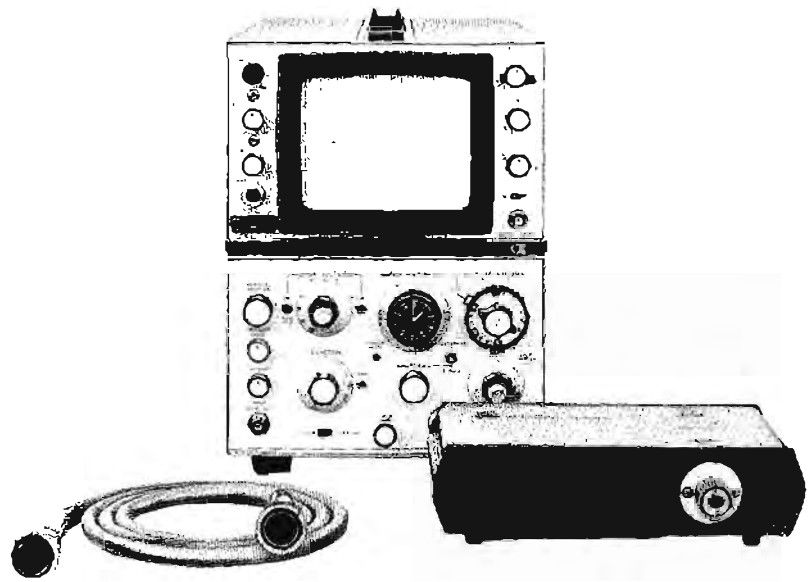
Trigger output: (at end of Delay time) approximately 1 V with less than 50 ns risetime from 1000-ohm source resistance.

Mixed time base: dual time base in which Main time base drives first portion of display and delayed time base completes sweep at up to 1000 times faster. May be operated in single sweep mode.

Weight: net, 3¾ lbs (1,7 kg); shipping, 6½ lbs (2,8 kg).

Price: HP Model 1822A, $900.

35 ps TDR/12.4 GHz sampling
Models 1815A, 1816A, 1817A



1815A 1816A 1817A

Calibrated 35 ps risetime time domain reflectometery and 12.4 GHz (28 ps risetime) sampling capabilities are now available as part of the versatile 180 system oscilloscope.

The Model 1815A TDR/Sampler plug-in, a double-sized plug-in for the 180 system, can be combined with appropriate remote sampler head and tunnel diode mount to obtain a calibrated TDR system which is three times faster than was previously available, providing considerably greater resolution. A direct readout in feet along the line (or in meters as Option 001) is obtained from the Model 1815A. Either Model 1106A (20 ps) or Model 1108A (60 ps) tunnel diode mount is compatible for TDR with the plug-in and samplers.

These same plug-in and sampler heads used for TDR measurements also serve as either a 4 GHz or 12.4 GHz sampling system with a direct readout in time. For sampling use, there is direct triggering to 500 MHz and to 18 GHz with Model 1104A/1106A trigger countdown.

Sampling heads, Model 1816A (90 ps risetime) and Model 1817A (28 ps risetime), are detachable, remote, single channel, feed-through samplers for convenient use in 50-ohm transmission systems. The plug-in and sampler heads provide the circuitry for operating the tunnel diode pulse generators.

Several new circuit techniques contribute to this new standard of versatility and accuracy. These include:

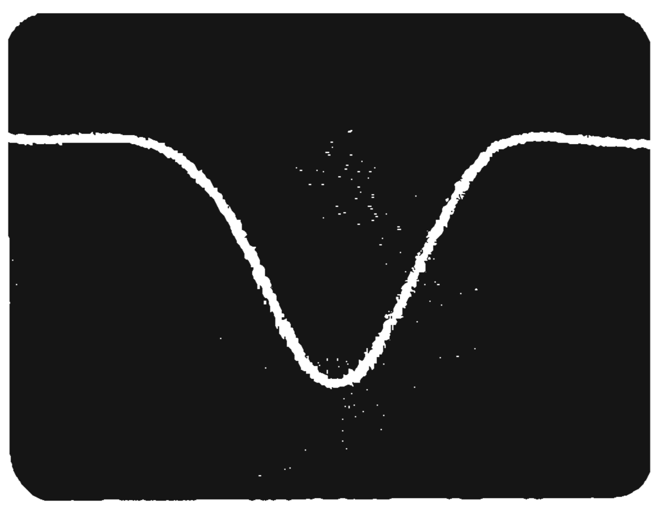
1. A new circuit for generating the sampling pulses, which is inherently far more stable with temperature variations.

2. A signal-averaging circuit (superseding the previous smoothing technique) which reduces noise and jitter by a ratio of 2:1 or more. This technique does not degrade risetime performance, with only a slight decrease in display rate. Performance can be fully optimized even with slow display rates by use of the Model 181A/AR variable persistence and storage mainframe.

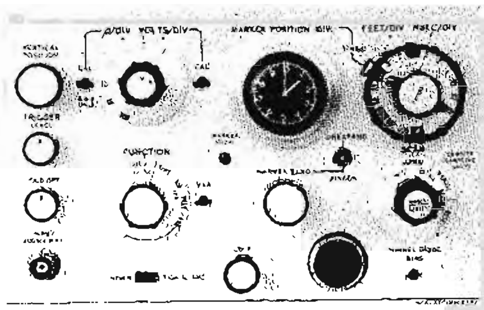
3. Unique marker zero which shifts reference of calibrated marker position to any point on the display. This permits direct read-out of differential time or distance measurements.

4. Electronic delay circuit which keeps the leading edge of a step function on-screen over all sweep speeds and for a wide ambient temperature range.

This calibrated TDR system allows analysis of coaxial microwave components, identifying discontinuities on the order of 0.25 inch apart. Typical components that can be analyzed are connectors, adapters, coaxial-to-circuit board transitions, loads, etc. Direct read-out in reflection coefficient, feet, or meters (optional) makes measurements faster and easier to interpret. Front panel calibration for air and polyethylene dielectrics is standard. In addition, the control allows variable calibration for different dielectrics from $\epsilon = 1$ to $\epsilon =$ approx. 4.



CRT display using Model 1815A/1817A/1106A TDR system shows the reflection from HP Model 874B Susceptance Standard set at 1 pF equivalent capacitive discontinuity. Scale: 20 ps/div horizontal, 0.1 ρ/div vertical.



1815A

Specifications, 1815A
TDR/sampler plug-in

Unless indicated otherwise, TDR and sampling performance specifications are same. Where applicable, TDR specification is given first, followed by Sampler specification in parentheses.

Vertical

Scale: reflection coefficient ρ (volts) from 0.005/div to 0.5/div in 7 calibrated ranges; 1, 2, 5 sequence.

Accuracy: ±3%; TDR only, ±5% on 0.01/div and 0.005/div in signal average mode.

Vernier: provides continuous adjustment between ranges; extends scale to greater than 0.002/div.

Signal average: reduces noise and jitter approx. 2:1.

Horizontal

Scale: round-trip time or distance (time) in four calibrated decade ranges of 1/div, 10/div, 100/div, and 1000/div. Concentric expand control provides direct read-out in 28 calibrated steps in 1, 2, 5 sequence from 0.01 ns/div to 1000 ns/div or from 0.01 feet/div to 1000 feet/div (0.01 ns/div to 1000 ns/div).

Accuracy: time, ±3%; distance, TDR only, ±3% ± variations in propagation velocity.

Marker position: ten-turn dial, calibrated in divisions; provides direct read-out of round-trip time or distance (time), number of divisions X decade range in units/div.

Marker zero: ten-turn control provides variable reference for marker position dial; allows direct read-out of round-trip time or distance (time) between two or more displayed events.

Zero finder: permits instant location of marker reference.

Dielectric, TDR only: calibrated for air, $\epsilon = 1$, and for polyethylene, $\epsilon = 2.25$. Also provides variable settings for dielectric constants from $\epsilon = 1$ to $\epsilon =$ approx 4.

Triggering, sampling only:

Pulses: less than 50 mV for pulses 5 ns or wider for jitter <20 ps.

CW: signals from 500 kHz to 500 MHz require at least 80 mV for jitter less than 2% of signal period plus 10 ps; usable to 1 GHz. CW triggering may be extended to 18 GHz with HP Models 1104A/1106A trigger countdown.

Recorder outputs: approx. 100 mV/div; vertical and horizontal outputs at BNC connectors on rear panel of mainframe.

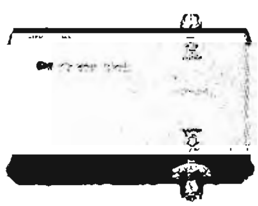
Display modes: repetitive scan, normal or detail; single scan; manual scan; record.

Weight: net, 5 lbs (2,3 kg); shipping, 10 lbs (4,5 kg).

Option 001: distance calibrated in meters. Price: Model 1815A Option 001, on request.

Price: HP Model 1815A, $1100.

Samplers and tunnel diodes



1817A

1816A

Specifications, 1817A and 1816A
28 ps and 90 ps samplers

Unless indicated otherwise, Model 1817A and Model 1816A specifications are same. Where applicable, Model 1817A specification used with Model 1106A tunnel diode mount is given first, followed by Model 1816A specification (in parentheses) used with Model 1108A tunnel diode mount.

TDR system

System risetime: less than 35 ps (110 ps) incident as measured with Model 1106A (Model 1108A).

Overshoot: less than ±5%.

Internal reflections: less than 10% with 45 ps (145 ps) TDR; use reflected pulse from shorted output.

Jitter: less than 15 ps; with signal averaging, typically 5 ps.

Internal pickup: $\rho \leq 0.01$.

Noise: measured tangentially as a percentage of the incident pulse when terminated in 50Ω and operated in signal averaging mode. Less than 1% (0.5%) on 0.005/div to 0.02/div; less than 3% (1%) on 0.05/div to 0.5/div.

Low frequency distortion: ≤ ±3%.

Maximum safe input: 1 volt.

Sampler system

Risetime: less than 28 ps (90 ps)

Input: 50Ω feed-through.

Dynamic range: 1 volt.

Maximum safe input: 3 volts (5 volts).

Low frequency distortion: ≤ ±3%.

Noise:

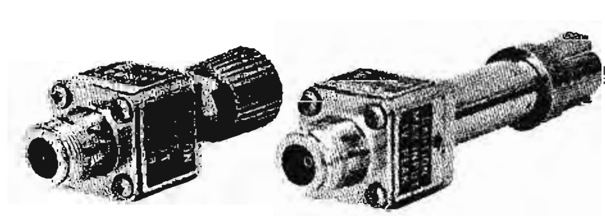
Normal: less than 8 mV (3 mV) tangential noise on 0.01 V/div to 0.5 V/div. Noise decreases automatically on 0.005 V/div.

Signal average: reduces noise and jitter approx. 2:1.

Tunnel diode mount: direct connection for either Model 1106A or Model 1108A tunnel diode mount for TDR system.

Weight: net, 3 lbs (1,4 kg); shipping, 7 lbs (3,2 kg).

Price: HP Model 1817A, $1500; HP Model 1816A, $800.



1106A 1108A

Specifications, 1106A and 1108A
20 ps and 60 ps tunnel diode mounts

Tunnel diode mount connects directly to sampler head for TDR system.

Amplitude (both): greater than 200 mV into 50Ω.

Risetime: Model 1106A, approx. 20 ps; Model 1108A, less than 60 ps.

Output impedance: 50Ω ±2%.

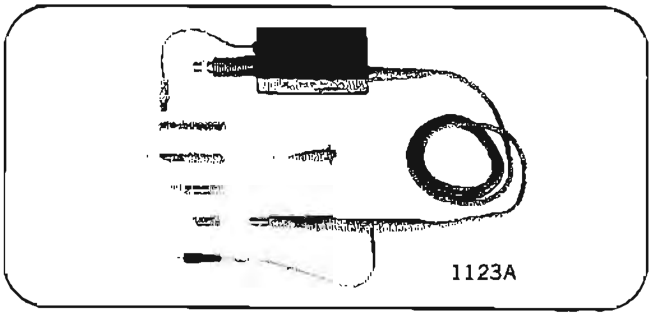
Source reflection: Model 1106A, less than 10% with 45 ps TDR; Model 1108A, less than 10% with 145 ps TDR.

Weight (both): net, 1 lb (0,5 kg); shipping, 3 lbs (1,4 kg).

Price: HP Model 1106A, $550; HP Model 1108A, $175

Accessories

Probes and probe accessories



Model 1123A Active Probe

For probing high source impedances at high frequencies, the Model 1123A should be used to apply input signals to the Model 1802A 100 MHz plug-in. This X1 active probe has very low drift and noise, and provides an input RC of 100 k ohms and only 3.5 pF. Divider tips, blocking capacitors, and other convenient accessories are supplied.

Specifications, 1123A

Bandwidth: dc to greater than 220 MHz (3 dB down).

Pulse response

Risetime: <1.6 ns (10% to 90%), over full dynamic range.

Overshoot, ringing, perturbations: 4% pk-pk with Model 1802A (dc to 100 MHz); 6% pk-pk with 1 GHz system. (Probe must be properly terminated in 50 ohms.)

Gain: adjustable to X1 into 50-ohm load.

Dynamic range

At output: ±0.5 V peak.

At input: ±0.5 V peak around a reference voltage which can be offset with variable control from 0 to ±0.5 V dc.

Noise: increases noise level by less than 300 μV pk-pk when used with Model 1802A (dc to 100 MHz).

Drift

Probe tip assembly: less than 100 μV/°C.

Amplifier assembly: less than 1 mV/°C.

Input impedance: 100 k ohms shunted by less than 3.5 pF.

Output impedance: 50 ohms.

Maximum input: ±50 V (dc + peak ac).

Weight: net, 2¼ lbs (1,0 kg); shipping 4¼ lbs (1,9 kg).

Power: supplied by Model 1802A plug-in. HP Model 1122A Power Supply may be used to power up to four Model 1123A Active Probes.

Length: over-all length is approx. 4½ feet.

Accessories furnished

Model 10214A 10:1 divider: increases input impedance to 1 megohm shunted by approx. 3 pF. Increases input dynamic range to ±5 V and maximum input voltage to ±350 V (dc + peak ac). Divider accuracy, ±5%.

Model 10215A 100:1 divider: increases input impedance to 1 megohm shunted by approx. 3 pF. Increases input dynamic range to ±50 V and maximum input voltage to ±500 V (dc + peak ac). Divider accuracy, ±5%.

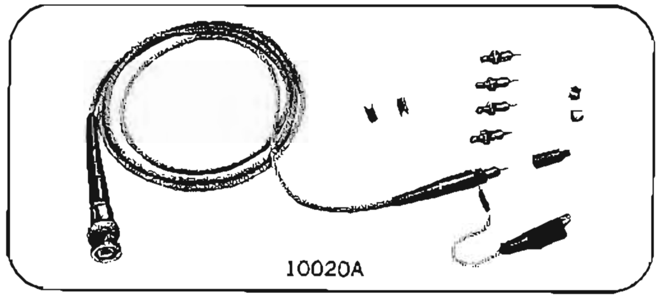
Model 10217A blocking capacitor: provides 0.001 μF, ac-coupling with lower cutoff of 1.6 kHz, or 160 Hz when using divider. Add less than 3 pF shunt capacitance; maximum input voltage ±50 V (dc + peak ac), or ±200 V (dc + peak ac) when using divider.

Model 10228A blocking capacitor: provides 0.18 μF, ac-coupling with lower cutoff of 12 Hz, or 1.2 Hz when using divider. Adds less than 25 pF shunt capacitance; maximum input voltage ±50 V (dc + peak ac), or ±200 V (dc + peak ac) when using divider.

Model 10229A hook tip: may be used for circuit probing directly or with dividers and blocking capacitors.

Also included: Model 1123A also includes ground leads, spare tips, and solder sockets; a storage case is provided for the probe and its accessories.

Price: HP Model 1123A (including accessories), $325.



Resistive dividers

Model 10020A miniature resistive dividers facilitate signal measurement with Model 1802A 100 MHz plug-in for low source impedances. Dividers allow matching various source impedances, all with just 0.7 pF of shunt capacitance.

Division Ratio	Input R* (ohms)	Division Accuracy	Max. V† (rms)	Input C (pF)
1:1	50		6	
5:1	250	±3%	9	0.7
10:1	500	±3%	12	0.7
20:1	1000	±3%	15	0.7
50:1	2500	±3%	25	0.7
100:1	5000	±3%	35	0.7

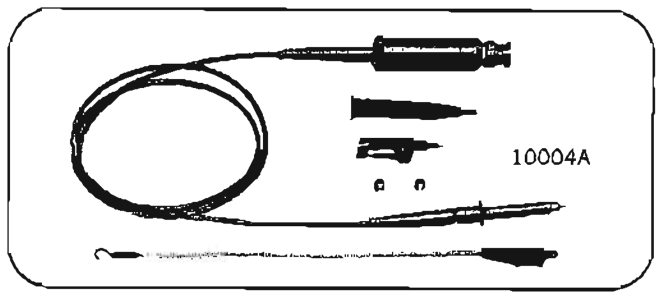
*When terminated in 50 ohms.
†Limited by power dissipation of resistive element.

Accessories furnished: Model 10218A BNC adapter tip, 4-ft. cable, a 6-32 adapter tip, ground leads, and Model 10240B blocking capacitor.

Weight: net 1 lb (0,5 kg); shipping, 3 lbs (1,4 kg).

Price: HP Model 10020A, $100.00.

For Model 10201A-D resistive dividers (0.4 pF), see page 523.



Divider Probes

These miniature, lightweight, 10:1 probes reduce loading on the circuit under test while maintaining full bandwidth capability of the oscilloscope. They may be used with any oscilloscope having an input RC of 1 megohm shunted by between 15 to 30 pF. A thumbwheel adjustment on the probe boot permits compensation for optimum step response. Each probe includes slip-on pincer tip, spanner tip, and ground lead.

Model 10004A	Model 10006A	Model 10005A
Length: 3½ feet	Length: 6 feet	Length: 10 feet
Capacitance: 10 pF	Capacitance: 14 pF	Capacitance: 17 pF
Price: $35.00	Price: $40.00	Price: $45.00

BNC Tip

Model 10011A BNC Tip for Models 10004A, 10005A, 10006A probes. Price: $8.00.

Probe Tip Kits

Probe Tip Kits, Models 10036A and 10037A, extend usefulness of 10004A, 10005A, and 10006A probes. Model 10036A consists of an assortment including tips for the following: 0.08-inch jack; 0.025- and 0.045-inch square pin; 0.040- and 0.062-inch dia. pin; and a long pin tip. Model 10037A contains six 0.025-inch square-pin tips. Price: Model 10036A, $20.00; Model 10037A, $15.00.

Testmobiles

Three different testmobiles are available for use with the 180 system. For description and specifications see page 550.

Oscilloscope camera

Oscilloscope cameras and accessories are available for permanent records of oscilloscope waveforms. For description and specifications see pages 551-553.

Panel Cover

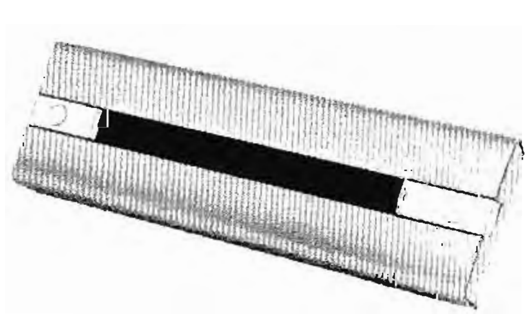
Carrying Cover

Model 10166A Panel Cover

The Model 10166A panel cover, made of fiberglass material, provides protection to the front panel controls of the Model 180A or 181A. Panel cover also provides space for probe and accessory storage. Price: $25.00.

Model 10167A Carrying Case

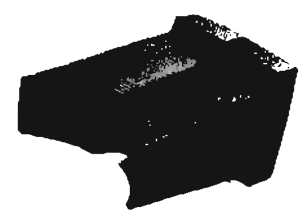
The Model 10167A Carrying Cover, made of flexible vinyl material, fits over the cabinet Model 180A or 181A. The top of the cover is slotted for access to the carrying handle. Price: $20.



Panel Cover

Panel cover

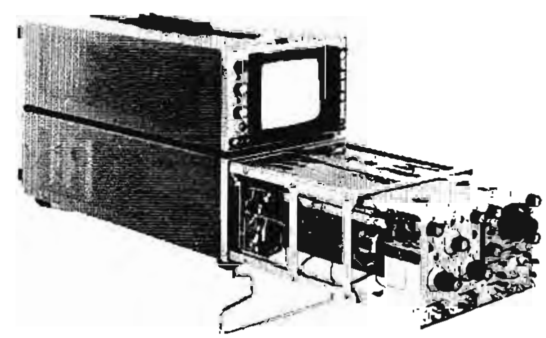
Cover for 180AR or 181AR protects panel from dust and accidental damage. May be used on the instrument whether rack mounted or when carried as a portable instrument. Price: HP Part No. 5060-0437, $25.00.



Viewing Hood

10176A Viewing Hood

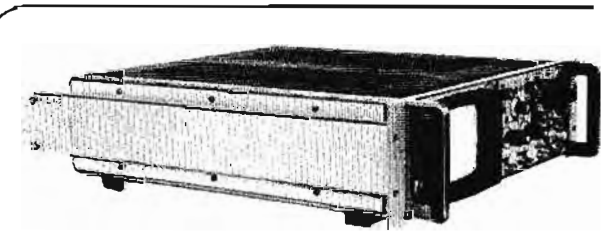
The Model 10176A viewing hood is a face-fitting, vinyl mask to aid in viewing fast transients. Price: $7.00.



Plug-in Extender

Plug-in extender

The plug-in extender, HP Model 10407A, is available to allow calibration and maintenance of the plug-ins, while the unit is operating. Price: $65.00.



Slide Adatper

Slide adapter

Both fixed and pivoted 22-inch slides are available for slide mounting the 180AR/181AR. Price: HP Part No. 00180-93006 slide adapter (required for either slide), $22.50; HP Part No. 1490-0714 fixed slides, $32.50; HP Part No. 1490-1719 pivoted slides, $37.50.

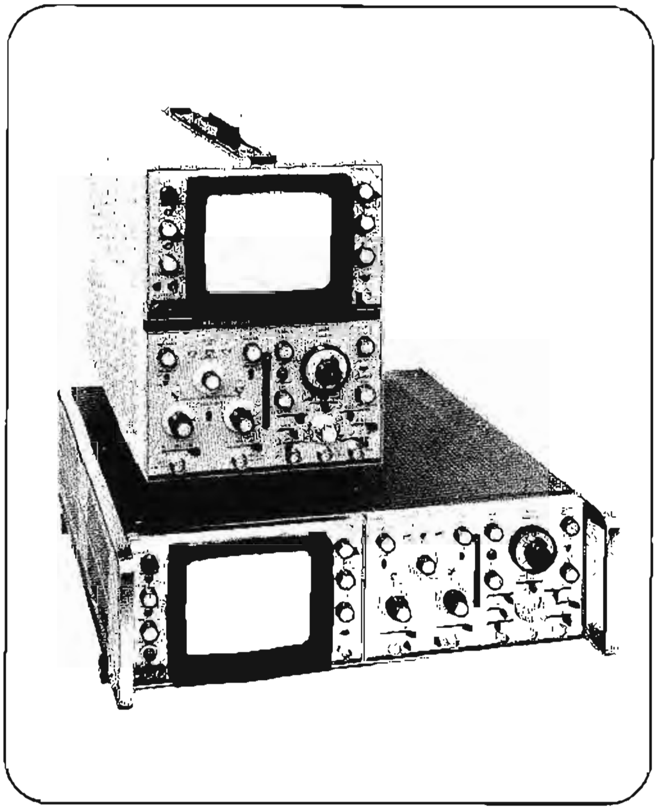
Blank plug-ins

Blank plug-ins are available for either vertical or horizontal compartments in the mainframe. Also available is a double-size blank plug-in. Price: K01-1801A (vertical), $65.00; K01-1821A (horizontal), $65.00; K53-180A (double), $65.00.

RUGGEDIZED OSCILLOSCOPES

Designed to meet military requirements

AN/USM-281 (cabinet), AN/USM-296 (rack)



- Operating altitude to 25,000 feet.
- Vibration 0.010 to 0.060 D.A., 5-33 Hz.
- Shock to Mil-S-901C Class I (400-pound hammer drop).
- Operating humidity to 95% at 65°C.
- RFI protection to Mil-I-6181D and Mil-I-16910C Class I.

Now the HP Model 180E offers you the solution to an age-old problem: to provide a highly accurate, versatile, lightweight, general-purpose oscilloscope which will meet the rigid requirements of military operations. The 180E is fully specified for electrical performance as well as environmental performance.

In the past, the military user has had to sacrifice electrical performance in order to have an instrument rugged enough to withstand extreme environments. The 180E meets all electrical performance specifications of the 180A, but offers unexcelled environmental performance.

The complete system, including 180E mainframe, 1801E vertical amplifier plug-in, 1821E time base plug-in, and the 10164A front panel cover, may be ordered through a government contract only as the AN/USM-281. The system is also available under Federal Stock Number 6625-053-3112. A rack version is also available using the 180ER mainframe. Military designation for the rack system is AN/USM-296. Alternatively, the individual items may be ordered by HP Model Number (see cross-reference table).

Description	MIL designation	HP Model No	Price
Portable cabinet system with PL-1186, PL-1187, CW-946	AN/USM-281	E02-180E	$3,100
Rack-mount system with PL-1186, PL-1187	AN/USM-296	E02-180ER	2,925
Portable oscilloscope	OS-189 (P)/USM-281	180E	1,215
Rack-mount oscilloscope	OS-194 (P)/USM-296	180ER	1,205
Dual channel vertical amplifier	PL-1186	1801E	800
Time base and delay generator	PL-1187	1821E	920
Time base	PL-1213	1820E	570
Panel covers with probes and accessories	CW-946/USM-281	10164A	165*

*If other probes than those normally supplied are desired, order 10164A Option 01 and subtract $65. Then select appropriate probes as separate items.

Environmental specifications

(Refer to 180A for electrical specifications.)

Temperature operating −28°C to +65°C

The instrument shall be operated at the maximum temperature for at least 16 hours. A complete performance test shall be made at the end of this heat run.

The instrument shall be allowed to stabilize at least 1 hour at the minimum temperature with the power off. It shall then be turned on and a complete performance test performed after a 30-minute warm-up.

Temperature nonoperating −62°C to +85°C

The instrument, nonoperating, is placed in the test chamber. The chamber is reduced to the minimum temperature and held for at least 72 hours. It is then raised to room ambient and a complete performance test performed after a 30-minute warm-up. The procedure is repeated with the test chamber held at the maximum temperature for at least 48 hours.

Humidity/temperature −28°C to +65°C at humidities to 95%

In order to comply with a greater number of military specifications, two different temperature/humidity tests were conducted. In test No. 1, instrument was operating throughout test, and performance tests made at various temperatures from −28°C to +65°C with the humidity constant at 95% (except uncontrolled at temperatures below +5°C) for cycle 1 and repeated for 4 additional 35 hour cycles at humidities of 90%, 75%, 50% and 25%. In test No. 2 instrument nonoperating except during test period at end of each of ten 24 hour cycles (no dry out period) consisting of subjecting the instrument to temperatures from +20°C to +65°C at a constant humidity of 95%.

Altitude operating 25,000 feet

The instrument operating shall be subjected to a pressure of 11.1 inches of mercury (temperature and humidity uncontrolled) for at least 1 hour. A performance test shall be conducted at this pressure. The pressure, with the instrument still operating, shall be increased to normal ground. At the completion of this test the instrument shall pass a complete performance test.

Altitude nonoperating 50,000 feet

The instrument, nonoperating, shall be subjected to a pressure of 3.4 inches of mercury (temperature and humidity uncontrolled) for at least 1 hour.

The pressure shall then be increased to normal ground and the instrument shall pass a complete performance test.

Vibration 5 to 33 Hz

Instrument shall be subjected to vibration as follows for at least 5 minutes at each frequency. If a resonant frequency is found, the instrument shall be vibrated at that frequency for at least 2 hours.

Frequency	Amplitude
5-14 Hz	0.060 D.A.
15-25 Hz	0.040 D.A.
26-33 Hz	0.020 D.A.

Repeat in all three planes, and at the conclusion of the test conduct a complete performance test.

Shock

AN/USM-281 (E02-180E)

Passed MIL-S-901C Grade A; No. 400 hammer at 1-, 3-, 5-foot drops in 3 planes.

AN/USM-296 (E02-180ER)

10 G's for 11 ±1 milliseconds to each of the 6 sides method as per MIL-E-4970A Procedure II (sandbox).

Both models

Each edge raised 15° or 4", whichever is greater, from solid table top and dropped. Four drops per edge.

At the conclusion of the shock test the instrument shall pass a complete performance test.

EMC MIL-I-16910C and MIL-I-6181D

Tests were conducted according to two military specifications MIL-I-16910C class 1 and MIL-I-6181D. Both specifications were met completely. In keeping with the requirements of these specifications the following conditions apply: no input signal applied, oscilloscope in CHOP mode, intensity bright, and RFI filter on face of CRT.

Reliability (MTBF) 5000 hrs (MIL HDBK 217)

5 oscilloscopes were randomly selected from finished stock and given a complete evaluation. All instruments were then cycled 6 hrs. on, 2 hrs. off. Every 24 hrs., four of the oscilloscopes were given a performance check and the fifth one a complete evaluation (instrument receiving complete evaluation was rotated each day). When each instrument had accumulated 1000 hrs. of operating time the test was terminated, with each instrument receiving a complete evaluation. One random failure was noted during the test. The 100-volt regulator in one oscilloscope failed to fire when turned on at low line. Normal line operation was satisfactory. No recalibration was allowed during any part of the test. Using this information (5000 total hrs. and 1 failure) and referring to MIL HDBK 217, the MTBF is 5000 hrs.

Line voltage and frequency variation

115 V/230 V ±10% at 50-400 Hz.
Power consumption—less than 110 watts with plug-ins.

Package drop

20 Gs (22 milliseconds duration) on each of eight corners.
38 Gs (22 ms duration) on bottom.

AN/USM 281 (180 E SYSTEM)									
• CONFORMS COMPLETELY * NOT SPECIFICALLY TESTED TO MEET THIS SPECIFICATION	MIL-STD-810A GROUND	MIL-T-21200F CLASS 3	MIL-E-16400F CLASS 2/4	MIL-E-4158C OUTDOOR EQUIP.	MIL-E-4158C INDOOR EQUIP.	MIL-E-4970A PROC. 3	MIL-F-18870C CLASS 4-5	MIL-S-8512B PROC. 3	MIL-E-11991B GROUND
TEMP. NON-OPER.	•	•	•	•	•	•	•	•	•
TEMP. OPER.	N/A	•	•	*	•	•	•	•	N/A
ALTITUDE OPER.	•	•	N/A	•	•	•	•	•	•
ALTITUDE NON-OPER.	•	•	N/A	•	•	•	•	•	•
HUMIDITY	*	*	•	•	•	•	•	•	*
VIBRATION	*	•	•	N/A	N/A	*	•	•	*
SHOCK	•	*	•	N/A	N/A	•	•	•	•
EMC	N/A	•	•	•	•	N/A	N/A	•	•
POWER LINE REQ.	N/A	•	•	•	•	N/A	N/A	N/A	•
PACKAGE DROP	•	•	N/A	N/A	N/A	N/A	N/A	N/A	•
AN/USM-296 (180 ER SYSTEM)									
TEMP. NON-OPER.	•	•	•	•	•	•	•	•	•
TEMP. OPER.	N/A	•	•	*	•	•	•	•	N/A
ALTITUDE OPER.	•	•	N/A	•	•	•	•	•	•
ALTITUDE NON-OPER.	•	•	N/A	•	•	•	•	•	•
HUMIDITY	*	*	•	•	•	•	•	•	*
VIBRATION	*	•	•	N/A	N/A	*	•	•	*
SHOCK	•	*	*	N/A	N/A	•	*	•	•
EMC	N/A	•	•	•	•	N/A	N/A	•	•
POWER LINE REQ.	N/A	•	•	•	•	N/A	N/A	N/A	•
PACKAGE DROP	•	•	N/A	N/A	N/A	N/A	N/A	N/A	•

PROBES

Versatile line of probes for all applications

When used with any of the following instruments, these Hewlett-Packard probes do not degrade the specified performance of the oscilloscope or plug-in. These probes may be quickly and accurately compensated for optimum step response.

	120B	122A/AR	130C	132A	1200 series	140 system	180 system (except 1802A)
10001A,B	●	●	●	●	●	●	
10002A	●	●	●	●	●	●	
10003A	●	●	●	●	●	●	●
10004A							●
10005A							●
10006A							●
10012A	●	●	●	●	●	●	
10025A	●	●	●	●	●	<500 kHz	

Voltage divider probe specifications

Model No.	Over-all Length	Divider Atten.	Resistance MΩ	Capacitance	Compensation Range(pF)	Peak Volts	Division Accuracy	Price
10001A	5′	10:1	10	10 pF	15-55	600	2%	$30
10001B	10′	10:1	10	20 pF	15-45	600	2%	$35
10002A	5′	50:1	9	2.5 pF	15-55	1000	3%	$40
10003A	4′	10:1	10	10 pF	15-55	600	2%	$30
10004A	3.5′	10:1	10	10 pF	15-30	500	3%	$35
10005A	10′	10:1	10	17 pF	15-30	500	3%	$45
10006A	6′	10:1	10	14 pF	15-30	500	3%	$40
10012A	6′	10:1	10	16 pF	30-55	500	3%	$35
10025A	6′	1:1	—	150 pF	—	600	—	$15

Probe accessories

Probe tips

For probes 10001A-10003A: Model 10035A kit contains pincer jaw, banana tip, pin tip, hook tip, and spring tip. Price: Model 10035A, $5. Model 10010C BNC adapter tip. Price: Model 10010C, $10.

For probes 10004A-10006A and 10012A: furnished with each probe are: slip-on pincer tip, spanner tip, and ground lead.

Model 10036A kit contains spring tips for 0.08 inch jack; 0.025 and 0.045 inch square pin; 0.040 and 0.062 inch dia. pin, and a long pin tip. Price: Model 10036A, $20.

Model 10037A kit contains six spring tips for 0.025 inch square pins. Price: Model 10037A, $15.

Model 10011A BNC adapter tip. Price: Model 10011A, $8.

Terminations

Model 10100A 50 ohm feed-through, $15.

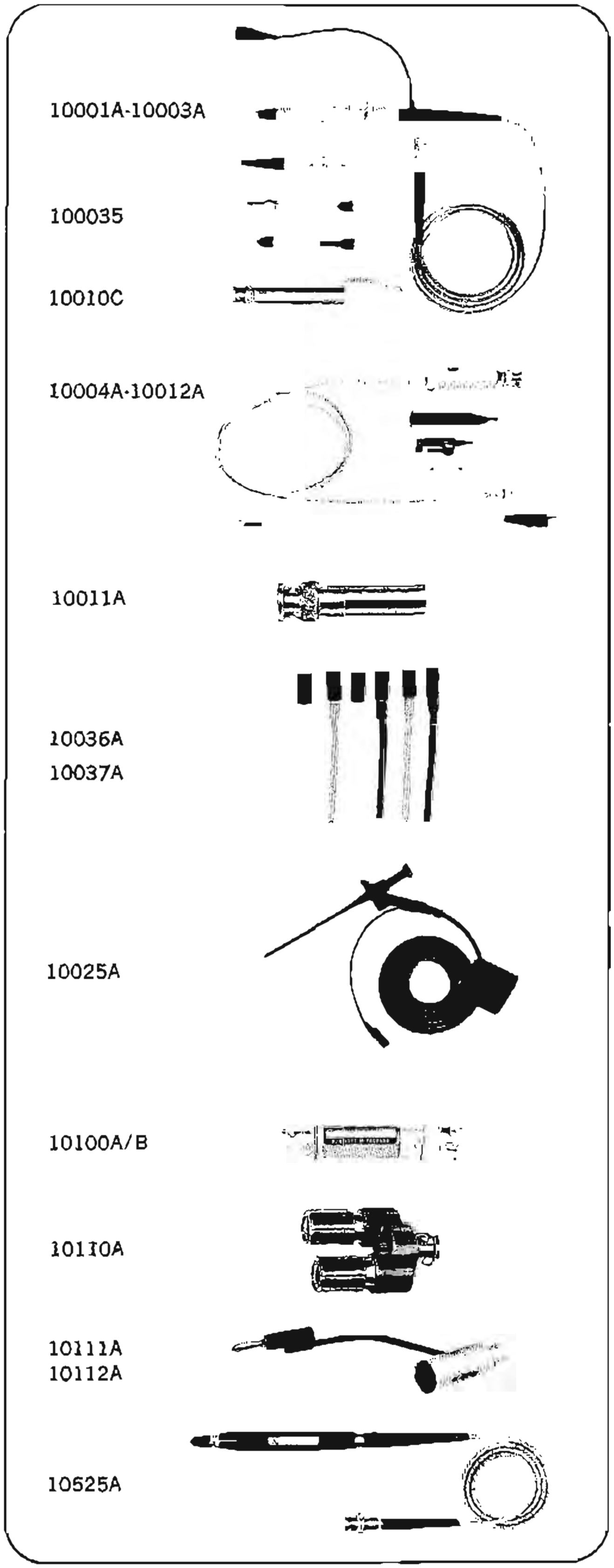
Model 10100B 100 ohm (±2 ohm) feed-through for 1110A current probe. Price: Model 10100B, $18.

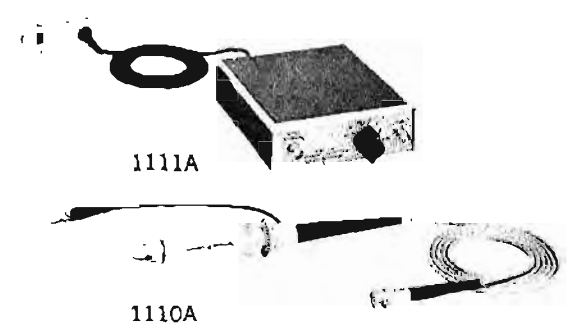
Adapters

Model 10110A male BNC to dual female banana post. Price: Model 10110A, $5.

Model 10111A female BNC to shielded banana post. Price: HP Model 10111A, $7.

Model 10112A miniature female BNC to shielded banana post. For use with 1200 series oscilloscopes. Price: HP Model 10112A, $7.





1111A

1110A

Special purpose probes

Current probe

With the HP Model 1110A Current Probe you can observe fast-rise, ac current waveforms on any wideband oscilloscope.

Specifications, 1110A

Sensitivity: 1 mV/mA.

Accuracy: ±3%.

Bandwidth: lower limit: 1700 Hz (850 Hz with Model 10100B 100-ohm termination). Upper limit: inversely proportional to capacitance of load: 4 pF load, 45 MHz, 7 ns risetime; 30 pF load: 35 MHz, 9 ns risetime.

Maximum dc current: 0.5 ampere.

Maximum ac current: 15 amperes pk-pk above 4 kHz; decreasing below 4 kHz at the rate of 3.8 A/kHz (30 A pk-pk max. with Model 10100B 100 ohm termination).

Insertion impedance: approximately 0.01 ohm, shunted by 1 μH; capacitance to ground is less than 3 pF.

Dimensions: aperature 5/32" (4 mm) dia; 5 ft cable.

Price: HP Model 1110A, $100.

Accessory available: Model 10100B 100-ohm feed-through termination; decreases sensitivity to 0.5 mV/mA, lower cut-off to 850 Hz, increases maximum ac current to 30 A pk-pk above 4 kHz; price, $18.

Current probe amplifier

The Model 1111A Amplifier *increases* the 1110A Probe sensitivity and extends low frequency response. When used with a 50 mV/cm sensitivity oscilloscope, the Model 1111A attenuator indicates directly in mA/cm on the CRT thus eliminating cumbersome conversion factors.

Specifications, 1110A with 1111A

Sensitivity: 1 mA/cm to 50 mA/cm in X1, and 100 mA/cm to 5 A/cm in X100 (1, 2, 5 sequence when used with an oscilloscope at 50 mV/cm sensitivity).

Accuracy: ±3% on 50 mA/cm sensitivity and below; ±4% on 100 mA/cm sensitivity and above (when Models 1110A and 1111A are calibrated together).

Bandwidth: 50 Hz to 20 MHz (18 ns risetime).

Noise: less than 100 μA pk-pk, referred to input.

Maximum ac current: 50 A pk-pk above 700 Hz decreasing below 700 Hz at the rate of 1.4 A/20 Hz.

Output impedance: 50 ohms.

Dimensions: amplifier: 1½" high, 5⅛" wide, 6" deep (38 x 130 x 150 mm).

Weight: Model 1111A: net, 2 lbs (0,9 kg); shipping, 3 lbs (1,4 kg).

Power: 115 or 230 V ±10%, 50 to 1000 Hz, approx 1.5 W.

Price: Model 1111A, $160.

TTL logic probe*

Here's a timesaver (picture on preceding page) for design and trouble-shooting of TTL and DTL logic and systems. The tip of the 10525A flashes brightly for 0.1 s to clearly indicate presence of single pulses as short as 30 ns (negative pulses produce momentary extinction). It lights to partial brilliance connected to a pulse train, is fully lighted connected to a "high" logic state (>+1.4 V), and extinguishes connected to a "low" logic state. Triggering is automatic; there are no slope or level controls to adjust. The probe is powered from the tested circuit's 5 V supply, or from an HP 6214A or similar power supply.

*Does not connect to oscilloscope.

Specifications, 10525A

Input impedance: 10 kΩ. Trigger threshhold: +1.4 V.

Pulse width sensitivity: 30 ns for ±2 V or greater pulses referenced symmetrically about +1.4 V. Overload protection: −50 to +200 V continuous; −200 to +200 V transient; 120 V ac for 10 s. Power required: (through BNC shown in photo) 5 V ±10%, 75 mA. Temperature: 0 to 55°C. Power connection adapters supplied. Price: on req; quantity discounts available.

Active probe

Model 1123A Active Probe: 1:1 probe with 220 MHz bandwidth, 1.6 ns risetime, 100 k ohms and 3.5 pF input impedance. Powered by either Model 1802A plug-in or Model 1122A power supply. Complete 1123A specifications on page 544.

Probe power supply

Model 1122A power supply powers up to four Model 1123A Active Probes.

Specifications, 1122A

Probe-driving capability: up to four Model 1123A Active Probes.

Dimensions: 5⅛" wide, 3-7/16" high, 11⅝" deep (130 x 87 x 295 mm).

Weight: net, 5¼ lbs (2,4 kg); shipping, 7 lbs (3,2 kg).

Price: HP Model 1122A, $225.

High quality cables

Hewlett-Packard 50-ohm coaxial cables insure faithful transmission of fast-rise, high frequency signals. Mismatch loss is reduced to a minimum by using close tolerance (1%) 50-ohm cable and high quality connectors.

Cable specifications

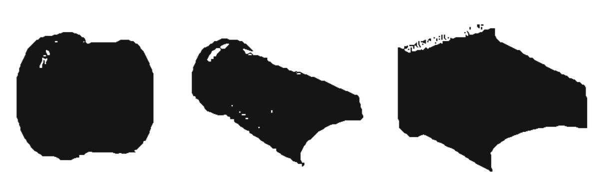
HP Model	Length	Description	Price
10120A	3' (91 cm)	male BNC-to-male BNC	$10
10121A	8" (20.3 cm)	male BNC-to-male BNC	$10
10122A	3' (91 cm)	male BNC-to-male type N	$10
10123A	6' (183 cm)	male BNC-to-male BNC	$11
10124A	9' (274 cm)	male BNC-to-male BNC	$12
10127A	1' (30.5 cm)	GR-to-male BNC	$16
10128A	1' (30.5 cm)	GR-to-female BNC	$16

Viewing hoods

The Model 10175A polarized hood *increases contrast* and reduces glare for viewing dim traces under all ambient light conditions; price, $15.

The Model 10174B hood with removable vinyl face mask is ideal for viewing fast transients; designed for use on Hewlett-Packard round bezels. Price, $15.

Model 10176A flexible viewing hood is for use on rectangular bezels of 1200 series and 180 systems. Price, $7.



10175A 10175B 10176A

TESTMOBILES

Store, transport test equipment conveniently

Models 1116A, 1117B, 1118A, 1119A-D

Hewlett-Packard Testmobiles provide easy, convenient portability of test equipment to multiple test locations. These testmobiles can also be equipped to provide extra storage space for equipment and accessories which will increase test bench working area.

Model 1116A Testmobile

The Model 1116A can be tilted from horizontal to 30° above horizontal, and can also be folded for easy transportation to the test site or for more convenient storage.

Dimensions: 40" high, 20" wide, 24" deep (1016 x 508 x 610 mm).
Weight: net, 34 lbs (15,3 kg); shipping, 42 lbs (18,9 kg).
Price: HP Model 1116A, $95.

Model 1117B Testmobile

The Model 1117B can be equipped as a complete, portable test center. The top instrument tray can be tilted. The front or rear frame can accommodate standard 19 inch RETMA rack panels, with central power distribution to the instruments provided by four standard NEMA plugs on the back panel.

Dimensions: 39" high, 20" wide, 24" deep (991 x 508 x 610 mm).
Weight: net, 85 lbs (38,3 kg); shipping, 117 lbs (52,7 kg).
Price: HP Model 1117B (without drawers), $185.

Model 10475A 3-inch drawer for 1117B

Weight: net, 9 lbs (4,1 kg); shipping, 13 lbs (5,9 kg).
Price: HP Model 10475A, $30.

Model 10476A 8-inch drawer for 1117B

Weight: net, 11 lbs (5 kg); shipping, 25 lbs (11,3 kg).
Price: HP Model 10476A, $35.

Model 1118A Testmobile

The Model 1118A is designed to accept cabinet models of the 180 system or the 1200 series oscilloscopes only. Instrument height may be adjusted from 32 to 42 inches. The legs may be folded for easy carrying or storage.

Dimensions: 32" to 42" high (813 mm to 1067 mm).
Weight: net, 11 lbs (5 kg); shipping, 16 lbs (7,2 kg).
Price: HP Model 1118A, $95.

Model 1119A Testmobile

The Model 1119A, for standard Hewlett-Packard modular instruments, has a unique trunnion mounting that allows the instrument to be rotated a full 360°.

Dimensions: 38" high, 19¼" wide, 23½" deep (965 x 489 x 597 mm).
Weight: net, 42 lbs (19,1 kg); shipping, 50 lbs (22,5 kg).
Price: HP Model 1119A, $110.

Model 10479A tilt tray for 1119A or 1119B

For use with instruments other than standard Hewlett-Packard modular size.

Dimensions: 17¼" wide, 23" deep (438 x 584 mm).
Weight: net, 12 lbs (5,5 kg); shipping, 15 lbs (6,8 kg).
Price: HP Model 10479A, $35.

Model 10480A storage cabinet for 1119A

Contains 1⅝" drawer for cables and accessories; mounts in place of lateral brace.

Dimensions: 11¼" high, 18¼" wide, 15" deep (286 x 464 x 381 mm).
Weight: net, 19½ lbs (8,9 kg); shipping, 22½ lbs (10 kg).
Price: HP Model 10480A, $35.

Model 1119B Testmobile

Model 1119B is the same as Model 1119A except that the Model 10480A Storage Cabinet is factory-installed in place of the lateral brace.

Dimensions: same as 1119A Testmobile.
Weight: net, 58 lbs (26,3 kg); shipping, 69 lbs (31,3 kg).
Price: HP Model 1119B, $145.

Model 1119C Testmobile

Model 1119C is designed for use with cabinet models of the 180 system and 1200 series, which attach to a pivotable support bracket. The lateral brace contains storage space for small accessories.

Dimensions: 38" high, 13¼" wide, 23½" deep (965 x 474 x 597 mm).
Weight: net, 30 lbs (14,6 kg); shipping, 38 lbs (17,2 kg).
Price: HP Model 1119C, $110.

Model 10479B tilt tray for 1119C and 1119D

For use with equipment other than Hewlett-Packard 180 system or 1200 series oscilloscopes.

Dimensions: 11¼" wide, 23" deep (401 mm x 507 mm).
Weight: net, 8 lbs (3,6 kg); shipping, 11 lbs (5 kg).
Price: HP Model 10479B, $35.

Model 10480B storage cabinet for 1119C

Contains 1⅝" drawer for cables and accessories; mounts in place of lateral brace.

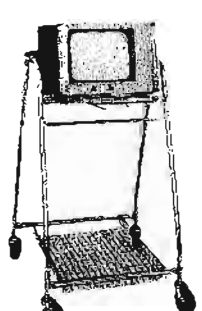
Dimensions: 11¼" high, 12¼" wide, 15" deep (286 x 449 x 381 mm).
Weight: net, 11 lbs (5 kg); shipping, 14 lbs (6,4 kg).
Price: HP Model 10480B, $35.

Model 1119D Testmobile

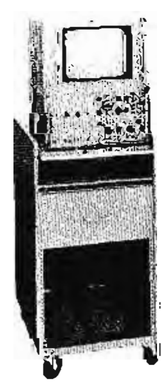
Model 1119D is same as Model 1119C except that the Model 10480B Storage Cabinet is factory-installed in place of the lateral brace.

Dimensions: same as 1119C Testmobile.
Weight: net, 43 lbs (19,8 kg); shipping, 51 lbs (23 kg).
Price: HP Model 1119D, $135.

1116A

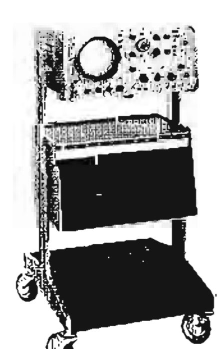


1117B



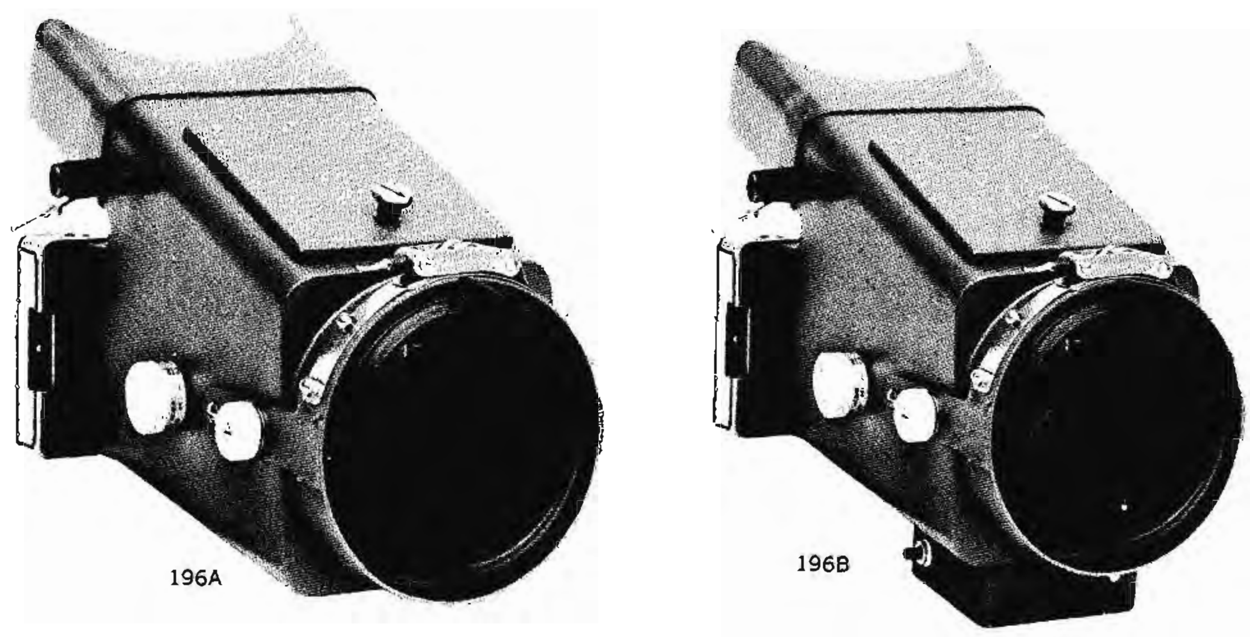
1118A

1119B



1119C

OSCILLOSCOPE CAMERA
Convenient pictures of oscilloscope traces
Model 196A/B

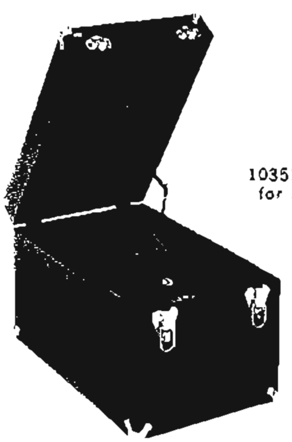


Description

The 196A/B provides a quick, convenient way for recording oscilloscope displays. The only difference between the 196A and 196B is that the 196B has an ultraviolet light source for illuminating internal graticules and the 196A doesn't. The 196A, therefore, doesn't require line power for operation.

A forward access port allows adjustment of shutter speed and diaphragm with the camera mounted on the oscilloscope. The lens may be adjusted vertically through 11 detented positions using an external knob, allowing multiple photos to be easily made. A quick-connect clamp offers speedy, reliable mounting to the oscilloscope.

Object-to-image ratio is preadjusted at the factory to 1:0.9 for optimum photos for most applications. The f/1.9 lens which is specifically designed for oscilloscope photography has extremely low distortion, which means accurate measurements can be made from the photographs.



10351A Carrying Case for 196A/B Camera.

Specifications, Model 196A/B

Object-to-image-ratio: 1 to 0.9; 1 to 1 optional.

Lens: 75 mm, *f*/1.9 high-resolution lens.

Focus: adjustable; factory-set for optimum resolution of both trace and graticule.

Lens opening: *f*/1.9 to *f*/16.

Shutter: speed and *f*-stop settings are completely visible and adjustable from access port; shutter speeds are: 1/50, 1/25, 1/10, 1/5, 1/2, 1 sec., Time, Bulb (solenoid operation on special order).

Print size: 3¼" x 4¼" (83 x 108 mm).

Image size: 2⅞" x 3-13/16" (73 x 96 mm).

Film: Polaroid® Land Film Packs, Type 107, 3000 speed.

Dimensions: 10" wide, 13½" long, 10¼" high, (254 x 343 x 262 mm).

Weight: net, 9 lbs (4,1 kg); shipping, 18 lbs (8,1 kg); 32 lbs (14,9 kg) with carrying case.

Power: Model 196B, 115 V ±10%, 60 Hz, 10 W.

Accessories available: Model 10351A Carrying Case, $40; Model 10355A Tektronix Adapter, $15.

Price: HP Model 196B, $475; HP Model 196A (identical with Model 196B, but without black light source), $425.

Special order: 1:1 object-to-image ratio, add $25; and order C01-196A for Model 196A, C06-196B for Model 196B;

Conversion kits: 196A-95C, converts "A" to "B"; price, $50; 196A-95D, same as above but with Option 12; price, $65.

Option 12: Model 196B for 115 or 230 V ±10%, 50 to 60 Hz operation, add $15.

®by Polaroid Corporation

OSCILLOSCOPE CAMERA

Permanent records of oscilloscope traces

Model 197A

The Model 197A Oscilloscope Camera provides an accurate, convenient way of recording oscilloscope displays. It is a precision instrument, meant for long, hard use.

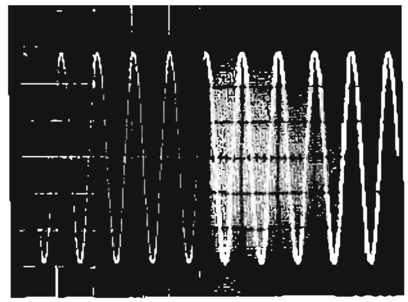
The Model 197A employs a new electronic shutter which provides accurate exposure times from 1/30 to 4 s. The shutter may be tripped electrically from a remote source, and a sync output provides a contact closure when the shutter is opened, allowing synchronizing of other equipment with the camera. Circuitry is all solid-state.

The new $f/1.9$ lens, designed for Hewlett-Packard by Wollensak, is mounted in a direct line with the film and transmits a maximum amount of light for photography of dim traces.

An ultra-violet light is included in the Model 197A for illuminating the internal graticule used on HP oscilloscopes. The "black" light, adjustable in intensity to suit conditions, excites the phosphor on the tube face and causes it to photograph an intermediate gray. The gray background clearly distinguishes the thin black graticule lines by contrast. Trace intensity is not degraded by this induced fluorescence, and the resulting photographs are actually easier to read since the black graticule lines also contrast clearly with the trace, and their exact crossings can be accurately located. This black light has the additional advantage of presensitizing the film at the same time that the photograph is taken. The uniform glow of the CRT face lowers the apparent threshold sensitivity of the film, enabling it to record dimmer traces and making possible clear, sharp photographs of both repetitive and single sweep phenomena (see Figure 1). In addition to continuously adjustable ultraviolet intensity, the Model 197A also provides a "flash" feature which automatically turns the UV on and off. The "flash" permits recording of slow single-shot events and complete graticule information in a single exposure. In other cameras a double exposure is usually required.

All Model 197A controls are located outside the camera. Shutter speed, f-stop, and UV light brightness are color coded to provide an optimum starting point for the inexperienced photographer. The lightweight Model 197A is quickly and easily mounted on any oscilloscope, and swings away from the CRT face when not needed. The face-fitting, flexible hood has a low viewing angle for accurate alignment of the trace with an external graticule. The hood may be removed and replaced with a flat panel, allowing a series of cameras to be mounted on stacked oscilloscopes with heights as low as 7 inches.

Figure 1. "Half-and-half" photo made with special cathode ray tube compares photographic qualities of conventional external graticule (left) and UV-lighted internal graticule.



The Model 197A back may be rotated from the normal horizontal position to a vertical position, allowing two smaller pictures to be taken on one photograph. The back also can be moved through 11 detented positions for multiple exposures (see Figure 2) or it can be removed and replaced with a 4 x 5 inch Graflok® back. The entire film area of the back may be utilized through the use of the Model 197A's easily adjustable continuous reduction ratio feature. The camera may then be quickly refocused with a simple knob adjustment, using the furnished split image focusing plate stored in the camera.

197A

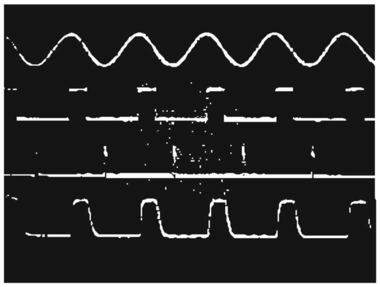


Figure 2. Multiple exposure photographs are easily made with the Model 197A Camera.

Specifications

Reduction ratio: continuously adjustable from 1:1 to 1:0.7; reference scale provided on focus plate.

Lens: 75 mm, *f*/1.9 high transmission lens, manufactured exclusively for HP by Wollensak; aperture ranges *f*/1.9 to *f*/16; optional 88 mm *f*/1.4 OscilloRaptar lens available.

Shutter: electronically operated and timed shutter, with all solid-state circuitry; shutter speeds are 1/30, 1/15, 1/8, 1/4, 1/2, 1, 2, 4 s, Time, and Bulb; shutter has a sync contact closure output for triggering external equipment and input jack for remote operation.

Camera back: Polaroid® Land Camera using pack film Type 107 supplied; Graflok® back available (see Options); backs may be interchanged without refocusing and may be rotated in 90-degree increments.

Mounting: quick lift on-off mounting with positive lock; swing away to left.

Viewing: low-angle, direct viewing flexible face mask; hood may be removed and replaced with panel to allow stacking on 7-inch high oscilloscopes (see Accessories Available).

Multiple exposure: back moves vertically through 11 detented positions at ½ cm per detent at 1:0.9 object-to-image ratio.

Focus: adjustable focusing with lock; split image focusing plate provided.

Dimensions: 14″ long, 10½″ high, 7⅝″ wide (356 x 267 x 194 mm) with hood; 12″ long, 6½″ high, 7⅝″ wide (305 x 165 x 194 mm) without hood.

Weight: net 10 lbs (4,5 kg); shipping 19 lbs (8,6 kg).

Power: 115 V $\pm 10\%$, 50 to 1000 Hz, 6 W.

Accessories furnished: combination split image focusing plate and reduction ratio scale.

Price: HP Model 197A, $540.

Option 01: without ultraviolet light, deduct $50.

Option 02: *f*/1.4 lens, add $270.

Option 03: Graflok back in place of Polaroid back; no charge.

Option 12: modified for 230 V operation; no charge.

"Polaroid"® by Polaroid Corp.
"Graflok"® by Graflex, Inc.

Accessories available

Camera Backs

10352A

10353A

The Model 197A is supplied with a Polaroid® Pack Film back as standard or a 4 x 5 Graflok® back as Option 03. These backs can also be ordered separately. Polaroid back Model 10353A, $85; Graflok back Model 10352A, $85.

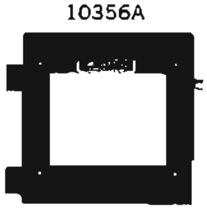
Oscilloscope Bezel Adapters

10355A

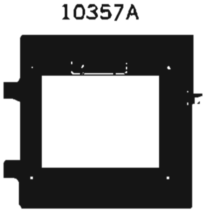
10356A

10357A

10360A



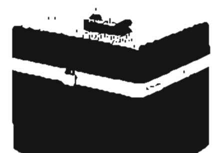
10361A



10362A

The Model 197A fits all HP oscilloscopes and can easily be fitted to other types by means of bezel adapters. Model 10355A adapts to Tektronix and Fairchild 5-inch round bezels, $15. Model 10356A adapts to Tektronix 560 Series rectangular bezels, $15. Model 10357A adapts to Tektronix 640 Series rectangular bezels, $15. The Model 10360A adapts the Model 196A/B camera to the HP rectangular bezel, $15. The Model 10361A adapts the Tektronix C12 camera to the HP rectangular bezel, $15. The Model 10362A adapts the Tektronix C27 camera to the HP rectangular bezel, $15. Model 10363A adapts Tektronix C30 or C40 cameras to HP rectangular bezel, $15.

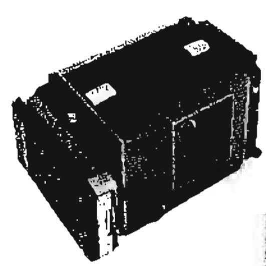
Carrying Case



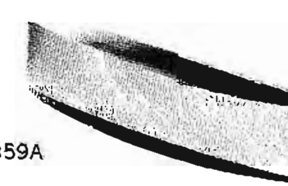
10358A

The Model 10358A carrying case is a sturdy fiber-glass and aluminum construction with foam padding to provide maximum protection for the Model 197A in transit or storage, $65.

Other accessories



10354A



10359A

Model 10354A Viewing Hood Replacement Plate is used in place of the Model 197A viewing hood and permits camera mounting on stacked oscilloscopes with heights as low as 7 inches, $7.

The Model 10359A Viewing Lens is a ground plastic lens which fits inside the viewing hood for easy trace viewing by those with farsighted vision, $25.

Glossary of oscilloscope terminology

Accelerating Voltage—The cathode-to-viewing-screen voltage applied to a cathode ray tube for the purpose of accelerating the electron beam.

Alternate Mode—A means of displaying output signals of two or more channels by switching the channels, in sequence, after each sweep.

Automatic Triggering—A mode of triggering in which one or more of the triggering circuit controls are preset to conditions suitable for automatically displaying repetitive waveforms. The automatic mode may also provide a recurrent trigger or recurrent sweep in the absence of triggering signals.

Bandwidth—A statement of the frequencies defining the upper and lower limits of a frequency spectrum where the amplitude response of an amplifier to a sinusoidal waveform becomes .707 (−3db) of the amplitude of a reference frequency. When only one number appears, it is taken as the upper limit.

Chopped Mode—A time sharing method of displaying output signals of two or more channels with a single cathode ray tube gun, in sequence, at a rate not referenced to the sweep.

Common Mode Rejection Ratio (CMRR)—Ratio of the deflection factor for a common-mode signal to the deflection factor for a differential signal.

Common-Mode Signal—The instantaneous algebraic average of two signals applied to a balanced circuit, all signals referred to a common reference.

Common-Mode Signal Maximum—The largest common-mode signal at which the specified common-mode rejection ratio is valid.

DC Balance—An adjustment of circuitry to avoid a change in dc level when changing gain.

DC Drift (Stability)—Property of retaining defined electrical characteristics for a prescribed period.

DC Shift—An error in transient response with a time constant approaching several seconds.

Deflection Axis—The major coordinates passing through the center of the viewing area.

Deflection Factor—The ratio of the input signal amplitude to the resultant displacement of the indicating spot (e.g., volts/division).

Delayed Sweep—A sweep that has been delayed either by a predetermined period or by a period determined by an additional independent variable.

Differential Amplifier—An amplifier whose output signal is proportional to the algebraic difference between two input signals.

Dual-Beam Oscilloscope—An oscilloscope in which the cathode ray tube produces two separate electron beams that may be individually or jointly controlled.

Dual Trace—A mode of operation in which a single beam in a cathode ray tube is shared by two signal channels. See Alternate Mode and Chopped Mode.

Free-Running Sweep—A sweep that runs without being triggered and is not synchronized by any applied signal.

Guarded Input—Means of connecting an input signal so as to prevent any common mode signal from causing current to flow in the input, thus differences of source impedance do not cause conversion of the common mode signal into a differential signal.

Input RC Characteristics—The dc resistance and capacitance to ground present at the input of an oscilloscope.

Internal Graticule—A scale for measurement of quantities displayed on the crt whose rulings are a permanent part of the inner surface of the cathode ray tube faceplate.

Jitter—An aberration of a repetitive display indicating instability of the signal or of the oscilloscope. May be random or periodic, and is usually associated with the time axis.

Magnified Sweep—A sweep whose time per division has been decreased by amplification of the sweep waveform rather than by changing the time constants used to generate it.

Mixed Sweep—In a system having both a delaying sweep and a delayed sweep, a means of displaying the delaying sweep to the delaying pickoff and the delayed sweep beyond that point.

Risetime—The interval between the instants at which the pulse amplitude first reaches specified lower and upper limits. Unless otherwise stated, these limits shall be 10% and 90% of the pulse's amplitude.

Single Sweep—Operating mode for a triggered-sweep oscilloscope in which the sweep must be reset for each operation, thus preventing unwanted multiple displays.

Sweep—An independent variable of a display; unless otherwise specified, this variable is a linear function of time, but may be any quantity that varies in a definable manner.

Sweep Holdoff—The interval between sweeps during which the sweep and/or trigger circuits are inhibited.

Time Base—The sweep generator in an oscilloscope that generates the time function, which is usually linear and expressed in sec/cm.

Time Base Accuracy—Accuracy of the time base usually expressed in terms of average rate error as a percent of full scale.

Trigger—A pulse used to initiate some function.

Triggering Level—The instantaneous level of a triggering signal at which a trigger is to be generated.

Triggering Slope—The positive going (+ slope) or negative slope (− slope) portion of a triggering signal from which a trigger is to be derived.

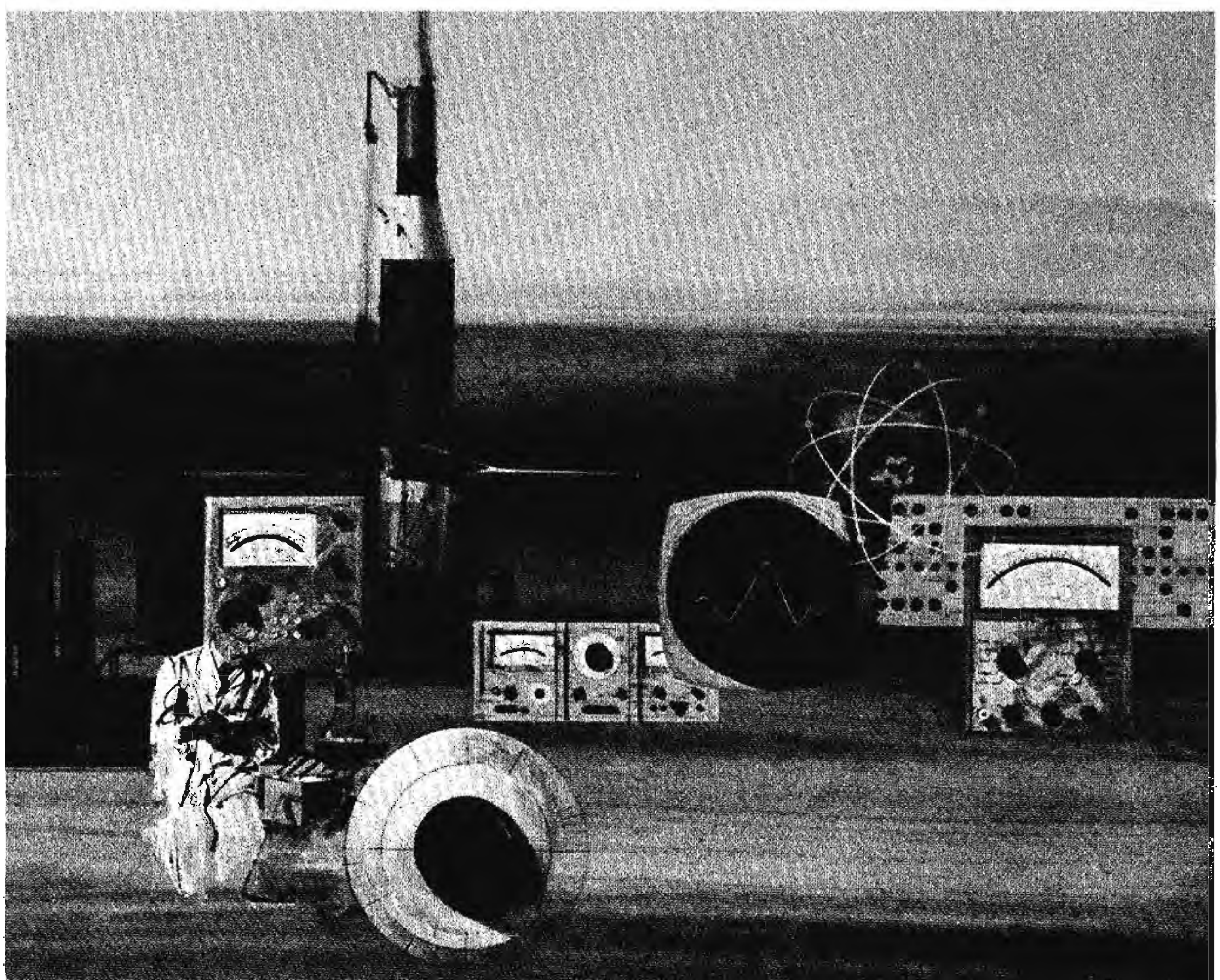
Cathode-ray tube phosphor characteristics

Phosphor	Trace Color: Under Excitation	Trace Color: After-Glow	Persistence	Relative Burn Resistance	Relative Visual Brightness
P2	yellowish-green	yellowish-green	medium short	6	6.5
P4	white	white	medium	8	5
P7	white	yellowish-green	long	3	4.5
P11	blue	blue	medium short	3	2.5
P31	green	green	medium short	10	10

Description of Persistence	Time to Decay to 10% of Initial Brightness
medium short	10 microsec to 1 millisec
medium	1 millisec to 100 millisec
long	100 millisec to 1 sec

Phosphor	Application
P2	Persistence useful for observing low rep rate phenomena.
P4	White trace; high contrast display.
P7	Longer persistence for low speed occurrences. Used primarily in medical application.
P11	Highest writing rate; used in photographic applications.
P31	Standard HP phosphor because of its high visual brightness and high burn resistance.

DC Power Supplies



POWER SUPPLIES — SELECTION GUIDE

The following is a step-by-step procedure which, when used with the Condensed Listing on the following pages and the Definitions on pages 562, 563 will be helpful in choosing the right power supply.

(1) Determine dc output voltage rating

A dc voltage requirement is often expressed as a nominal rating, but power supplies are rated in terms of maximum output under worst operating conditions. For example, if the dc voltage required is nominally 32 volts, adjustable ±10%, a 36 volt supply (not 32 volts) should be obtained, provided operation is actually desired at 110% of nominal (35.2 volts). This can be important if "marginal checking" of a system or a load circuit is to be accomplished by varying the dc power supply feeding it.

(2) Determine dc output current rating

The output current rating of a power supply must be selected on the basis of the peak current requirement, not the average current requirement; this results from the fact that the current limiting protection circuitry internal to the supply is extremely fast in order to protect the series power transistors. The current limit circuit is normally adjustable to between 105 and 110% of the nominal current rating of the power supply. If inverse current loading is involved, the power supply must have a current rating equal to or greater than the sum of peak current delivered and peak current absorbed.

(3) Consult condensed listing

Enter the Condensed Listing at the voltage rating found from (1). Supplies above this point are eliminated from consideration because of insufficient output voltage. Many supplies below this point are also eliminated because of a current rating too small compared with (2). If the desired output voltage-current combination does not appear in the Condensed Listing, consider series and parallel combinations of power supplies; Hewlett-Packard's Auto-Series and Auto-Parallel feature permits one knob control and equal voltage and current sharing.

(4) Constant voltage and/or constant current output

Most applications require constant voltage power supplies. However, some load devices require a constant current source of dc power. Still other applications (e.g. battery charging and electrolytic capacitor forming) call for supplies which have automatic crossover between constant voltage and constant current operation.

If the requirement involves constant current performance, then the Condensed Listing should be used to determine which supplies remaining from (3) are capable of constant current operation. Remember that all Remote Programming constant voltage supplies can also be converted to constant current use with one external resistor.

(5) Specifications for load regulation, line regulation, ripple and transient response

Generally speaking, a Hewlett-Packard power supply employs one of two basic circuit technique — (1) a transistor regulator, or (2) an SCR regulator. (In the case of high power output rating, the transistor regulator is preceded by an SCR preregulator.) All low output power supplies use circuit technique (1), since this results in both lower cost and better performance. Either circuit technique (1) or (2) may be utilized in a supply of moderate output power capability. Power supplies of very high output power employ circuit technique (2).

These two circuit techniques result in distinctly different performance characteristics — particularly with regard to regulation, ripple and transient response.

Specification	Transistor Regulated
Load Regulation	0.001% to 0.05%
Line Regulation	0.001% to 0.05%
Ripple and Noise	50 μv to 1 mv
Transient Response	Less than 50μsec.

Specification	SCR Regulated
Load Regulation	0.1% to 1%
Line Regulation	0.1% to 1%
Ripple and Noise	0.1% to 1%
Transient Response	Less than 50-200 msec.

(6) Is remote programming required?

If it is desired to control the output of the power supply remotely using switched or variable values of resistance, or if the supply is to be controlled by means of a voltage input, then look on the Condensed Listing for those power supplies with a check under "Remote Programming."

(7) Physical configuration

Power supplies are available in three basic packages — rack mounting (standard 19" RETMA), bench, and modular. For high output ratings, rack mounting is the only practical configuration. All supplies which are not normally rack mounting are easily adapted to rack applications using standard hardware available from Hewlett-Packard. Reference to the appropriate catalog pages will indicate the nature and cost of this rack mounting adapting hardware.

(8) Miscellaneous requirements

Depending on the particular application, check also for remote error sensing, permissible values of input line voltage and frequency, front and/or rear output terminals, meters, etc. Many of these miscellaneous requirements can be checked directly on the Condensed Listing. In other cases it will be necessary to refer to the more detailed information on the catalog pages referenced by the Condensed Listing.

A spec sheet can be obtained from any Hewlett-Packard sales office.

Power supply series designations

Series designations identify groupings of Hewlett-Packard power supplies that have similar circuit techniques and operating characteristics.

The model numbers assigned to each Series can be determined from the Product Category Index on next page.

Note that each multiple letter Series designation (1) suggests the general type of power supply in a given category and (2) indicates (in the third letter) the nature of the power supply case and its "normal" mode of installation. A final "B" indicates Bench supplies and a final "R" applies to units which are Rack mounted. Absence of a "B" or an "R" as the final letter means that the supplies have not been designed primarily for either Bench or Rack use, or that the series includes both full rack width and half rack width instruments.

Notice that these designations are not part of the model number. They do not appear on the instrument and should not be used when ordering.

Series	Description
BENCH	Small Laboratory Bench
CCB	Constant-Current, Bench
DPR	Dual Power Rack
HVB	High Voltage Bench
HVR	High Voltage Rack
ICS	Low Voltage for Integrated Circuits
LAB	Laboratory Bench
LVR	Low Voltage Rack
MOD	Plug-In Modular
MPB-3	3½"-High Medium Power Bench
MPB-5	5¼"-High Medium Power Bench
MPM	Medium Power Modular
MVR	Medium Voltage Rack
PS/A	Power Supply/Amplifier
SCR-1P	Primary SCR Regulated, Output Ratings — 300 and 900 Watts
SCR-3	SCR Regulated, Output Ratings up to 3 KW
SCR-10	SCR Regulated, Output Ratings up to 10 KW
SLOT	Fixed Output Modules
STB	High Stability Supply/Calibrator

Further information on power supplies can be found in the 1969 DC Power Supply Catalog & Handbook. Available from your Hewlett-Packard Sales Office.

PRODUCT CATEGORY INDEX

POWER SUPPLIES

BENCH SUPPLIES

													Page
BENCH*	output	0–10 V 0–1A	0–10 V 0–1A	0–25 V, 0–400 mA	0–25 V, 0–400 mA	0–30 V 0–150 mA	0–50 V, 0–200 mA	0–50 V, 0–200 mA					570, 571
	model	6213A	6214A	6215A	6216A	721A	6217A	6218A					
LAB*	output	0–7.5 V 0–3 A	0–20 V, 0–0.6 A 0–40 V, 0–0.3 A	0–20 V, 0–0.6 A 0–40 V, 0–0.3 A	0–20 V, 0–1.5 A	0–20 V, 0–1.5 A 0–40 V, 0–0.75 A	0–30 V, 0–1 A 0–60 V, 0–0.5 A	0–40 V, 0–0.75 A	0–160 V, 0–0.2 A	0–320 V, 0–0.1 A			572, 573
	model	6203B	6204B	(dual) 6205B	6201B	6200B	6206B	6202B	6207B	6209B			
HVB*	output	0–1600 V 0–5 mA	0–3000 V 0–6 mA										580
	model	6515A	6516A										
MPM*	output	0–24 V, 0–3 A	0–25 V, 0–1.5 A 0–50 V, 0–75 A	0–50 V 0–1.5 A									569
	model	6224B	6220B	6226B									
MPM-8* MPB-5*	output	0–7.5 V 0–5 A	0–10 V, 0–10 A	0–20 V, 0–3 A	0–20 V, 0–5 A	0–20 V, 0–10 A	0–40 V, 0–1.5 A	0–40 V, 0–3 A	0–40 V, 0–5 A	0–60 V, 0–1 A	0–60 V, 0–3 A	0–100 V, 0–750 mA	574, 575
	model	6281A	6282A	6284A	6285A	6286A	6289A	6290A	6291A	6294A	6296A	6299A	
STB*	output	0–20 V, 0–1 A	0–40 V, 0–0.5 A	0–100 V, 0–200 mA	0–3000 V, 0–6 mA	0–10 V, 0–2 A							566, 567
	model	6101A, 6111A	6102A, 6112A	6106A, 6116A	6110A	6113A							
OCB*	output	0–50 V 0–500 mA	0–100 V 0–250 mA										568
	model	6177B	6181B										
Medium Voltage Multiple Output	output	0–500 V, 0–0.1 A and 12.6/6.3 V ac		0–500 V, 0–0.2 A; —300 V, 0.05 A; 0 to —150 V, .005 A; 12.6/6.3 V ac									579
	model	711A		712									

RACK SUPPLIES

													Page
DPR	output	0–20 V, 0–3 A	0–40 V, 0–1.5 A										574, 575
	model	6253A	6255A										
LVR	output	0–10 V 0–50 A	0–10 V, 0–100 A	0–40 V 0–10 A	0–20 V 0–20 A	0–40 V 0–3 A	0–40 V 0–5 A	0–40 V 0–10 A	0–40 V, 0–30 A	0–40 V, 0–50 A	0–60 V, 0–3 A	0–60 V, 0–15 A	576, 577
	model	6259B	6260A	6263B	6264B	6265B	6266B	6267B	6268A	6269A	6271B	6274A	
MVR	output	0–320 V 0–600 mA	0–320 V 0–1.5 A										579
	model	890A	895A										
HVR	output	0–1000 V 0–200 mA	0–2000 V 0–100 mA	0–4000 V 0–50 mA									580
	model	6521A	6522A	6525A									
SCR-1P	output	0–20 V, 0–15 A	0–20 V, 0–45 A	0–36 V, 0–10 A	0–40 V, 0–25 A	0–60 V, 0–5 A	0–60 V, 0–15 A	0–120 V, 0–2.5 A	0–600 V, 0–1.5 A				581
	model	6427B	6428B	6433B	6434B	6438B	6439B	6443B	6448B				
SCR-3	output	0–15 V, 0–200 A	0–36 V, 0–100 A	0–64 V, 0–50 A									582
	model	6453A	6456B	6459A									
SCR-10	output	0–4 V, 0–200 A	0–8 V, 0–1000 A	0–16 V, 0–600 A 0–18 V, 0–500 A	0–36 V, 0–300 A	0–64 V, 0–150 A	0–110 V, 0–100 A	0–220 V, 0–50 A	0–300 V, 0–35 A	0–440 V, 0–25 A 0–500 V, 0–20 A 0–600 V, 0–15 A			583
	model	6463A	6464A	6466A	6469A	6472A	6475A	6477A	6479A	6483B			

SPECIAL PRODUCTS

									Page
DIGITAL VOLTAGE SOURCE	output	0–±10 V 0–10 mA	0–±50 V 0–1 A	0–±100 V 0–500 mA					564, 565, 113
	model	6933A	6130B	6131B					
PS/A*	output: power supply	−20 V to +20 V, 0–0.5 A			−50 V to +50 V, 0–1 A				587
	output: amplifier	40 V p-p, 0–0.5 A			100 V p-p, 0–1 A				
	model	6823A			6824A				
IOS*	output	4–5.5 V, 0–8 A							578
	model	6384A							
MOD*	output	0–18 V, 0–300 mA	0–18 V, 0–1 A	0–36 V, 0–150 mA	0–36 V, 0–500 mA	0–160 V, 0–400 mA	0–320 V, 0–200 mA		586
	model	6343A	6344A	6346A	6347A	6354A	6357A		
STRAIN* GAGE SUPPLIES	output	0–25 V, 0–0.2 A							586
	model	801C							
KLYSTRON POWER SUPPLIES	output	0 to −900 V, −250 to −400 V, 6.0 V ac			0 to −800 V, −250 to −800 V, 6.3 V dc				296
	model	715A			716B				
NIM POWER SUPPLIES	output	±6 V/±12 V/±24 V 5 A/4 A/2 A							76, 77
	model	5580A/B							

															Page
SLOT*	output	5.8V±20% 0–1.5 A	5.8V±20% 0–3 A	5.8V±20% 0–8 A	13V±20% 0–500 mA	13V±20% 0–1 A	13V±20% 0–2.2 A	13V±20% 0–6 A	±15V±20% 0–200 mA	±15V±20% 0–750 mA	26V±20% 0–250 mA	26V±20% 0–500 mA	26V±20% 0–1 A	26V±20% 0–1.5 A	26V±20% 0–3.5 A	584, 585
	model	60063 A	60065 A	60066 A	60122B	60123B	60125B	60126B	60133D	60155C	60242A	60243B	60244B	60245B	60246B	

*These supplies can also be rack mounted. Refer to pages indicated for details.

POWER SUPPLIES — CONDENSED LISTING

Output (volts)	Output (amperes)	Model	Series	Catalog page	Load regulation (mV)	Line regulation (mV)	RMS ripple & noise (mV)	Input line voltage (Vac)	Input line frequency	Remote programming	Bench or Rack*	CV/CC**	Price
0-4	0-2000	6463A	SCR-10	583	50 mV combined		280	3φ 208/460 ±10%	57-63	√	R	√	$3500
4-5.5	0-8	6384A	ICS	578	1 mV	1 mV	1 mV	115 ±10%	48-63		B		220
5.8 ±20%	0-15	60063A	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
5.8 ±20%	0-3	60065A	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
5.8 ±20%	0-8	60066A	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
0-7.5	0-3	6203B	LAB	572	5 mV	3 mV	0.2	115 ±10%	50-400	√	B	√	169
0-7.5	0-5	6281A	MPB-3	574	5 mV	2 mV +0.01%	0.2	115 ±10%	50-400	√	B	√	210
0-8	0-1000	6464A	SCR-10	583	25 mV combined		80	3φ 208/460 ±10%	57-63	√	R	√	3300
0-10	0-1	6213A	BENCH	570	.01% +4 mV	.01% +4 mV	0.2	115 ±10%	50-400		B		90
0-10	0-1	6214A	BENCH	570	.01% +4 mV	.01% +4 mV	0.2	115 ±10%	50-400		B	√	115
0-10	0-2	6113A	STB	566	0.001% +1.1 mV	0.001%	0.04	115 ±10%	48-63	√	B		375
0-10	0-10	6282A	MPB-5	574	1 mV +0.01%	1 mV +0.01%	0.5	115 ±10%	50-60	√	B	√	350
0-10	0-20	6256B	LVR	576	200 μV +0.01%	200 μV +0.01%	0.2	115 ±10%	57-63	√	R	√	450
0-10	0-50	6259B	LVR	576	200 μV +0.01%	200 μV +0.01%	0.5	115 ±10%	57-63	√	R	√	650
0-10	0-100	6260A	LVR	576	200 μV +0.01%	200 μV +0.01%	1.0	230 ±10%	57-63	√	R	√	775
13 ±20%	0-0.5	60122B	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
13 ±20%	0-1	60123B	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
13 ±20%	0-2.2	60125B	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
13 ±20%	0-6	60126B	SLOT	584	0.05%	0.05%	1 mV	115 ±10%	48-440		R		See p. 584
±15 ±20%	0-0.2 A	6053D	SLOT	584	0.03%	0.03%	0.3	115 ±10%	48-440		R		See p. 584
±15 ±20%	0-0.75	60155C	SLOT	584	0.03%	0.01%	0.3	115 ±10%	48-440		R		See p. 584
0-15	0-200	6453A	SCR-3	582	10 mV +0.2% combined		150	3φ 208/230/460 ±10%	57-63	√	R	√	1375
0-16 or 0-18	0-600 or 0-500	6466A	SCR-10	583	10 mV +0.2% combined		160 or 180	3φ 208 – 460 ±10%	57-63	√	R	√	2600
0-18	0-0.3	6343A	MOD	586	3 mV or 0.03%	3 mV or 0.03%	1.0	115 ±10%	48-440	√	R		120
0-18	0-1	6344A	MOD	586	3 mV or 0.03%	3 mV or 0.03%	1.0	115 ±10%	48-63	√	R		165
−20 to +20	0-0.5	6823A	PS/A	587	5 mV +0.02%	5 mV +0.02%	2	115 ±10%	50-440	√	B	√	194
0-20	0-0.6	6204B	LAB	572	4 mV +0.01%	4 mV +0.01%	0.2	115 ±10%	50-400	√	B		144
0-20 and 0-40	0-0.6 and 0-0.3	6205B	LAB	572	4 mV +0.01%	4 mV +0.01%	0.2	115 ±10%	50-440	√	B		235
0-20	0-1	6101A	STB	566	600 μV +0.001%	0.001%	0.04	115 ±10%	48-63	√	B		265
0-20	0-1	6111A	STB	566	600 μV +0.001%	0.001%	0.04	115 ±10%	48-63	√	B		375
0-20	0-1.5	6200B	LAB	572	4 mV +0.01%	4 mV +0.01%	0.2	115 ±10%	50-400	√	B	√	189
0-20	0-1.5	6201B	LAB	572	4 mV +0.01%	4 mV +0.01%	0.2	115 ±10%	50-400	√	B	√	169
0-20 Dual	0-3	6253A	DPR	574	4 mV +0.01%	2 mV +0.01%	0.2	115 ±10%	50-400	√	R	√	445
0-20	0-3	6284A	MPB-3	574	4 mV +0.01%	2 mV +0.01%	0.2	115 ±10%	50-400	√	B	√	210
0-20	0-5	6285A	MPB-5	574	1 mV +0.01%	1 mV +0.01%	0.5	115 ±10%	50-60	√	B	√	350
0-20	0-10	6263B	LVR	576	200 μV +0.01%	200 μV +0.01%	0.2	115 Vac ±10%	57-63	√	R	√	435
0-20	0-10	6286A	MPB-5	574	1 mV +0.01%	1 mV +0.01%	0.5	115 ±10%	50-60	√	B	√	395
0-20	0-15	6427B	SCR-1P	581	20 mV	10 mV	40	115 ±10%	57-63	√	R	√	380
0-20	0-20	6264B	LVR	576	200 μV +0.01%	200 μV +0.01%	0.2	115 Vac ±10%	57-63	√	R	√	525

*"B" indicates bench type and "R" indicates full rack width type supplies. All bench supplies (except Models 721A, 711A, 712B and 715A) can be rack mounted using accessory rack mounting hardware.

**Automatic crossover between constant voltage (cv) and constant current (cc) operation.

additional listings on next page

Output (volts)	Output (amperes)	Model	Series	Catalog page	Load regulation (mV)	Line regulation (mV)	RMS ripple & noise (mV)	Input line voltage (Vac)	Input line frequency	Remote programming	Bench or Rack*	CV/CC**	Price
0-20	0-45	6428B	SCR-1P	581	40 mV	20 mV	40	115 ± 10%	57-63	√	R	√	$550
0-24	0-3	6224B	MPM	569	.01% + 4 mV	.01% + 2 mV	0.2	115 ± 10%	50-60	√	B	√	325
0-25	0-0.2	801C	–	586	2 mV	2 mV	0.1	105 - 125	55-65		R		175
0-25	0-0.4	6215A	BENCH	570	.01% + 4 mV	.01% + 4 mV	0.2	115 ± 10%	50-400		B		90
0-25	0-0.4	6216A	BENCH	570	.01% + 4 mV	.01% + 4 mV	0.2	115 ± 10%	50-400		B	√	115
0-25	0-1	6220B	MPM	569	.01% + 2 mV	.01% + 2 mV	0.2	115 ± 10%	50-400	√	B	√	250
26 ± 20%	0-0.25	60242A	SLOT	584	0.05%	0.05%	1 mV	115 ± 10%	48-440		R		See p. 584
26 ± 20%	0-0.5	60234B	SLOT	584	0.05%	0.05%	1 mV	115 ± 10%	48-440		R		See p. 584
26 ± 20%	0-1	60244B	SLOT	584	0.05%	0.05%	1 mV	115 ± 10%	48-440		R		See p. 584
26 ± 20%	0-1.5	60245B	SLOT	584	0.05%	0.05%	1 mV	115 ± 10%	48-440		R		See p. 584
26 ± 20%	0-3.5	60246B	SLOT	584	0.05%	0.05%	1 mV	115 ± 10%	48-440		R		See p. 584
0-30	0-0.15	721A	–	570	30 mV	± 15 mV	0.15	115 ± 10%	50-60		B		145
0-30	0-1	6206B	LAB	572	4 mV + 0.01%	4 mV + 0.01%	0.2	115 ± 10%	50-400	√	B		169
0-36	0-0.15	6346A	MOD	586	3 mV or 0.02%	3 mV or 0.02%	1.0	115 ± 10%	48-440	√	R		120
0-36	0-0.5	6347A	MOD	586	3 mV or 0.02%	3 mV or 0.02%	1.0	115 ± 10%	48-63	√	R		165
0-36	0-10	6433B	SCR-1P	581	36 mV	18 mV	36	115 ± 10%	57-63	√	R	√	370
0-36	0-100	6456B	SCR-3	582	10 mV + 0.2% combined		160	3φ 208/230/460 ± 10%	57-63	√	R	√	1275
0-36	0-300	6469A	SCR-10	583	10 mV + 0.2%		180	3φ 208/230/460 ± 10%	57-63	√	R	√	2300
0-40	0-0.3	6204B	LAB	572	4 mV + 0.01%	4 mV + 0.01%	0.2	115 ± 10%	50-400	√	B		144
0-40 and 0-20	0.03 and 0-0.6	6205B	LAB	572	4 mV + 0.01%	4 mV + 0.01%	0.2	115 ± 10%	50-440	√	B		235
0-40	0-0.5	6102A	STB	566	350 μV + 0.001%	0.001%	0.04	115 ± 10%	48-63	√	B		265
0-40	0-0.5	6112A	STB	566	350 μV + 0.001%	0.001%	0.04	115 ± 10%	48-63	√	B		375
0-40	0-0.75	6200B	LAB	572	4 mV + 0.01%	4 mV + 0.01%	0.2	115 ± 10%	50-400	√	B	√	189
0-40	0-0.75	6202B	LAB	572	4 mV + 0.01%	4 mV + 0.01%	0.2	115 ± 10%	50-400	√	B	√	169
0-40 Dual	0-1.5	6255A	DPR	574	2 mV + 0.01%	2 mV + 0.01%	0.2	115 ± 10%	50-400	√	R	√	445
0-40	0-1.5	6289A	MPB-3	574	2 mV + 0.01%	2 mV + 0.01%	0.2	115 ± 10%	50-400	√	B	√	210
0-40	0-3	6265B	LVR	576	200 μV + 0.01%	200 μV + 0.01%	0.2	115 Vac ± 10%	57-63	√	R	√	525
0-40	0-3	6290A	MPB-5	574	1 mV + 0.01%	1 mV + 0.01%	0.5	115 Vac ± 10%	50-60	√	B	√	350
0-40	0-5	6266B	LVR	576	200 μV + 0.01%	200 μV + 0.01%	0.2	115 Vac ± 10%	57-63	√	R	√	435
0-40	0-5	6291A	MPB-5	574	1 mV + 0.01%	1 mV + 0.01%	0.5	115 ± 10%	50-60	√	B	√	395
0-40	0-10	6267B	LVR	576	200 μV + 0.01%	200 μV + 0.01%	0.2	115 Vac ± 10%	57-63	√	R	√	525
0-40	0-25	6434B	SCR-1P	581	40 mV	18 mV	40	115 ± 10%	57-63	√	R	√	550
0-40	0-30	6268A	LVR	576	200 μV + 0.01%	200 μV + 0.01%	1	230 ± 10%	48-63	√	R	√	695
0-40	0-50	6269A	LVR	576	200 μV + 0.01%	200 μV + 0.01%	1 mV	230 ± 10%	48-63	√	R	√	875
– 50 to + 50	0-1	6824A	PS/A	587	5 mV + 0.02%	5 mV + 0.02%	10	115 ± 10%	50-60	√	B	√	350
0-± 50	0-1	6130A	DVS	564	2 mV	2 mV	1 mV	115 ± 10%	50-400	√	B		1500
0-50	0-0.2	6217A	BENCH	570	.01% + 1 mV	0.1% + 4 mV	0.2	115 ± 10%	50-400		B		90
0-50	0-0.2	6218A	BENCH	570	.01% + 1 mV	.01% + 4 mV	0.2	115 ± 10%	50-400		B	√	115
0-50	0-0.5	6177B	CCB	568	0.0015%	0.001%	50 ppM	115 ± 10%	48-63	√	B		425
0-50	0-0.5	6220B	MPM	569	2 mV + .01%	2 mV + .01%	0.2	115 ± 10%	50-400	√	B	√	250
0-50	0-1.5	[illegible]	MPM	569	2 mV + .01%	2 mV + .01%	0.2	115 ± 10%	50-60	√	B	√	325

CONDENSED LISTING continued

Output (volts)	Output (amperes)	Model	Series	Catalog page	Load regulation (mV)	Line regulation (mV)	RMS ripple & noise (mV)	Input line voltage (Vac)	Input line frequency	Remote programming	Bench or Rack*	CV/CC**	Price
0-60	0-1	6294A	MPB-3	574	2 mV +0.01%	2 mV +0.01%	0.2	115 ± 10%	50-400	√	B	√	$210
0-60	0-3	6296A	MPB-5	574	1 mV +0.01%	1 mV +0.01%	0.5	105-125	50-60	√	B	√	395
0-60	0-3	6271B	LVR	576	200 μV +0.01%	200 μV +0.01%	0.2	115 V ac ± 10%	48-63	√	R	√	435
0-60	0-5	6438B	SCR-1P	581	60 mV	30 mV	120	105-125	57-63	√	R	√	360
0-60	0-15	6439B	SCR-1P	581	120 mV	60 mV	60	105-125	57-63	√	R	√	550
0-60	0-15	6274A	LVR	576	0.2 mV +0.01%	0.2 mV +0.01%	0.5	100-130	48-63	√	R	√	695
0-64	0-50	6459A	SCR-3	582	10 mV +0.2% combined		160	3φ 208/230/460 ± 10%	57-63	√	R	√	1275
0-64	0-150	6472A	SCR-10	583	100 mV +0.2% combined		160	3φ 208/230/460 ± 10%	57-63	√	R	√	2600
0-100	0-0.2	6106A	STB	566	200 μV +0.001%	0.001%	0.04	115 ± 10%	48-63	√	B		265
0-100	0-0.2	6116A	STB	566	200 μV +0.001%	0.001%	0.04	115 ± 10%	48-63	√	B		375
0-100	0-0.25	6181B	CCB	568	0.0015%	0.001%	50 ppM	115 Vac ± 10%	48-63	√	B		425
0-100	0-0.5	6131A	DVS	564	2 mV	2 mV	5.0	115 Vac ± 10%	50-400	√	R		1500
0-100	0-0.75	6299A	MPB-3	574	2mV +0.01%	2 mV +0.01%	0.2	115 ± 10%	50-400	√	B	√	225
0-110	0-100	6475A	SCR-10	583	100 mV +0.2% combined		220	3φ 208/230/460 ± 10%	57-63	√	R	√	2600
0-120	0-2.5	6443B	SCR-1P	581	120 mV	60 mV	240	115 ± 10%	57-63	√	R	√	360
0-160	0-0.2	6207B	LAB	572	2 mV +0.02%	2 mV +0.02%	0.5	115 ± 10%	48-63	√	B	√	235
0-160	0-0.4	6354A	MOD	586	2 mV +0.005%	1 mV +0.005%	1.0	115 ± 10%	48-63	√	R	√	259
0-220	0-50	6477A	SCR-10	583	100 mV +0.2% combined		330	3φ 208/230/460 ± 10%	57-63	√	R	√	2600
0-300	0-35	6479A	SCR-10	583	100 mV +0.2% combined		300	3φ 208/230/460 ± 10%	57-63	√	R	√	2600
0-320	0-0.1	6209B	LAB	572	2 mV +0.02%	2 mV +0.02%	1.0	115 ± 10%	48-63	√	B	√	235
0-320	0-0.2	6357A	MOD	586	2 mV +0.005%	1 mV +0.005%	1.0	115 ± 10%	48-63	√	R	√	259
0-320	0-0.6	890A	MVR	579	10 mV or 0.007%	10 mV or 0.007%	1.0	115 ± 10%	57-63	√	R		445
0-320	0-1.5	895A	MVR	579	10 mV or 0.007%	10 mV or 0.007%	1.0	115 ± 10%	57-63	√	R		625
−250 to −400 0 to −900	.03-.05 0-10 μA	715A‡	—	296	1% 1%	1% 1%	7 10	115/230 ± 10%	50-60		B		365
0-500	0-0.1	711A‡	—	579	1000 or 0.5%	1000 or 0.5%	1	115/230 ± 10%	50-1000		B		275
0 to +500 −300 0 to −150	0-0.2 0-0.05 0-0.005	712C‡	—	579	0.01% +5 mV 50 mV 50 mV	0.01% +50 mV 50 mV 50 mV	0.5 30 15	115 ± 10%	50-60	√	B	√	490
0-440 or 0-500 or 0-600	0-25 or 0-20 or 0-15	6483B	SCR-10	583	100 mV +0.5% combined		440 500 600	3φ 208/230/460 ± 10%	57-63	√	R	√	2600
1-600	0-1.5	6448B	SCR-1P	581	600 mV	600 mV	600 mV	115 V ac ± 10%	57-63	√	R	√	550
−250 to −800 0 to −800 6.3 V (ADJ)	0-2.0	716B‡	—	296	0.05% — —	0.05% 0.05% 1%	1 0.5 2	115/230 ± 10%	50-60		B		875
0-1000	0-0.2	6521A	HVR	580	20 mV or 0.005%	20 mV or 0.005%	1.0	115 ± 10%	50-500		R	√	750
0-1600	0-0.005	6515A	HVB	580	16 mV or 0.01%	16 mV or 0.01%	2.0	115 ± 10%	60		B		235
0-2000	0-0.1	6522A	HVR	580	20 mV or 0.002%	20 mV or 0.005%	1.0	115 ± 10%	50-500		R	√	750
0-3000	0-0.006	6110A	STB	566	100 μV +0.001%	0.001%	0.4	115 ± 10%	57-63		B		495
0-3000	0-0.006	6516A	HVB	580	16 mV or 0.01%	16 mV or 0.01%	2.0	115 ± 10%	57-63		B		295
0-4000	0-0.05	6525A	HVR	580	20 mV or 0.001%	20 mV or 0.005%	1.0	115 ± 10%	50-500		R	√	750

All Supplies: 50°C maximum ambient temperature rating. Floating output (ground either side), continuously variable output, low output impedance at all frequencies, 3-wire input, computer-quality electrolytics, 1 year warranty. No turn-on, turn-off overshoot; short-circuit-proof, all semiconductor except as noted by‡.

Transistor Supplies: Glass-epoxy printed circuit board construction, fully automatic overload protection — short-circuit-proof.

Options

Options are mechanical and/or electrical modifications to standard instruments performed at the factory. Below is a list of all the options available on Hewlett-Packard DC Power Supplies. To determine which options are available for a particular supply, refer to the appropriate product (pages 456-586).

No.	Description
01	208 ±10% V ac, 3-phase Input, 57-63 Hz. Input is factory wired for 208 V ac.
02	230 ±10% V ac, 3-phase Input, 57-63 Hz. Input is factory wired for 230 V ac.
03	460 ±10% V ac, 3-phase Input, 57-63 Hz. Input is factory wired for 460 V ac.
04	Casters. Factory mounts 4 casters on base of standard instrument.
05	50 Hz ac Input. Standard instrument is wired for 60 Hz ac. Option 05 includes alignment and in some cases internal rewiring.
06	Overvoltage "Crowbar" Protector. Protects delicate loads against power supply failure or operator error. Compact, inexpensive, can be factory installed at rear of power supply. Virtual short circuit (SCR crowbar) is placed across load within 10 microseconds after trip voltage is exceeded. For complete specifications, refer to appropriate data sheet.
07	Ten-Turn Output Voltage Control. Replaced concentric coarse and fine voltage control.
08	Ten-Turn Output Current Control. Replaces concentric coarse and fine current control.
09	Ten-Turn Output Voltage and Current Controls. Same as Options 07 and 08 on same instrument.
10	Chassis Slides: Enables convenient access to power supply interior for maintenance. Chassis slides are attached to supply at factory.
11	Internal Overvoltage Protection "Crowbar": Protects delicate loads by monitoring the output voltage and firing an SCR that shorts the output when the preset value is exceeded.
13	Three Digit Graduated Decadial Voltage Control: Includes 10-turn control replacing coarse and fine voltage control.
14	Three Digit Graduated Decadial Current Control: Includes 10-turn control replacing coarse and fine current control.
15	No 5V and 0.075A Meter Ranges: Model 6205B is available without the lower meter ranges, resulting in a $40 price reduction from the standard 230-volt transformer.
16	115 V ac ±10%, Single Phase Input: Factory modification includes the installation of a 115-Volt input power transformer to replace the standard 230-Volt transformer.
17	208 V ac ±10%, Single Phase Input: Factory modification includes the installation of a 208-Volt input power transformer to replace the standard 115 or 230-Volt transformer.
18	230 V ac ±10%, Single Phase Input: Factory modification includes the installation of a 230-Volt input power transformer to replace the standard 115-Volt transformer.
26	115 V ac ±10%, Single Phase Input: Factory modification consists of reconnecting the multi-tap input power transformer for 115-Volt operation.
28	230 V ac ±10%, Single Phase Input: Factory modification consists of reconnecting the multi-tap input power transformer for 230-Volt operation.
31	380 V ac ±10%, 57-63 Hz, 3-phase input.
32	400 V ac ±10%, 57-63 Hz, 3-phase input.
33	UHF Connectors: Installed instead of standard BNC connectors.

Accessories

Rack Kit 5¼" H x 9½" W for mounting nine 801C power supplies—14500A . . . $18

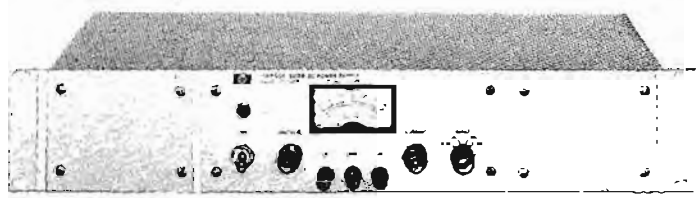
MOD Series rack kit 3½" H x 9½" W capable of accommodating up to six "A" size modules or one "B" and four "A" modules, or two "B" and two "A" modules, or three "B" modules—14503A $19

MOD Series rack kit 5¼" H x 9½" W capable of accommodating up to 10 "A" size modules or any combination of "A", "B" and "C" size modules having the same equivalent mounting area as 10 "A"-size modules—14505A $29

15½" high tilt rack mounting tray and brackets for Model 6946A—14526A . . . $55

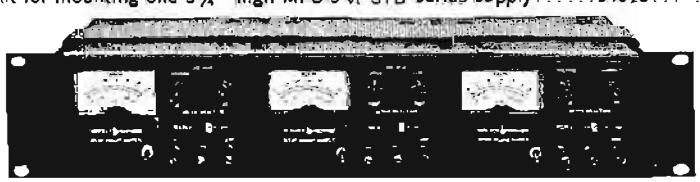
15½" high flush rack mounting brackets for Model 6946A—14528A $10

15½" high tilt rack mounting brackets—14529A $10



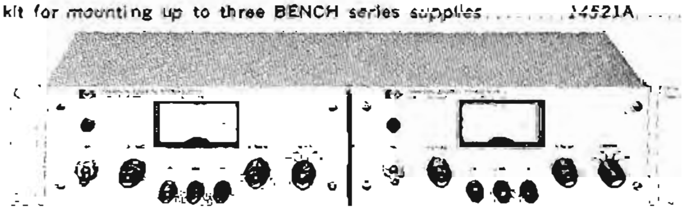
14513A, 14515A

Rack kit for mounting one 3½" high HVB, LAB, MPB-3, or STB series supply . . . . . 14513A $20
Rack kit for mounting one 5¼" high MPB-5 or STB series supply . . . . . 14515 . . . . . $23



14521A

Rack kit for mounting up to three BENCH series supplies . . . . 14521A $25



14523A, 14525A

Rack kit for mounting two 5¼" high MPB-5 or STB series supplies . . 14525A $12
Rack kit for mounting two 3½" high HVB, LAB, MPB3 or STB series supplies 14523A $10

POWER SUPPLIES

DEFINITIONS

A separate 1969 DC Power Supply Catalog/Handbook is available on request; it contains a wealth of detail on definitions, theory, operation and applications of DC power supplies. You can get your free copy from the local H-P sales office, or by contacting Harrison Division, 100 Locust Avenue, Berkeley Heights, New Jersey, 07922.

Ambient temperature. The room temperature, or effective temperature of the environment in which the power supply is operating.

Auto-parallel or automatic parallel operation. A master-slave parallel connection of the outputs of two or more Hewlett-Packard supplies used for obtaining a current output greater than that obtainable from one supply. Auto-Parallel operation is characterized by one-knob control, equal current sharing, and no internal wiring changes. Normally only supplies having the same model number may be connected in Auto-Parallel; in certain cases, however, supplies of the same Series are capable of mixed Auto-Parallel operation.

Auto-series or automatic series operation. A master-slave series connection of the outputs of two or more Hewlett-Packard power supplies used for obtaining a voltage greater than that obtainable from one supply. Auto-Series operation, which is permissible up to 300 volts off ground, is characterized by one-knob control, equal or proportional voltage sharing, and no internal wiring changes. Supplies of mixed model numbers may be connected in Auto-Series without restriction, provided that each slave is listed as being capable of Auto-Series operation.

Auto-tracking or automatic tracking operation. A master-slave connection of two or more Hewlett-Packard power supplies each of which has *one* of its output terminals in common with *one* of the output terminals of *all* of the other power supplies, such a connection pattern being characterized by one-knob control, proportional output voltage from all supplies, and no internal wiring changes. Useful where simultaneous turn-up, turn-down or proportional control of all power supplies in a system is required.

Constant current power supply. A regulated power supply which acts to keep its output current constant in spite of changes in load, line, or temperature. Thus, for a change in load resistance, the output current remains constant to a first approximation, while the output voltage changes by whatever amount necessary to accomplish this.

Constant voltage power supply. A regulated power supply which acts to keep its output voltage constant in spite of changes in load, line, or temperature. Thus, for a change in load resistance, the output voltage of this type of supply remains constant to a first approximation, while the output current changes by whatever amount necessary to accomplish this, the most common type of regulated dc power supply.

Constant voltage/constant current (CV/CC) with automatic crossover. A power supply which acts as a constant voltage source for comparatively large values of load resistance and as a constant current source for comparatively small values of load resistance. The automatic crossover or transition between these two modes of operation occurs at a "critical" or "crossover" value of load resistance $R_c = E_s/I_s$ where E_s is the front panel voltage control setting and I_s is the front panel current control setting.

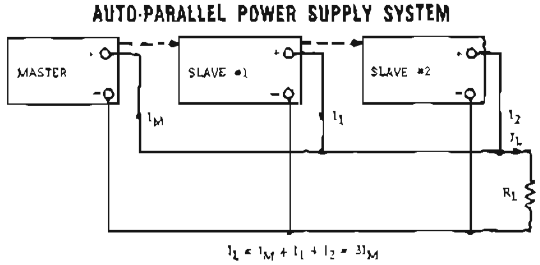
Constant voltage/current limiting (CV/CL) with automatic crossover. The same as CV/CC operation except for a slightly poorer regulation characteristic for low values of load resistance, i.e., in the "constant current" region of operation.

"Crowbar" voltage protector. A separate circuit which monitors the output of a power supply and instantaneously throws a short circuit (or "crowbar") across the output terminals of the power supply whenever a preset voltage limit is exceeded. An SCR is usually used as the "crowbar" device.

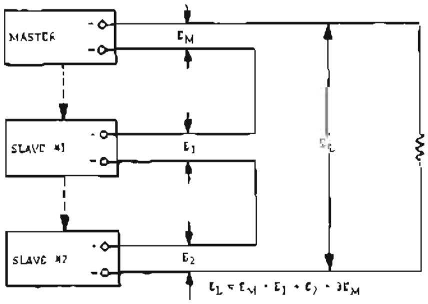
Drift. A term loosely used to describe the slow variations in the output of a regulated power supply due to STABILITY and/or TEMPERATURE COEFFICIENT.

Line regulation of a constant current power supply. The change in the static value of the dc output current resulting from a change in ac input voltage from

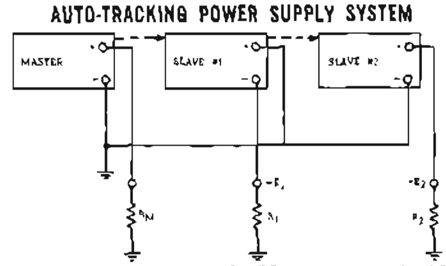
AUTO-PARALLEL POWER SUPPLY SYSTEM



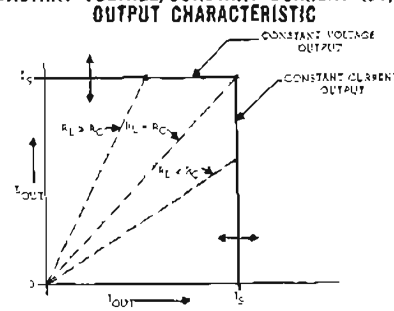
AUTO-SERIES POWER SUPPLY SYSTEM



AUTO-TRACKING POWER SUPPLY SYSTEM



CONSTANT VOLTAGE/CONSTANT CURRENT (CV/CC) OUTPUT CHARACTERISTIC



low line (usually 105 volts) to high line (usually 125 volts) or from high line to low line.

Line regulation of a constant voltage power supply. The change in the static value of dc output voltage resulting from a change in ac input voltage from low line (usually 105 volts) to high line (usually 125 volts) or from high line to low line.

Load regulation of a constant current power supply. The change in the static value of dc output current resulting from a change in load resistance from short circuit to a value which gives maximum rated output voltage.

Load regulation of a constant voltage power supply. The change in the static value of dc output voltage resulting from a change in load resistance from open circuit to a value which yields maximum rated output current.

Output Impedance of a power supply. At any given frequency of load change, $\Delta E_{out}/\Delta I_{out}$. Strictly speaking the definition applies only for a sinusoidal load disturbance, unless, of course, the measurement is made at zero frequency (dc). The output impedance of an ideal constant voltage power supply would be zero at all frequencies, while the output impedance for an *ideal* constant-current power supply would be infinite at all frequencies.

Recovery time. See Transient Recovery Time.

Remote error sensing or Remote sensing. A feature found on most HP power supplies, which, by means of two extra wires between the supply and the load, permits the power supply to achieve its optimum regulation at the load terminals rather than at the power supply output terminals, thus compensating for the IR drop present in the current carrying leads connecting the load to its power supply. The current through the sensing leads is so small that in spite of the resistance of these leads, their voltage drop is negligible.

Remote programming. A feature of most HP power supplies which makes possible control of the regulated output by means of a remotely varied resistance. This feature also permits control of the output of a power supply by means of a voltage input rather than by means of a control resistance.

Ripple. The residual ac component which is superimposed on the dc component of the output of a regulated power supply. Ripple is usually specified in terms of its RMS value.

Stability. Obviously a misnomer, this term refers to the instability in power supply output which occurs in the presence of constant load, constant line and constant ambient temperature for a stated period of time (usually 8 hours) following warm-up. This small output variation, which is related in part to the internal temperature rise of the power supply, is the zero frequency component of noise which must be present in any dc amplifier or regulator, even though all input, output, environmental, and control parameters are held constant.

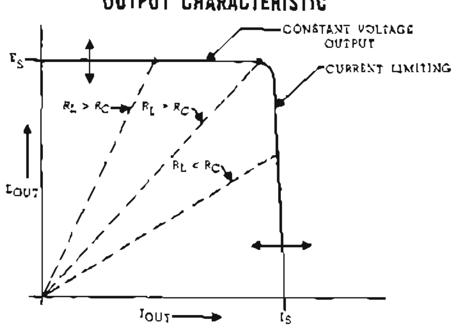
Temperature coefficient. For a power supply operated at constant load and under conditions of constant input ac line voltage, the change in output voltage (for a constant voltage supply) or output current (for a constant current supply) for each degree change in the ambient temperature.

Transient recovery time. Sometimes referred to as recovery time, transient response time, or response time — loosely speaking the time required for the output voltage of a power supply to come back to within a level approximating the normal dc output following a sudden change in load current. More exactly, Transient Recovery Time is the time "X" required for output voltage recovery to within "Y" millivolts of the nominal output voltage following a "Z" amp step change in load current — where:

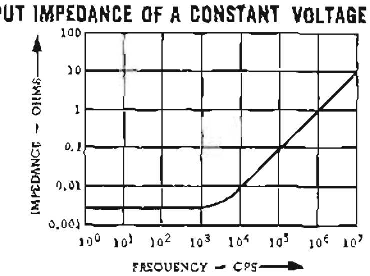
"Y" is specified separately for each model but is generally of the same order as the load regulation specification, the nominal output voltage is defined as the dc level half way between the static output voltage before and after the imposed load change, and

"Z" is the specified load current change, normally equal to the full load current rating of the supply.

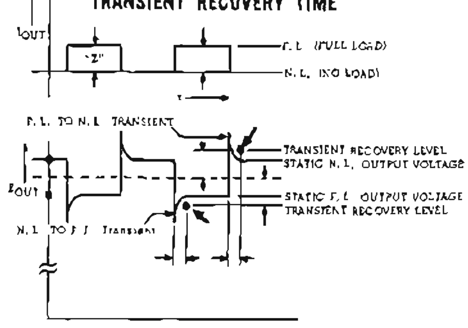
CONSTANT VOLTAGE/CURRENT LIMITING (CV/CL) OUTPUT CHARACTERISTIC



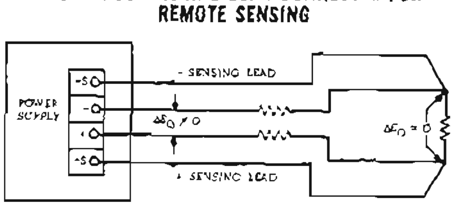
TYPICAL OUTPUT IMPEDANCE OF A CONSTANT VOLTAGE POWER SUPPLY



TRANSIENT RECOVERY TIME



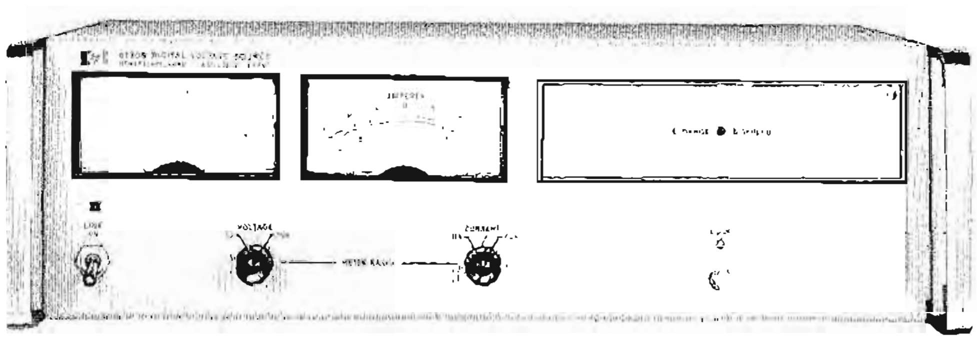
POWER SUPPLY AND LOAD CONNECTED FOR REMOTE SENSING



DIGITAL VOLTAGE SOURCES

System-compatible, fast bipolar output

Models 6130B, 6131B



Advantages:

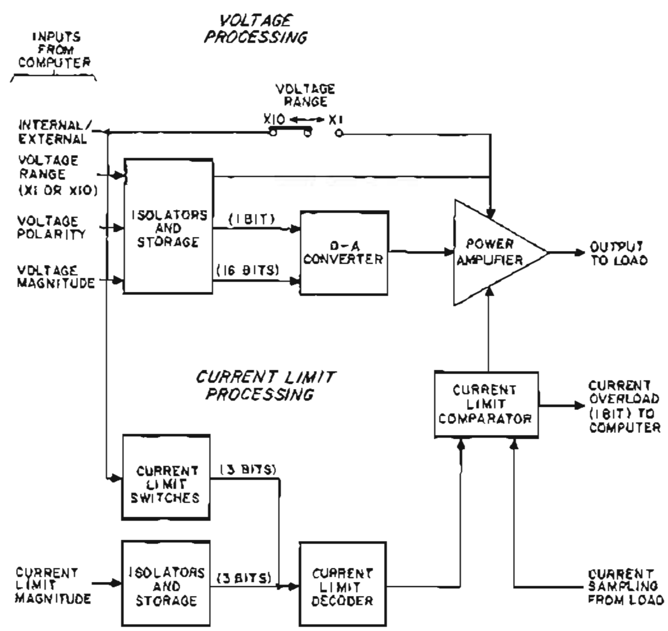
- High speed digital programming through zero
- Solid-state processing on all data lines
- Compatible with existing digital systems
- Multiplex capability with Hewlett-Packard computers (to eight units)
- Isolates and stores data inputs
- Output current sinking capability of up to 500 mA
- No overshoot or programmed output voltage
- Current limit protection
- No turn-on, turn-off, or power removal overshoot
- Output automatically shorts during ac input power removal or input data disconnect

Description

Both Digital Voltage Sources, Model 6130B and Model 6131B, are digitally-programmed regulated dc power supplies with bipolar outputs. All data processing is performed by solid-state circuits (no relays), thus, the output voltage can be programmed from −50 V to +50 V in less than 100 μs (the voltage range of the 6131B is −100 V to +100 V and requires less than 200 μs for a complete swing of output).

The plug-in board design provides the flexibility needed to suit the coding and logic levels of most computers. For the Digital Voltage Sources to interface with either a BCD or binary input, only two plug-in boards are replaced. A multiplex input/output card is now available for multiplex operation of eight Digital Voltage Sources with the Hewlett-Packard computers. See "Interface Kit." Each instrument is manufactured in accordance with customer specifications on input and output data.

The Digital Voltage Source consists of three main sections: (1) output voltage processing (2) current limit processing and (3) high-speed power amplifier as illustrated in the following block diagram.



NOTE TIMING SIGNALS ARE OMITTED FOR CLARITY.

The *voltage magnitude* input is a 4-digit, BCD (8421) or binary code that programs the output between −9.999 and +9.999 volts with 1 mV resolution. The voltage range input multiplies the voltage magnitude X1 or X10. In the Model 6130B X10 range, for example, the output is programmable between −50.00 and +50.00 volts with 10 mV resolution. The voltage polarity input designates the output voltage sign, + or −.

The *current limit magnitude* input is a three-bit code. Two bits select a current limit of 20, 50, 70, or 100 mA. The third bit multiplies the magnitude by 1 or 10. In the X10 range, the current limit is programmed to 200, 500, 700, or 1000 mA.

The internal/external input selects either the internal (DVS) control or the external (computer) control.

The output voltage data processor isolates, stores, and converts the *voltage polarity* and *magnitude* inputs to the corresponding analog output voltage between −9.999 and 9.999

V. This section also receives the appropriate voltage range data from either the computer or the voltage range switch on the Digital Voltage Source, depending on the state of the internal/external signal from the computer. The voltage range data programs the power amplifier for X1 or X10 output (−9.999 to +9.999 or −50.00 to +50.00 V).

Current limit magnitude and range are provided by the computer or the current limit switches on the Digital Voltage Source, depending on the state of the internal/external signal as in the voltage range input. They are decoded and compared to a sample of the load current. If the output current exceeds the programmed current limit, the power amplifier output is open-circuited electronically, and the computer is notified of the overload condition.

Specifications

Dual range dc output

6130B: −10 to +10 V dc (1 mV increments) @ 0-1A
−50 to +50 V dc (10 mV increments) @ 0-1A
6131B: −10 to +10 V dc (1 mV increments) @ 0-.5A
−100 to +100 V dc (10 mV increments) @ 0-.5A
NOTE: Binary voltage increments are half of the above values.

Current sinking: the ability to absorb energy from the load rather than supply is defined as current sinking. This occurs when current is flowing into the positive terminal and out of the negative terminal. Model 6130B is capable of up to 500 mA current sinking; 6131B will handle 250 mA current sinking.

Current limit: 20, 50, 70, 100, 200, 500, 700, or 1000 mA with an accuracy of 5%. (Common to both units; upper limits for these units are safeguarded by a separate fixed current limit circuit which limits output current to 110% of current rating.) Current limit operates in both the source and sink modes. The reaction time for the adjustable current limit circuitry to open-circuit the output may be varied from 5 μsec to 2 msec by adding an external capacitor at the rear terminals.

AC power input: 115 V ac ±10%, 48-440 Hz.

Load regulation: for a load current change equal to the current rating of the supply.
Low-volt (X1) range: 0.2 mV.
High-volt (X10) range: 2 mV.

Line regulation: for a change in line voltage from 103.5 to 126.5 V ac.
Low-volt (X1) range: 0.2 mV.
High-volt (X10) range: 2 mV.

Ripple and noise: at any line voltage and load condition within rating.
Low-volt (X1) range: 1 mV p-p (dc to 20 MHz).
High-volt (X10) range: 5 mV p-p (dc to 20 MHz).

Input/output data requirements: BCD or binary format, and the input/output coding, levels, and polarity of the data for the Digital Voltage Source are selected by the customer. Two plug-in boards are modified at the factory to fit these requirements. To identify the input/output data, the two boards are assigned Hewlett-Packard part numbers and the overall unit is given a (J) option number. For interfacing with Hewlett-Packard computers, 2114A, 2115A, 2116A/B, see J-numbers under "Options".

Programming speed: *time required to attain 99.9% of programmed value, using a resistive load.*
Voltage: 6130B: −50 V to +50 V in less than 100 μsec.
6131B: −100 V to +100 V in less than 200 μsec.
Voltage data transfer rate: greater than 10,000 words/sec.
Current limit: less than 50 μsec.
Voltage range: less than 2 msec.

Meters: the front panel includes a voltmeter and ammeter with 3% accuracy and the following ranges:

6130B		6131B	
Volts:	−60 to +60 V	**Volts:**	−120 to +120 V
	−10 to +10 V		−10 to +10 V
Amps:	−1.2 to +1.2 A	**Amps:**	−.60 to +.60 A
	−0.3 to +0.3 A		−.15 to +.15 A
	−0.12 to +0.12 A		−.06 to +.06 A

Transient recovery time: less than 100 μseconds is required for output voltage recovery to within 0.1% of the range setting following a change in output current equal to the current rating of the supply.

Output Impedance:
0—10 Hz: less than .001Ω (typically .0005Ω).
10 Hz—1 KHz: less than .1Ω (typically .05Ω).
1 KHz—100 KHz: less than 10Ω (typically 5Ω).
100 KHz—1 MHz: less than 200Ω (typically 100Ω).

Temperature ranges:
Operating: 0 to 55°C.
Storage: −40 to +75°C.

Resolution: (Binary/BCD)
Low-volt (X1) range: (0.5 mV/1 mV).
High-volt (X10) range: (5 mV/10 mV).

Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warm-up.
Low-volt (X1) range: less than 100 μV/°C.
High-volt (X10) range: less than 500 μV/°C.

Accuracy: includes deviations resulting from full line and load changes and a ±5°C change in temperature from 25°C.
Low-volt (X1) range: 1 mV.
High-volt (X10) range: 10 mV.

Options: *at no extra cost, "J" number options indicate the following compatibilities with Hewlett-Packard computers, 2114A, 2115A, 2116A/B:*
J-19: Binary-coded decimal (BCD) inputs from multiplex input/output card.
J-20: *Binary inputs from multiplex input/output card.*
Other options: 28--$10. See page 561.

Hewlett-Packard Interface Kit: 14535A: Kit supplies complete connecting hardware—cable, multiplex card, and program—for one Digital Voltage Source unit. Multiplex card will handle up to eight units. Cables for connecting other units are optional. Consult HP office.

Pocket Programmer: 14533A: This accessory replaces the computer by manually programming all inputs by switch closures. The Pocket Programmer is plugged into the connector on the rear of these units, which normally connect to a computer.—$97.

3-ft. Extension Cable for Pocket Programmer: 14534A: Includes 50-conductor cable.—$50.

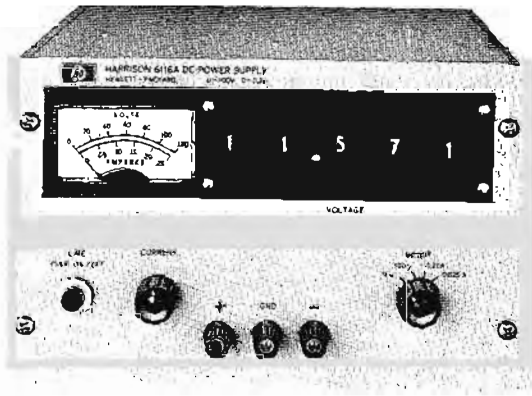
Price: $1,500. (for either model).

HIGH STABILITY SUPPLY/CALIBRATOR

STB series

Models 6101A—6116A

Models 6101A · 6106A



Models 6110A · 6116A

Model		6101A	6102A	6106A	6110A	6111A	6112A	6113A	6116A
DC output		0-20V 0-1A	0-40V 0-500mA	0-100V 0-200mA	0-3000V 0-6mA	0-20V 0-1A	0-40V 0-500mA	0-10V 0-2A	0-100V 0-200mA
Load regulation: For full rated output current change	Front terminals	0.001% (10ppm) plus 600 μV	0.001% (10ppm) plus 350 μV	0.001% (10ppm) plus 200 μV	0.001% (10ppm) plus 100 μV	0.001% (10ppm) plus 200 μV	0.001% (10ppm) plus 350 μV	0.001% (10ppm) plus 1.1 mV	0.001% (10ppm) plus 200 μV
	Rear terminals	0.001% (10ppm) + 100 μV			———	0.001% (10ppm) + 100 μV			
Line regulation: For a 10% change in the nominal line voltage		0.001% (10ppm)		0.001% (10ppm)			0.001% (10ppm)		
Ripple and noise		40 μV RMS 100 μV P-P		40 μV RMS 100 μV P-P	400 μV RMS 1 mV P-P	40 μV RMS 100 μV P-P			
Temperature coefficient: Output voltage change per °C after 30 minute warm-up.	Front panel control	0.005% (50ppm) plus 30 μV	0.005% (50ppm) plus 50 μV	0.005% (50ppm) plus 100 μV	0.001% (10ppm) plus 50 μV	0.001% (10ppm) + 10 μV			
	Remote programming	0.001% (10ppm) plus 10 μV	0.001% (10ppm) plus 10 μV	0.001% (10ppm) plus 50 μV	———				
Stability: Total drift after 30 minute warm-up and with 3°C ambient variation.	Front panel control	For 8 hrs. 0.01% + 300 μV	For 8 hrs. 0.01% + 500 μV	For 8 hrs. 0.01% + 1 mV	For 8 hrs. 0.01% + 500 μV For 1 month 0.012% + 500 μV	For 8 hours: 0.01% + 100 μV For 1 month: 0.012% + 120 μV Controlled Environment **for 8 hours: (0.0005%) + 10 μV			
	Remote programming	For 8 hrs. — 0.10% + 100 μV For 1 month — 0.012% + 120 μV							
Output Impedance		DC — 100 Hz: <0.002 Ω 100 Hz — 1 kHz: <0.02 Ω 1 kHz — 100 kHz: <0.5 Ω 100 kHz — 1 MHz: <3 Ω			At 3000 V DC — 1000 Hz; <50 Ω At 3 V DC — 100 Hz; <0.05 Ω	DC—100 Hz: <0.002Ω 100 Hz—1 kHz: <0.02Ω 1 kHz—100 kHz: <0.5Ω 100 kHz—1 MHz: <3Ω			
Remote programming: All programming terminals are located on rear barrier strip		Coefficient — 1000 ohms per volt Accuracy — 0.1% plus 1 mV Resettability — 0.01% + 200 μV			———	Coefficient—1000 ohms per volt Accuracy—0.1% plus 1 mV Resettability—0.01% + 200 μV			
Meters ranges Single meter with switch to select scale		0-2.5V/0-25V 0-120mA/0-1.2A	0-5V/0-50V 0-60mA/0-600mA	0-12V/0-120V 0-25mA/0-250mA	0-3500V 0-7mA	0-2.5V/0-25V 0-120mA/0-1.2A	0-5V/0-50V 0-60mA/0-600mA	0-1.2V/0-12V 0-250mA/0-2.5A	0-12V/0-120V 0-25mA/0-250mA
Size	Inches	8½W × 3½H × 12⅝D			8½W × 5¼H × 16D	8½W × 5¼H × 12⅝D			
	Centimeters	21.6W × 8.9H × 32D			21.6W × 14H × 40.6D	21.6W × 14H × 32D			
Weight: Net/Shipping (lb.)	Pounds	10/13	10/13	10/13	19/23	11/15	11/15	11/15	11/15
	Kilograms	4.5/5.9	4.5/5.9	4.5/5.9	7.7/10.4	5.0/6.8	5.0/6.8	5.0/6.8	5.0/6.8
Price		$265	$265	$265	$495	$375	$375	$375	$375
Options: Refer to p. 561 for description.		06 — $95 28 — $10	06 — $95 28 — $10	06 — $95 28 — $10	*05 — $50 18 — $50	06 — $95 28 — $10	06 — $95 28 — $10	06 — $95 28 — $10	06 — $95 28 — $10

*No charge if ordered with option 18 **Constant load current, line voltage, and ambient temperature

Advantages

Low output drift and temperature coefficient.

Low output ripple

Low output impedance

High accuracy remote programming (except 6110A)

Remote error sensing (except 6110A)

No overshoot on turn-on, turn-off, or power removal

Output continuously adjustable to zero volts

High output voltage resolution — ten-turn coarse and one-turn fine control (6101A, 6102A and 6106A)

In-line 5-digit thumb-wheel voltage programmer (6110A, 6111A, 6112A, 6113A, 6116A)

All silicon design

Positive or negative output

Short circuit proof

Continuously variable current limit control

Output voltage and current metering

Easily rack mounted for systems applications

Auto-series and auto-tracking operation

Multiple range meter

Resettability — 0.01% +200 μV

Description

The STB Series of high stability dc bench supplies has been designed for those applications requiring performance an order of magnitude better than well-regulated laboratory supplies. The performance advantages of the STB Series exist with regard to virtually every important aspect of power supply performance — ripple, stability, temperature coefficient, output resolution, programming accuracy, load and line regulation.

The all-silicon circuit uses as its reference element a temperature-compensated zener diode having a temperature coefficient of 20 ppm/°C. A high gain feedback amplifier employing a "diff-amp" (matched silicon differential amplifier package) monitors and controls the output voltage. Critical components, including the zener reference diode and low level portions of the feedback amplifier, are enclosed in an oven which is temperature-controlled entirely with solid-state components — no moving parts to wear out.

Models 6111A, 6112A, 6113A, and 6116A are similar to models 6101A, 6102A and 6106A except for the built-in 5-digit thumb-wheel voltage programmer.

Model 6110A is a high-voltage high-stability supply that is all silicon (no tubes) and also can provide a positive or negative output. The 6110A is ideally suited for high-voltage photomultipliers requiring an exceptionally stable power source. It can also be used as a 0-3000 volt calibrator.

Specifications

AC input: Model 6110A—115 Vac ±10%, 57-63 Hz, 1A, 50 W. Other Models—115 Vac ±10%, 48-63 Hz, 0.5A, 52 W.

Temperature ranges: operating: 0 to 50°C.
storage: −20°C to +85°C.

Transient recovery time: less than 50 μs is required for output voltage to recover to within 10 millivolts of the nominal output voltage following a full load change in output current.

Less than 100 μs is required for output voltage recovery to within the load regulation specification.

The nominal output voltage is defined as the means between the no load and full load voltage.

Controls: 6101A, 6102A & 6106A—A 10 turn pot permits continuous adjustment of the output voltage over its entire range. A single-turn pot allows fine trimming of the output voltage; resolution is 100 μV +0.002% of the output voltage. A single-turn front-panel pot permits the current limit setting to be varied continuously from zero to a value slightly in excess of the full current rating.
6110A, 6111A, 6112A, 6113A & 6116A—An in-line 5-digit (thumb-wheel) voltage programmer permits control of the output voltage with an accuracy of 0.1% +1 mV (6110A is 0.1% +100 mV and 6113A is 0.1% + 10 μV) of the output voltage. Resolution is 100 μV (except 6110A, which is 10 mV). The 6111A, 6112A, 6113A & 6116A have a single-turn front panel pot that permits the current limit setting to be varied continuously from zero to a value slightly in excess of the full current rating. The 6110A has a fixed current limit built-in to the supply.

Overload protection: an all electronic, continuously acting current limit protects the power supply for all overloads regardless of how long imposed, including a direct short circuit across the output terminals.

Output terminals: The dc output of the supply is floating; thus, the supply can be used as either a positive or negative source. Terminals for +OUT, −OUT, and GND are provided on both the front and back of the supply (except 6110A which has front terminals only). In addition, the rear barrier strip includes terminals for remote programming, remote sensing, Auto-Series, and Auto-Tracking operation (except 6110A).

Cooling: convection cooling is employed. The supply has no moving parts.

Finish: light gray front panel with dark gray case.

Power cord: a 3-wire 5-foot power cord is provided with each unit.

Accessories: see rack kits on page 561.

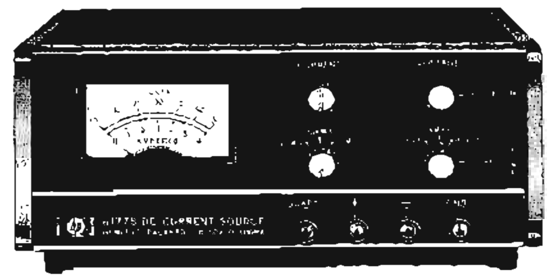
CONSTANT CURRENT SUPPLIES

CCB Series

Models 6177B-6181B

Advantages

- Precision constant current regulation
- Rapid programming
- Output useful to microampere region
- High output impedance over wide frequency band
- Remote programming using resistance or voltage control
- Can be modulated from external ac source
- Continuously variable voltage limit
- Auto parallel operation
- Front and rear output terminals
- Floating output can be used as positive or negative source
- No overshoot for turn-on, turn-off, or power removal
- Rear terminals for monitoring output voltage



6177B

Description

Precision performance, low price, and small size and weight, combine to make the new CCB "B" Series supplies useful as general purpose laboratory constant current sources for semiconductor circuit development and component evaluation. Their ripple, regulation, and drift characteristics are orders of magnitude better than comparably priced constant current supplies.

In standard constant current supplies, placing a voltmeter across the output terminals degrades the load regulation and diminishes the load current. The CCB Series eliminates this error by using an operational amplifier to feed the front panel voltmeter.

Special attention has been given to circuit details so that well regulated performance is maintained down to low output currents (0.2 μA).

Other design precautions contribute to the dc isolation and ac shielding properties which are necessary for a high performance constant current supply.

The CCB "B" Series now has two models, 6177B and 6181B, which can be precisely programmed with either voltage or resistance. In voltage programming, for example, the Model 6177B (with top output of 500 mA at 50 V dc) offers three ranges: 5 mA, 50 mA, and 500 mA, with a voltage programming ratio of 200 mV/mA on the 5 mA range. With every program change of 1 mV, the constant current output changes by only 5 μA.

Specifications

DC output: Model 6177B: 0-500 mA, 0-50 V dc compliance; Model 6181B: 0-250 mA, 0-100 V dc compliance.

AC input: 115 V ac ±10%, 48-64 Hz.

Output ranges: Model 6177B: 0-5 mA, 0-50 mA, 0-500 mA; Model 6181B: 0-2.5 mA, 0-25 mA, 0-250 mA.

Current programming values

Voltage: Model 6177B: 0-1 V span for all output ranges; Model 6181B: 0-2.5 V span for all output ranges (i.e. a 10 mV program change results in a 1 mA change on Model 6181's 250 mA range, but only in a .1 mA change on its 25 mA range).

Resistance: Model 6177B: 0-2000Ω span for all output ranges; Model 6181B: 0-5000Ω span for all output ranges (i.e. a 20Ω change on Model 6181's 250 mA range results in 1 mA change, but only .1 mA on the 25 mA range).

Load regulation: less than 25 ppm of output +5 ppm of range switch setting for a load change resulting in an output voltage change from zero to maximum rated output.

Line regulation: less than 25 ppm for a 10% change in the nominal line voltage.

RMS ripple & noise: less than 50 ppm of output +25 ppm of range switch setting.

Transient recovery time: less than 200 μs for output current recovery to within 1% of the nominal output current following a full load change in output voltage.

Current programming speed: less than 500 μsec from zero to 0.99 of desired output current.

Temperature coefficient: less than 75 ppm of output +5 ppm of range switch setting per degree C.

Stability: less than 100 ppm of output +25 ppm of range switch setting. Stability is measured for eight hours after 30 minutes warm-up under conditions of constant line, load, and temperature.

Resolution: 0.02% of range switch setting.

Temperature rating: operating: 0 to 55°C. Storage: −40 to +85°C.

Controls: three-position output current and meter range switch. 10-turn output current control, voltage limit control, meter switch, power switch, and pilot light.

Output terminals: a positive and negative output terminal are included on the front panel, as well as a ground terminal. The supply may be operated floating or either side may be grounded. A rear panel barrier strip includes output terminals and other terminals necessary for remote programming, ac modulation, and other control functions.

Meter ranges: Model 6177B: 6, 60, 600 mA, 60 V dc; Model 6181B: 3, 30, 300 mA, 120 V dc.

Size: 3" (7,6 cm) H x 7¾" (19,6 cm) W x 11¾" (29,8 cm) D. Package size is half rack width and is easily rack mounted using accessories listed on page 561.

Weight: 10 lbs (4,53 kg) net, 13 lbs (5,9 kg) shipping.

Options: 14—$35; 28—$10. See page 561 for details.

Accessories: see rack kits, etc. on page 561.

Price: $425 (for either model).

MEDIUM POWER MODULAR

MPM series

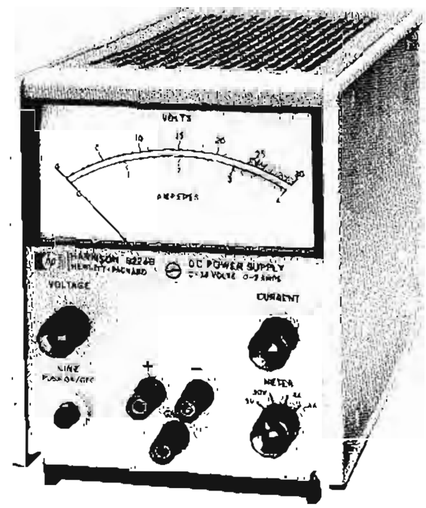
Models 6220B-6226B

The MPM Series consists of compact constant voltage/constant current dc power supplies suitable for either bench or rack operation. They are packaged in one-third rack width modules for use in the modular enclosure system, described on page 225. MPM supplies are designed to satisfy the need for a general purpose and reliable source of power for engineers experimenting with transistor circuit design.

Models 6224B and 6226B possess all of the advantages of the preceding "A" versions of these models plus the following improvements:

a. Increased output voltage.
b. Ten-turn voltage and current controls for better output settability.
c. Multiple range meter for increased bench utility.
d. Special circuitry for faster programming.
e. All silicon semiconductors for greater reliability.

In addition a dual range supply, Model 6220B has been added to the series. This supply can be used as a 0-25 volt source at 0-1 A or a 0-50 volt source at 0-0.5 A.



6224B

Specifications

Model		6220B			6224B	6226B
Output	DC voltage	0-25 V	Dual range	0-50 V	0-24 V	0-50 V
	DC current	0-1 A		0-0.5 A	0-3 A	0-1.5 A
Input: 115 V ac ±10%		50-400 Hz 0.5A,44W			50-60 Hz 1.8 A, 164 W	50-60 Hz 1.8 A, 164 W
Load regulation: the constant voltage load regulation is given for a load current change equal to the current rating of the supply. The constant current load regulation is given for a load voltage change equal to the voltage rating of the supply.	CV	0.01% plus 2 mV			0.01% plus 4 mV	0.01% plus 2 mV
	CC	0.01% plus 250 μA			0.01% plus 250 μA	0.01% plus 250 μA
Line regulation: for a ±10% change in the nominal line voltage at any output voltage and current within rating.	CV	0.01% plus 2 mV			0.01% plus 2 mV	0.01% plus 2 mV
	CC	0.01% plus 250 μA			0.01% plus 250 μA	0.01% plus 250 μA
Ripple and noise: at any line voltage and under any load condition within rating.	CV	200 μV rms/1 mV p-p (dc to 20 MHz)				
	CC	200 μA rms/1 mA p-p (dc to 20 MHz)				
Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warm-up.	CV	0.02% plus 1 mV			0.02% plus 500 μV	0.02% plus 500 μV
	CC	0.02% plus 1 mA		0.02% plus 0.5 mA	0.02% plus 1.5 mA	0.02% plus 0.8 mA
Stability: under constant ambient conditions, total drift for 8 hours following 30 minutes warm-up.	CV	0.1% plus 5 mV			0.1% plus 2.5 mV	0.1% plus 2.5 mV
	CC	0.1% plus 5 mA		0.1% plus 2.5 mA	0.1% plus 7.5 mA	0.1% plus 4 mA
Remote programming: all programming terminals are located on rear barrier strips.	CV	200 ohms per volt			200 ohms per volt	200 ohms per volt
	CC	500 ohms per amp		1000 ohms per amp	500 ohms per amp	500 ohms per amp
Meter ranges		0-6 V, 0-60 V, 0-0.12 A, 0-1.2 A			0-3 V, 0-30 V, 0-0.4 A, 0-4 A	0-6 V, 0-60 V, 0-0.18 A, 0-1.8 A
Weight: (net/shipping)	lbs.	16/20			16/20	16/20
	kg	7,25/9,1			7,25/8.6	7,25/8,6
Price:		$250			$325	$325
Options: refer to page 561 for description		13—$35 14—$35 28—$10				

CV = Constant Voltage   CC = Constant Current

Output impedance
DC to 100 Hz—less than 0.001 ohm, 100 Hz to 1 kHz—less than 0.01 ohm, 1 kHz to 100 kHz—less than 0.2 ohm, 100 kHz to 1 MHz—less than 2 ohms.

Transient recovery time: less than 50 μseconds is required for output voltage recovery in constant voltage operation to within 10 millivolts of the nominal output voltage following a change in output current equal to the current rating of the supply. The nominal output voltage is defined as the mean between the no load and full load voltages.

Temperature ratings: operating: 0-50°C (consult factory for derating information for operation between 50°C and 71°C); storage: −20°C to +85°C.

Controls: ten-turn output voltage and current controls permit continuous adjustment over entire output span. Switch selects front panel meter voltage or current scale.

Finish: light gray panel with dark gray case.

Size: 6¼" H x 5⅛" W x 11" D (15.9 cm H x 13 cm W x 28 cm D).

SMALL LABORATORY SUPPLIES

BENCH Series

Models 721A, 6213A-6218A

Advantages:

- High quality—low cost
- Short circuit-proof—current limit circuit protects the supply against any overload, including a direct short circuit across the output terminals, for any time interval without damage
- Compact—impact-resistant case
- Floating output—supply can be operated as a positive or negative source
- Silicon differential amplifiers compare the output voltage with a stable reference voltage; provide improved stability
- No turn-on, turn-off, or power removal overshoot
- Coarse and fine controls
- Low output ripple and drift
- Rack mounting hardware available
- Fully serviceable

Description

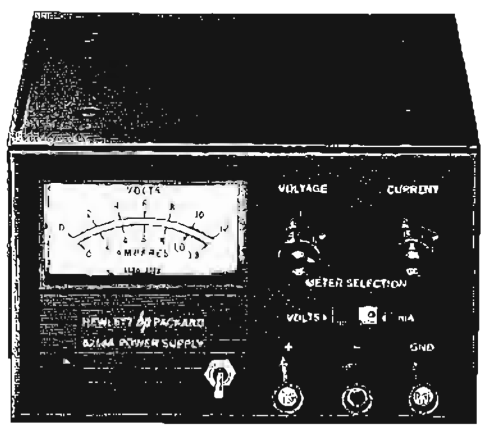
Six extremely compact well-regulated dc power supplies, designed especially for bench use, comprise the BENCH series. New fabrication techniques employed minimize manufacturing costs while retaining component and circuit quality. Reliable, yet low cost, these "hand-size" battery substitutes have overall performance features ideal for circuit development, component evaluation, and other laboratory applications.

The all-silicon circuit uses an input differential amplifier to compare the output voltage with reference voltage derived from a temperature-compensated zener diode. These stable input and reference circuits are combined with a high gain feedback amplifier to achieve low-noise drift-free performance. Output voltage is fully adjustable to zero. Special design precautions prevent output overshoot during turn-on or turn-off, or when ac power is suddenly removed.

The front panel meter can be switched to monitor output voltage or current. Constant voltage/constant current or constant voltage/current limiting insures short-circuit proof operation, and permits series and parallel connection of two or more supplies when greater voltage or current is desired.

The molded, impact-resistant case includes an interlocking feature for stacking several units vertically, thus minimizing bench space required for multiple supplies. Alternatively, up to three units can be mounted side by side in a 19" rack using a special Rack Mounting Kit. See page 561.

Model 6213A
Constant Voltage/Current Limiting



Model 6214A
Constant Voltage/Constant Current

Common Specifications

Transient recovery time: less than 50 μseconds is required for output voltage recovery in constant voltage operation to within 15 millivolts of the nominal output voltage following a change in output current equal to the current rating of the supply; the nominal output voltage is defined as the mean between the no load and full load voltages.

Output impedance:
Less than 0.03 ohm from DC to 1 kHz.
Less than 0.5 ohm from 1 kHz to 100 kHz.
Less than 3 ohms from 100 kHz to 1 MHz.

Temperature ratings:
Operating: 0 to 55°C (consult factory for derating information for operation over 55°C).
Storage: −40°C to +75°C.

Size: — 3¼" H x 5¼" W x 7" D.
— 8,26 cm H x 13,34 cm W x 17,78 cm D.

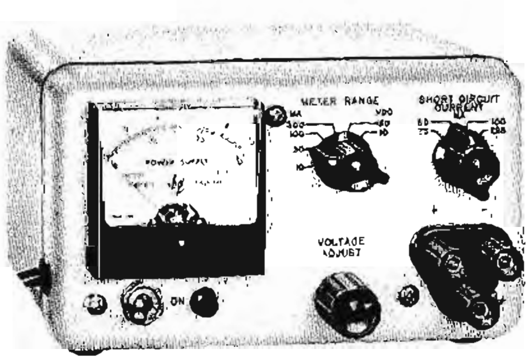
Output terminals: either positive or negative output terminal may be connected to ground through a separate terminal provided for that purpose, or the supply may be operated floating at up to 300 volts off ground.

Cooling: convection cooling is employed — no moving parts.

Option 28 — 230 vac ± 10%, single phase input: factory modification consists of reconnecting the multitap input power transformer for 230-volt operation; **Price $10.**

Specifications

		Constant voltage/current limiting			Constant voltage/constant current		
Model		**6213A**	**6215A**	**6217A**	**6214A**	**6216A**	**6218A**
Output	DC voltage DC current	0–10 V 0–1 A	0–25 V 0–400 mA	0–50 V 0–200 mA	0–10 V 0–1 A	0–25 V 400 mA	0–50 V 0–200 mA
Input: 115 V ac ± 10%, 50-400 Hz		0.29 A, 28 W	0.25 A, 25 W	0.25 A, 25 W	0.29 A, 28 W	0.25 A, 26 W	0.25 A, 26 W
Load regulation: the constant voltage load regulation is given for a load current change equal to the current rating of the supply; the Constant Current load regulation is given for a load voltage change equal to the voltage rating of the supply.	CV	4 mV			4 mV		
	CC	–	–	–	500 μA		
Line regulation: for a change in line voltage from 103.5 to 126.5 (or 126.5 to 103.5) at any output voltage and current within rating.	CV	4 mV			4 mV		
	CC	–	–	–	750 μA	500 μA	500 μA
Ripple and noise: at any line voltage and load condition within rating.	CV	200 μV rms/1 mV p-p (dc to 20 MHz)			200 μV rms/1 mV p-p (dc to 20 MHz)		
	CC	–	–	–	150 μA rms/500 μA p-p (dc to 20 MHz)		
Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warm-up.	CV	(0.02% + 1 mV) per °C			(0.02% + 1 mV) per °C		
	CC	–	–	–	6 mA per °C	2 mA per °C	1 mA per °C
Stability: under constant ambient conditions, total drift for 8 hours following 30 minutes warm-up.	CV	0.1% + 5 mV				0.1% + 5 mV	
	CC	–	–	–	15 mA	5 mA	2.5 mA
Resolution:	CV	<5 mV	<5 mV	<10 mV	<5 mV	<5 mV	10 mV
	CC	–	–	–	<75 μA	<20 μA	10 μA
Controls:		On-off switch and separate pilot light; one-turn coarse and fine voltage controls; meter switch selects volts or mA			On-off switch and separate pilot light; concentric coarse and fine voltage control; concentric coarse and fine current control; meter range switch		
Meter ranges: accuracy is 3% of full scale.		0–12 V, 0–1.2 A	0–30 V, 0–500 mA	0–60 V, 0–250 mA	0–12 V, 0–1.2 A	0–30 V, 0–500 mA	0–60 V, 0–250 mA
Weight: (net/shipping)	lbs. kg.	4.5/6.5 2,0/2,9	4.5/6.5 2,0/2,9	4.5/6.5 2,0/2,9	4.75/6.75 2,2/3,1	4.75/6.75 2,2/3,1	4.75/6.75 2,2/3,1
Price		**$90**	**$90**	**$90**	**$115**	**$115**	**$115**



Model 721A

Model 721A

The forerunner of the BENCH Series, the Model 721A Power Supply was designed to produce dc voltages for transistor investigation, and its reliability has made it a popular reorder item. Its fully regulated output voltage range of 0 to 30 volts is sufficient for most types of transistors in use today. It has a three terminal output so that either the positive or negative terminal may be grounded. Particularly useful are 4 choices of current limit values, and multiple range metering.

Specifications

DC output: 0-30 V dc, 0-150 mA.

AC input: 105-125/210-250 volts, 50 to 60 Hz (cps), 16 W.

Load regulation: less than 0.3% or 30 mV (whichever is greater) output voltage change from no load to full load.

Line regulation: less than 0.3% or ± 15 mV (whichever is greater) output voltage change for a line input change from 105 to 125 or 125 to 105 volts.

Ripple and noise: less than 150 μV rms at any line voltage and under any load condition within rating.

Temperature ratings: operating: 0 to 50°C; storage: −20 to +85°C.

Output impedance: less than 0.2 ohm in series with less than 30 μH; meter range switch in 10 or 30 V dc position.

Overload protection: automatically limits peak output current to selected values (25, 50, 100, or 225 mA) regardless of the load resistance.

Controls: 6-position rotary switch selects current or voltage meter ranges; 4-position rotary switch selects maximum output current, 25, 50, 100, or 225 mA.

Output terminals: three banana jacks spaced ¾" apart. Positive and negative terminals are isolated from chassis; supply can be operated floating up to 400 volts off ground.

Weight: net, 4 lbs (1,81 kg); shipping, 7 lbs (3,17 kg).

Size: 7" (1.8 cm) W x 4⅜" (11.1 cm) H x 5¼" (13.3 cm) D.

Price: $145.

LABORATORY BENCH SERIES

LAB Series

Models 6200B - 6209B

LAB Series supplies, already regarded as the industry standard because of their reliability, versatility, and performance specifications, have recently been updated. The glass epoxy printed wiring board now mounts all circuit components via plated- through holes; a new package design achieves greater rack-mounting rigidity and ease in assembly. New production techniques result in improved reliability and lowered costs permitting Hewlett-Packard to manufacture these instruments at a competitive price.

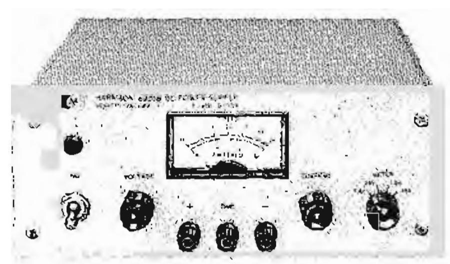
In addition, on models 6200B, 6201B, 6202B, and 6203B, special circuitry has been included to increase the down-programming speed, thus making it commensurate with the up-programming capability.

To further increase bench utility, multiple range meters have been included as standard on all models. Switching the meter range switch to the "wrong" position will result in no damage to the meter or degradation of power supply performance.

Optional overvoltage "crowbar" protection is available on all models with outputs under 100 V dc (this excludes only Models 6207B and 6209B).

Advantages

- Multiple range meter
- Remote programming and sensing
- High-speed programming
- Auto-series, auto-parallel, auto-tracking
- Short circuit proof
- Front and rear output terminals
- Floating output
- RFI conformance to MIL-I-6181D



6201B
CONSTANT VOLTAGE/CONSTANT CURRENT

Model		6200B‡	6201B‡	6202B‡	6203B
Output	DC Voltage	0-20 V / 0-40 V (DUAL RANGE)	0-20 V	0-40 V	0-7.5 V
	DC Current	0-1.5 A / 0-0.75 A (DUAL RANGE)	0-1.5 A	0-0.75 A	0-3 A
Input		115 V ac ± 10%, 50-400 Hz, 0.9 A, 70 W	115 V ac ± 10%, 50-400 Hz, 0.8 A, 66 W	115 V ac ± 10%, 50-400 Hz, 0.8 A, 66 W	115 V ac ± 10%, 50-400 Hz, 0.9 A, 70 W
Load regulation	Constant Voltage	0.01% plus 4 mV	0.01% plus 4 mV	0.01% plus 4 mV	5 mV
	Constant Current	0.03% plus 250 μA	0.03% plus 250 μA	0.03% plus 250 μA	0.03% plus 250 μA
Line regulation	Constant Voltage	0.01% plus 4 mV	0.01% plus 4 mV	0.01% plus 4 mV	3 mV
	Constant Current	0.01% plus 250 μA	0.01% plus 250 μA	0.01% plus 250 μA	0.01% plus 250 μA
Ripple and noise	Constant Voltage	200 μV rms/ 1mV p-p (DC-20 Mhz)	200 μV rms/ 1mV p-p (DC-20 Mhz)	200 μV rms/ 1mV p-p (DC-20 Mhz)	200 μV rms/ 1mV p-p (DC-20 Mhz)
	Constant Current	500 μA rms	500 μA rms	500 μA rms	500 μA rms
Remote programming	Constant Voltage*	200 ohms per volt	200 ohms per volt	200 ohms per volt	200 ohms per volt
	Constant Current†	500 ohms per amp / 1000 ohms per amp	1000 ohms per amp	1000 ohms per amp	500 ohms per amp
Overload protection		Constant voltage/constant current circuit provides complete protection for the power supply for any overload condition. In addition, continuously adjustable current limiting in constant voltage operation and continuously adjustable voltage limiting in constant current operation provides optimum protection for the load device.			
Controls		Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Coarse and Fine Current Control, Concentric Meter Range and Output Range Switch.	Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Coarse and Fine Current Control, Meter Range Switch.	Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Coarse and Fine Current Control, Meter Range Switch.	Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Coarse and Fine Current Control, Meter Range Switch.
Meter ranges		0-5 V, 0-50 V, 0-.18 A, 0-1.8 A	0-2.4 V, 0-24 V, 0-.18 A, 0-1.8 A	0-5 V, 0-50 V, 0-.09 A, 0-.9 A	0-.9 V, 0-9 V, 0-.4 A, 0-4 A
Price		$189	$169	$169	$169
Options Refer to page 561 for descriptions		07—$25	08—$25 09—$45 11—$50 13—$60 14—$60	28—$10	

*Voltage programming coefficient accuracy 100mv plus 2% of output voltage setting. ‡Similar Models are manufactured in Western Europe.

LAB Specifications

Transient Recovery Time—Less than 50 μs for output recovery to within 10 mv following a full load current change in output.

Internal Impedance — Less than 0.02 ohm from DC to 1 kc. Less than 0.5 ohm from 1 kc to 100 kc. Less than 3.0 ohms from 100 kc to 1 mc.

Cooling — Convection cooling is employed. No moving parts.

Power Cord — 3-wire, 5-foot power cord.

Size — 3½" (8,9 cm) H x 12⅝" (32 cm) D x 8½" (21,6 cm) W —Half rack width.

Finish — Light gray panel with dark gray case.

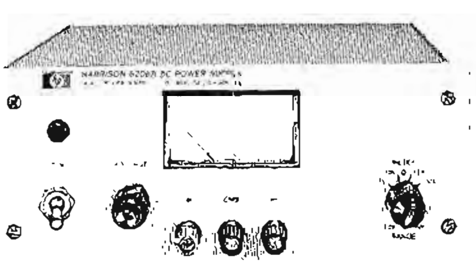
Accessories:*

Part Number	Description	Price
C05	8" black handle attached to side of 3½" H supply	$15.00
14513A	Rack Kit for mounting one 3½" H supply	$20.00
14523A	Rack Kit for mounting two 3½" H supplies	$10.00

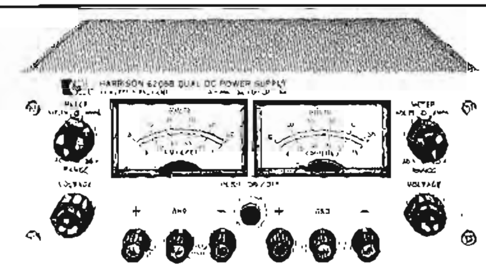
*See page 561 for further details.

High-Speed Programming — Models 6200B, 6201B, 6202B, 6203B; 30v/ms when programming in either direction between 1v and maximum rated output; less than 2 ms between 0 and 1v.

Maximum Ambient Operating Temperature — +50°C.



6206B DUAL RANGE

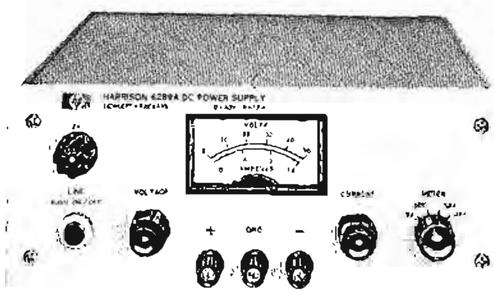


6205B DUAL OUTPUT

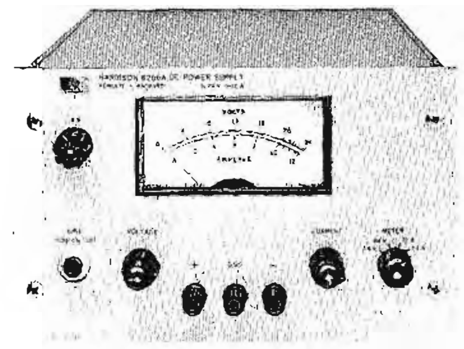
6204B‡	6205B	6206B	6207B	6209B
CONSTANT VOLTAGE/CURRENT LIMITING			CV/CC	
0-20 V, 0-0.6 A — DUAL RANGE — 0-40 V, 0-0.3 A	0-20 V, 0-0.6 A — TWO DUAL RANGE OUTPUTS — 0-40 V, 0-0.3 A	0-30 V, 0-1 A — DUAL RANGE — 0-60 V, 0-0.5 A	0-160 V 0-0.2 A	0-320 V 0-0.1 A
115 V ac ±10%, 50-400 Hz, 0.4 A, 24 W	115 V ac ±10%, 50-440 Hz, 0.5 A, 50 W	115 V ac ±10%, 50-400 Hz, 1.0 A, 66 W	115 V ac ±10%, 48-63 Hz, 1.0 A, 60 W	115 V ac ±10%, 48-63 Hz, 1.0 A, 60 W
0.01% plus 4 mV	0.01% plus 4 mV	0.01% plus 4 mV	0.02% plus 2 mV	0.02% plus 2 mV
—	—	—	200 μA	200 μA
0.01% plus 4 mV	0.01% plus 4 mV	0.01% plus 4 mV	0.02% plus 2 mV	0.02% plus 2 mV
—	—	—	200 μA	200 μA
200 μV rms/ 1mV p-p (DC-20 Mhz)	200 μV rms/ 1mV p-p (DC-20 Mhz)	200 μV rms/ 1mV p-p (DC-20 Mhz)	500 μV rms/ 30 mV p-p	1 mV rms/ 30 mV p-p
—	—	—	200 μA rms	200 μA rms
200 ohms per volt	200 ohms per volt	300 ohms per volt	300 ohms per volt	300 ohms per volt
—	—	—	75 K ohms per amp	150 K ohms per amp
Fixed current limit provides complete protection for any overload condition. This limit is set at approximately 700 mA for the 20 volt range and 350 mA for the 40 volt range.	Fixed current limit provides complete protection for any overload condition. This limit is set at approximately 700 mA for the 20 volt range and 350 mA for the 40 volt range.	Fixed current limit provides complete protection for any overload condition. This limit is set for approximately 1.2 A for the 30 volt range and 600 mA for the 60 volt range.	Same as 6200B	
Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Meter Range and Output Range Switch.	Combined Pilot Light and On-Off Button, Two Concentric Coarse and Fine Voltage Controls. Two Concentric Meter Range and Output Range Switches.	Off-On Switch, Pilot Light, Concentric Coarse and Fine Voltage Control, Concentric Meter Range and Output Range Switch.	Off-On Switch, Pilot Light, 10-turn Voltage Control, Concentric Coarse and Fine Current Control, Meter Range Switch.	Off-On Switch, Pilot Light, 10-turn Voltage Control, Concentric Coarse and Fine Current Control, Meter Range Switch.
0-5 V, 0-50 V, 0-.075 A, 0-.75 A	0-5 V, 0-50 V, 0-.075A, 0-.75A	0-7 V, 0-70 V, 0-.12 A, 0-1.2 A	0-20 V, 0-200 V, 0-24 mA, 0-240 mA	0-40 V, 0-400 V, 0-12 mA, 0-120 mA
10/13 lbs. (4,53/5,89 kg)	10/13 lbs. (4,53/5,89 kg)	12/17 lbs. (5,43/7,70 kg)	13/18 lbs. (5,89/8,15 kg)	13/18 lbs. (5,89/8,15 kg)
$144	$235	$169	$235	$235
07—$25 11—$50 13—$60 28—$10	07—$50 11—$50 13—$140 28— $10 15—Deduct $40	07—$25 11—$50 13—$60 28—$10	08—$25 14—$60 13—$35 28—$10	13—$60 28—$10 14—$60

‡Current programming coefficient accuracy 6% of current rating plus 10% of output current setting.

MEDIUM & DUAL POWER SUPPLIES
MPB-3, MPB-5, & DPR series
Models 6281A-6299A, 6253A, 6255A



MPB-3



MPB-5

The MPB-3 and MPB-5 Series of dc power supplies are highly regulated, medium power, constant voltage/constant current bench models. All include multiple range meters and provision for remote sensing, remote programming, auto-series, auto-parallel, and auto-tracking operation.

The DPR models contain two identical MPB-3 supplies mounted in a full rack-width chassis. All DPR features and specifications are identical to the MPB-3 with the exceptions listed on the following page.

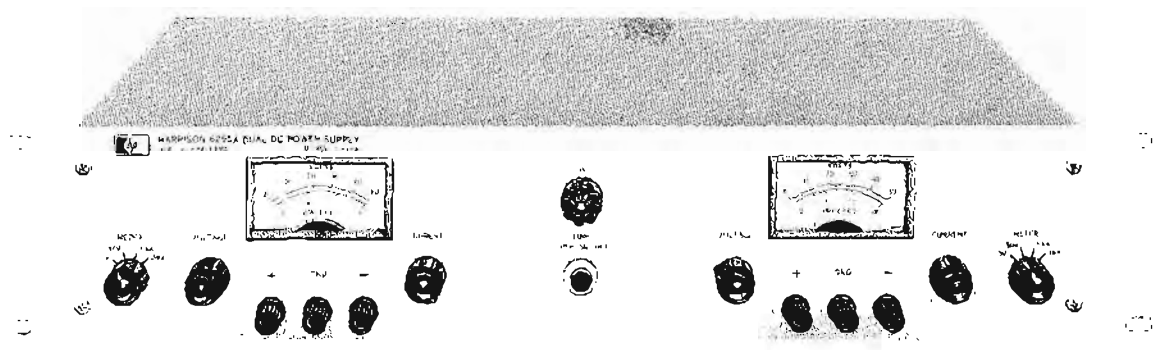
Advantages:

- Short circuit proof
- Constant voltage/constant current operation with automatic crossover
- Multiple range meters
- Floating output
- All silicon circuitry
- Front and rear output terminals
- No overshoot on turn-on, turn-off, or power removal
- Easily rack mounted
- Overvoltage protection "crowbar" option
- Auto-series, auto-parallel, auto-tracking

MPB-5 Specifications

Model		6282A	6286A	6288A	6290A	6291A	6296A
Output: DC Voltage		0-10V	0-20V	0-20V	0-40V	0-40V	0-60V
Output: DC Current		0-10A	0-5A	0-10A	0-3A	0-5A	0-3A
Input: 115 V ac ± 10%, 50-60 Hz		3.5A, 200W	3.5A, 160W	5.5A, 320W	3.5A, 170W	5.5A, 280W	4.5A, 250W
*Load regulation: The Constant Voltage Load Regulation specification is given for a load current change equal to the current rating of the supply. The Constant Current Load Regulation specification is given for a load voltage change equal to the voltage rating of the supply.	CV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV
	CC	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA
Line regulation: For a 10% change in the nominal line voltage at any output voltage and current within rating.	CV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV	0.01% plus 1 mV
	CC	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA	0.05% plus 1 mA
Ripple and noise: At any line voltage and under any load condition within rating.	CV	500 μV RMS (25 mV peak to peak DC to 20 MHz)					
	CC	5 mA RMS	3 mA RMS	5 mA RMS	3 mA RMS	3 mA RMS	3 mA RMS
Remote programming: All Programming terminals are located on rear barrier strips.	CV	200 ohms per volt	200 ohms per volt	200 ohms per volt	200 ohms per volt	200 ohms per volt	300 ohms per volt
	CC	100 ohms per amp	200 ohms per amp	100 ohms per amp	500 ohms per amp	200 ohms per amp	500 ohms per amp
Meter ranges: (Accuracy: 3%)		0-1.2 V, 0-12 V, 0-1.2 A, 0-12 A	0-2.4 V, 0-24 V, 0-.6 A, 0-6 A	0-2.4 V, 0-24 V, 0-1.2 A, 0-12 A	0-5 V, 0-50 V, 0-.4 A, 0-4 A	0-5 V, 0-50 V, 0-.6 A, 0-6 A	0-7 V, 0-70 V, 0-.4 A, 0-4 A
Weight: (Net/Shipping)	lbs	25/32	25/32	30/40	26/33	30/40	29/38
	kg	11,3/14,5	11,3/14,5	13,6/14,1	11,8/15,0	13,6/14,1	13,1/12,7
Price		$350	$350	$395	$350	$395	$395
Options: Refer to page 561 for description		05—$10 09—$45 No charge if ordered with Option 28 11—$55 13—$60 14—$60			07—$25 28—$50	08—$25	

*CV load regulation given for rear terminals only. At front terminals CV load regulation is 0.5 mv per amp greater due to front terminal resistance.



DPR

Output Impedance: MPB-5 series: 0.001Ω series with 1 μH. For other models, see table below.

Controls: Concentric coarse and fine output voltage and current controls permit continuous adjustment over entire output span. Models 6294A and 6299A incorporate a 10-turn front panel voltage control in lieu of the concentric coarse and fine voltage controls. Switch selects front panel meter voltage or current scale.

Finish: Light gray panel with dark gray case.

Accessories: Rack Kits 14513A and 14523A. See page 561.

Transient recovery time: Less than 50 μs is required for output voltage recovery in constant voltage operation to within 15 millivolts of the nominal output voltage following a change in output current equal to the current rating of the supply or 5 amperes, whichever is smaller. The nominal output voltage is defined as the mean between the no load and full load voltages.

Temperature ratings:

Operating: 0-50°C (consult factory for derating information for operation between 50°C and 71°C)
Storage −20°C to +85°C

Size:

MPB-3 — 3½" H x 8½" W x 14½" D
— 8,9 cm H x 21,8 cm W x 36,8 cm D

MPB-5 — 5¼" H x 8½" W x 16" D
— 13,3 cm H x 21,8 cm W x 40,7 cm D

DPR — 3½" H x 14½" D x 19" W
— 8,9 cm H x 36,8 cm D x 48,3 cm W

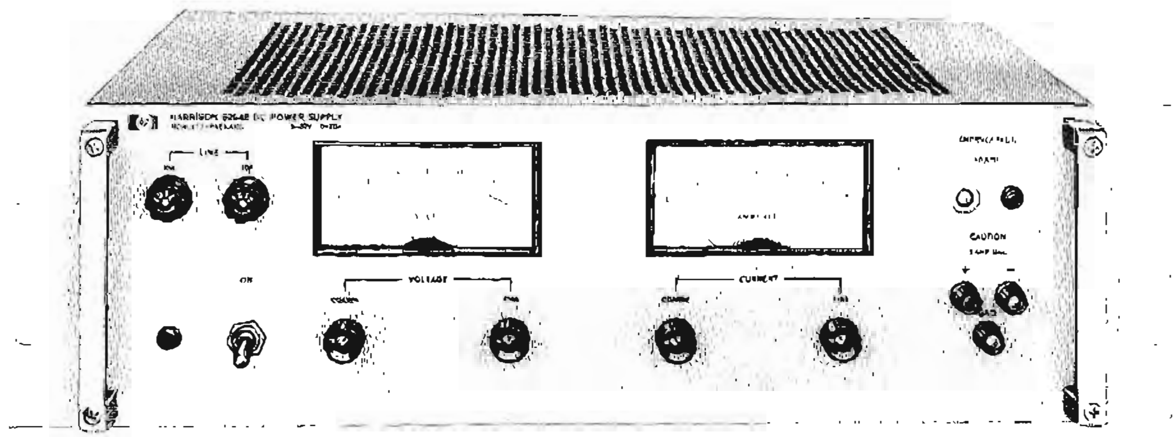
Model			MPB-3 6281A	MPB-3 6284A	DPR 6253A	MPB-3 6289A	DPR 6255A	MPB-3 6294A	MPB-3 6299A
Output	DC Voltage		0-7.5V	0-20V		0-40V		0-60V	0-100V
	DC Current		0-5A	0-3A		0-1.5A		0-1A	0-750 mA
Input: 115 V ac ±10%, 50-400 Hz			1.3 A 118 W	1.5 A 128 W	3 A 256 W	1.3 A 110 W	2.6 A 220 W	1.3 A 114 W	1.5 A 135 W
*Load regulation: The Constant Voltage Load Regulation is given for a load current change equal to the current rating of the supply. The Constant Current Load regulation is given for a load voltage change equal to the voltage rating of the supply.		C V	5 mV	0.01% plus 4 mV		0.01% plus 2 mV		0.01% plus 2 mV	0.01% plus 2 mV
		C C	0.01% plus 250 μA	0.01% plus 250 μA		0.01% plus 250 μA		0.01% plus 250 μA	0.01% plus 250 μA
Line regulation: For a 10% change in the nominal line voltage at any output voltage and current within rating.		C V	0.01% plus 2 mV	0.01% plus 2 mV		0.01% plus 2 mV		0.01% plus 2 mV	0.01% plus 2 mV
		C C	0.01% plus 250 μA	0.01% plus 250 μA		0.01% plus 250 μA		0.01% plus 250 μA	0.01% plus 250 μA
Ripple and noise: At any line voltage and under any load condition within rating.		C V	200 μV RMS/1 mV p-p (dc to 20 MHz)						
		C C	4 mA RMS	2 mA RMS		500 μA RMS		500 μA RMS	500 μA RMS
Remote programming: All Programming terminals are located on rear barrier strips.		C V	200 ohms per volt	200 ohms per volt		200 ohms per volt		300 ohms per volt	300 ohms per volt
		C C	200 ohms per amp	500 ohms per amp		500 ohms per amp		1000 ohms per amp	1000 ohms per amp
Output impedance:			1 mΩ+1 μH	2mΩ+1 μH		4mΩ+1 μH		8mΩ+1 μH	16mΩ+1 μH
Meter ranges (Accuracy: 3%)			0-.9 V, 0-9 V, 0-.6 A, 0-6 A	0-2.4 V, 0-24 V, 0-.4 A, 0-4 A		0-5 V, 0-50 V, 0-.18 A, 0-1.8 A		0-7 V, 0-70 V, 0-.12 A, 0-1.2 A	0-12 V, 0-120 V, 0-.1 A, 0-1 A
Weight: (Net/Shipping)		lbs. / kg	14/19 6,4/8,6	14/19 6,4/8,6	28/35 12,7/15,8	14/19 6,4/8,6	28/35 12,7/15,8	14/19 6,4/8,6	15/20 6,8/9,1
Price			$210	$210	$445	$210	$445	$210	$225
Options: Refer to page 561 for details	MPB-3		07—$25 08—$25 09—$45 11—$110 13—$60 14—$60 28—$10						
	DPR		07—$50 08—$50 09—$90 10—$125 11—$110 13—$120 14—$120 28—$10						

CC indicates constant current. CV indicates constant voltage.

LOW VOLTAGE RACK SUPPLIES

LVR Series

Models 6256B - 6274A



Model 6264B

NOTE: Chief difference in "A" model appearance is absence of crowbar adjust; crowbars are optional on "A" models.

Model		6256B	6259B	6260A	6263B	6264B
DC output		0–10 volts @ 0–20 amps	0–10 volts @ 0–50 amps	0–10 volts @ 0–100 amps	0–20 volts @ 0–10 amps	0–20 volts @ 0–20 amps
AC input		115 ±10% V ac 57–63 Hz 5 A, 375 W	115 ±10% V ac 57–63 Hz	230 ±10% V ac 57–63 Hz 11 A, 1700 W	115 V ac ±10% 57–63 Hz, 4 A, 350 W	115 V ac ±10% 57–63 Hz, 8 A, 600 W
Load regulation: the constant voltage load current change equal to the current rating of the supply. The constant current load regulation specification is given for the load voltage change equal to the voltage rating of the supply	CV	0.01% plus 200 μV	0.01% +200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
	CC	0.02% plus 500 μA	0.02% +1 mA	0.03% plus 2 mA	0.02% plus 500 μA	0.02% plus 500 μA
Line regulation: for a change in line voltage from 100 to 130 or 200 to 260 at any output voltage and current within rating.	CV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
	CC	0.02% plus 500 μA	0.02% plus 1 mA	0.03% plus 2 mA	0.02% plus 500 μA	0.02% plus 500 μA
Ripple and noise: at any line voltage and under any load condition within rating.	CV	200 μV rms/10 mV p-p	500 μV rms/10 mV p-p	1 mV rms/50 V p-p	200 μV rms/10 mV p-p	200 μV rms/10 mV p-p
	CC	5 μA rms	25 μA rms	50 mA rms	3 mA rms	5 mA rms
Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warmup	CV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
	CC	0.01% plus 2 mA	0.01% plus 4 mA	0.01% plus 8 mA	0.01% plus 2 mA	0.01% plus 2 mA
Remote programming: all programming ter-	CV	200 ohms/volts	200 ohms/volts	200 ohms/volt	200 ohms/volt	200 ohms/volt
	CC	10 ohms/amp	4 ohms/amp	2 ohms/amp	100 ohms/amp	10 ohms/amp
Meters	accuracy: 2%	0–12 V and 0–24 A	0–12 V and 0–60 A	0–12 V and 0–120 A	0–24 V and 0–12 A	0–24 V and 0–25 A
Input power connections		3-wire, 5-foot cord	Barrier strip	Barrier strip	3-wire, 5-foot cord	3-wire, 5-foot cord
	Inches	5¼ H x 17½ D x 19 W	7 H x 17½ D x 19 W	7 H x 17½ D x 19 W	3½ H x 17½ D x 19 W	5¼ H x 17½ D x 19 W
Weight: (lbs) (net/shipping)		42 (19,1 kg)/57 (25,9 kg)	—	90 (44,8 kg)/115 (52,2 kg)	34 (15,4 kg)/48 (12,7 kg)	42 (19,1 kg)/51 (25,9 kg)
Price		$450	$650	$775	$435	$525
Options: refer to page 561 for descriptions		05–$10, 07–$25, 08–$25, 09–$45, 10–$50.		05–$90, 06–$175, 10–$125,	05–$10, 07–$25, 08–$25, 09–$45, 10–$50.	
		13–$60, 14–$60, 27–$10, 28–$10		13–$35, 14–$35, 16–$50, 27–$15, 55–$20	13–$60, 14–$60, 27–$10, 28–$10	

CV = constant voltage CC = constant current

Advantages

- Overvoltage Protection Crowbar*
- Low peak-to-peak ripple
- Continuously variable output voltage and current—no range switching
- Auto-series, auto-parallel and auto-tracking operation
- Remote programming—voltage and current can be controlled by external resistance or control voltage

*Internal and standard on "B" models, external and optional on "A" models.

- Remote error sensing
- Low output impedance
- Constant voltage constant current operation with automatic crossover
- Fully rated for any overload condition including continuous short circuit operation
- Front panel voltmeter and ammeter
- RFI conformance to MIL-I-6181D

Specifications

Radio frequency interference: all models are free from conducted and radiated RFI to the extent that they meet all the requirements of MIL-I-6181D.

Maximum operating temperature: 0 to 55°C. Storage: −20 to +71°C.

Internal impedance as a constant voltage source: 0.1 mΩ in series with 1 μH.

Transient recovery time: less than 50 microseconds is required for output voltage recovery (in constant voltage operation) to within 10 millivolts of the nominal output voltage following a 5 amp change in output current.

Output terminals: an output terminal strip is located on the rear of the chassis. All power supply terminals are isolated from the chassis and either the positive or negative terminal may be connected to the chassis through a separate ground terminal located adjacent to the output terminals. All models include front panel output terminals. They are banana jack type and limited to 3 amps maximum current output.

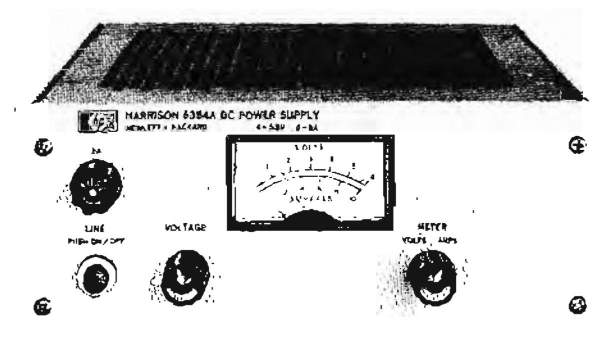
Finish: light gray front panel with dark gray case.

6265B	6266B	6267B	6268A	6269A	6271B	6274A
0–40 volts @ 0–3 amps	0–40 volts @ 0–5 amps	0–40 volts @ 0–10 amps	0–40 volts @ 0–30 amps	0–40 volts @ 0–50 amps	0–60 volts @ 0–3 amps	0–60 volts @ 0–15 amps
115 V ac, ±10% 57–63 Hz, 3 A, 180 W	115 V ac, ±10% 57–63 Hz, 4 A, 325 W	115 V ac, ±10% 57–63 Hz, 8 A, 550 W	230 ±10% V ac 57–63 Hz, 11 A, 1600 W	230 ±10% V ac 57–63 Hz, 18 A, 2600 W	115 V ac ±10% 57–63 Hz, 4 A, 300 W	115 V ac, ±10% 57–63 Hz, 16 A, 1700 W
0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
0.02% plus 500 μA	0.02% plus 500 μA	0.02% plus 500 μA	0.02% plus 3 mA	0.02% plus 3 mA	0.02% plus 500 μA	0.02% plus 2 mA
0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
0.02% plus 500 μA	0.02% plus 500 μA	0.02% plus 500 μV	0.02% plus 3 mA	0.02% plus 3 mA	0.02% plus 500 μA	0.02% plus 2 mA
200 μV rms/10 mV p-p	200 μV rms/10 mV p-p	200 μV rms/10 mV p-p	1 μV rms	1 μV rms/20 mV p-p	200 μV rms/10 mV p-p	500 μV rms
3 mA rms	3 mA rms	3 mA rms	20 mA rms	30 mA rms	3 mA rms	10 mA rms
0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 500 μV	0.01% plus 200 μV	0.01% plus 200 μV	0.01% plus 200 μV
0.01% plus 1 mA	0.01% plus 1 mA	0.01% plus 1 mA	0.01% plus 2 mA	0.01% plus 4 mA	0.01% plus 1 mA	0.01% plus 2 mA
200 ohms/volt	200 ohms/volt	200 ohms/volt	200 ohms/volt	200 ohms/volt	300 ohms/volt	300 ohms/volt
300 ohms/amp	200 ohms/amp	100 ohms/amp	6 ohms/amp	4 ohms/amp	300 ohms/amp	62 ohms/amp
0–50 V and 0–4A	0–50 V and 0–6 A	0–50 V and 0–12 A	0–50 V and 0–40 A	0–50 V and 0–60 A	0–70 V and 0–4 A	0–70 V and 0–18 A
3-wire, 5-foot cord	3-wire, 5-foot cord	3-wire, 5-foot cord	Barrier strip	Barrier strip	3-wire, 5-foot cord	Barrier strip
3½ H x 17½ D x 19 W	3½ H x 17½ D x 19 W	5½ H x 17½ D x 19 W	7 H x 16¾ D x 19 W	7 H x 17½ D x 19 W	3½ H x 17½ D x 19 W	5¼ H x 17½ D x 19 W
8,9 H x 44,4 D x 48,3 W	8,9 H x 44,4 D x 48,3 W	14 H x 44,4 D x 48,3 W	17,8 H x 42,7 D x 48,3 W	17,8 H x 44,4 D x 48,3 W	8,9 H x 44,4 D x 48,3 W	14 H x 44,4 D x 48,3 W
34 (15,4 kg)/48 (21,7 kg)	34 (15,4 kg)/48 (21,7 kg)	42 (19,1 kg)/57 (25,9 kg)	93 (42,2 kg)/120 (54,5 kg)	93 (42,4 kg)/120 (54,5 kg)	34 (15,4 kg)/48 (21,7 kg)	75 (34 kg)/95 (43,1 kg)
$350	$435	$525	$695	$875	$435	$695
05–$10, 07–$25, 08–$25, 09–$45, 10–$50, 13–$60, 14–$60, 27–$10, 28–$10			05–$10, 06–$175, 10–$125, 13–$35, 14–$35, 27–$15		05–$10, 07–$25, 09–$45, 10–$50, 13–$60, 14–$60, 27–$10, 28–$10	05–$10, 06–$175, 10–$125, 13–$35, 14–$35, 17–$50, 18–$50

INTEGRATED CIRCUIT SUPPLY
ICS Model
Model 6384A

This Model 6384A is specifically designed for use with integrated circuits, micromodular circuits, and other low voltage semiconductor circuitry. Included in this half rack instrument is an overvoltage "crowbar" protection circuit. If for any reason an incipient overvoltage condition occurs, this completely independent circuit shorts the output terminals with an SCR crowbar within 10 μs.

A temperature compensated zener diode is employed as the reference element in all-silicon series regulator feedback circuit which monitors and controls the output voltage. The resulting low ripple and low output impedance permit this supply to be used in critical applications where less well regulated supplies are not suited. See also the LVR Series on pp. 576-577.



6384A

Protection

Short circuit protection: The output is current limited and is fully rated for operation under any overload condition including a direct short circuit, regardless of how long maintained. Supply will automatically restore to normal operation upon overload removal.

Overvoltage protection: An independent built-in overvoltage crowbar circuit prevents the output voltage from exceeding a preset voltage under any failure condition. This crowbar circuit shorts the output within 10 μs following the onset of the overvoltage condition. The crowbar threshold voltage is variable between 4.5 and 6.0 volts by monitoring rear terminals while substituting a selected resistor.

Advantages:

- Low output drift
- High degree of output resolution
- Low peak to peak ripple and noise
- Low output impedance at all frequencies
- 200 μsec load transient recovery
- No overshoot for turn-on, turn-off, or power removal
- Floating output can be used as positive or negative source
- Fully rated for any overload condition

Specifications

Output: 4-5.5 V, 0-8A.

Load regulation: less than 1 mV from no load to full load.

Line regulation: less than 1 mV for a 10% change in the nominal line voltage.

Input: 48-63 Hz, 115 VAC ±10%, approximately 120 watts (230 V option available, see p. 561.)

Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warm-up: 0.01% + 200 μV.

Transient recovery time: less than 50 μs is required for output voltage recovery in constant voltage operation to within 10 mV of the nominal output voltage following a 20% change in output current. The nominal output voltage is defined as the mean between the no load and full load voltages.

Stability: under constant ambient conditions, total drift for 8 hrs. following 30 minutes warm-up: 0.03% + 10 mV.

Ripple and noise: at any line voltage and any load condition within rating: 5 mV p-p, 1 mV rms.

Temperature rating: operating: 0 to 55°C. Storage: −40 to +71°C.

Output impedance

Less than 0.001 ohm from dc to 100 Hz.
Less than 0.01 ohm from 100 Hz to 1 kHz.
Less than 0.05 ohm from 1 kHz to 10 kHz.
Less than 0.2 ohm from 10 kHz to 100 kHz.
Less than 2 ohms from 100 kHz to 1 MHz.

Controls

Single-turn output voltage control, combined off-on switch/pilot light, and switch that selects voltage or current meter.

Dimensions: 8½" (21,6 cm) wide x 3½" (8,9 cm) high x 12⅝" (32,1 cm) deep.

Weight: 12 lbs (5,44 kg) net; 15 lbs (6,8 kg) shipping.

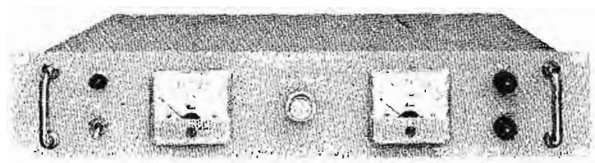
Accessories: same as HVB Series. Refer to page 580, then page 561.

Options: 28, 10 (see page 561).

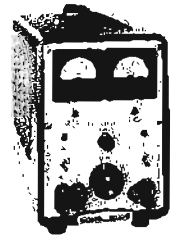
MEDIUM VOLTAGE SUPPLIES

MVR Series

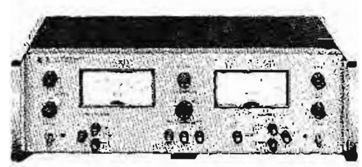
Models 711A, 712C, 890A, 895A



Model 890A



711A



712C

Advantages, MVR Series:

All solid-state
Short-circuit proof
Remote programming, remote error sensing

The MVR Series features a unique "Piggy-Back" circuit; low voltage series power transistors, which are required to dissipate only a fraction of their power rating, provide high regulation—yet the supply can withstand a direct short circuit across the output terminals.

All MVR models are short circuit proof. An all-electronic, continuously acting current limit circuit protects the supply for all overloads, including a direct short placed across the output terminals.

MVR Specifications

Outputs: 890A—0 to 320 volts, 0 to 600 mA, 895A—0 to 320 volts, 0 to 1.5 amps.

Line regulation: 0.007% or 10 mV for 10% charge in normal.

Load regulation: 0.007% or 10 mV.

Ripple and noise (rms maximum): 1 mV for both models.

Meters: 890A—320 V and 0.8 A; 895A—320 V and 1.5 A.

Dimensions: 890A—3½" H x 16¾" D x 19" W (88 x 425 x 483 mm); 895A—5¼" H x 16¾" D x 19" W (133 x 425 x 483 mm).

Maximum operating temperature: 50°C.

Temperature coefficient: less than 0.03%, plus 1.5 mV/°C.

Stability: better than 0.1% plus 5 mV.

Transient recovery time: less than 100 microseconds.

Output terminals: output terminal strip is located on the rear of the chassis.

Input ac: 115 V ac ±10%, 57 to 63 Hz.

Weight (net/shipping): 890A—35/43 lbs (15,8/9,4 kg); 895A—50/66 lbs (22,5/29,7 kg).

Price: 890A—$445; 895A—$625.

Models 711A, 712C

These easy-to-use general purpose, low-power medium-voltage laboratory supplies are particularly suitable for experimental setups and other medium-voltage bench applications. These instruments are designed for high regulation and low ripple. The 711A contains a 0-500-volt dc output at 100 mA along with an unregulated ac filament output, while the 712C contains four outputs—0-500 volts at 0-200 mA, 0 to —150 volts at 5 mA, —300 volts at 50 mA, and an unregulated ac filament source. The 712C is a new solid-state package.

712C Specifications

Output:
DC Main (CV/CC): 0 to 500 V @ 0-200 mA.
DC Fixed Bias: −300 V @ 0-50 mA.
DC Variable Bias: 0 to 150 V @ 5 mA.
AC Unregulated: 6.3 V CT @ 10 A.

Input: 115 V ac ±10%, 57-63 Hz, 2.5 A @ 115 V ac.

Load regulation:
DC Main: 0.01% +5 mV.
DC Fixed Bias: 50 mV.
DC Variable Bias is tied to fixed bias, hence source regulation is same as for fixed bias. Internal impedance 0 to 10,000 ohms, depending on bias control setting.

Line regulation:
For a 10% change in line voltage:
DC Main: CV—0.01% +5 mV, CC—100 μA.
DC Fixed Bias: 50 mV.

Ripple and noise:
DC Main: CV-500 μV rms, 15 mV p-p (dc—20 MHz); CC-0.1 mA rms.
DC Fixed & Variable Bias: CV—0.01% rms, 0.03% p-p.

Dimensions: 5-7/32" H x 16¾" W x 11⅛" D. (13.9 cm x 42.5 cm x 28.1 cm).

Weight: net 22 lbs (10 kg); shipping 26 lbs (11,8 kg).

Price: $490.

Accessories furnished: Rack Mounting Kit, HP 5060-0775.

711A Specifications

Outputs: 0 to 500 volts dc, 0 to 100 milliamps, 6.3 volts rms at 6 amps or 12.6 V rms CT at 3 amps unregulated.

Load regulation: less than 0.5% change or 1 volt change from no load to full load.

Line regulation: less than 0.5% change or 1 volt change for ±10% line voltage change.

Ripple and noise: less than 1 mV rms.

Input: 115 or 230 volts ±10%, 50 to 1000 cycles, approx. 145 watts.

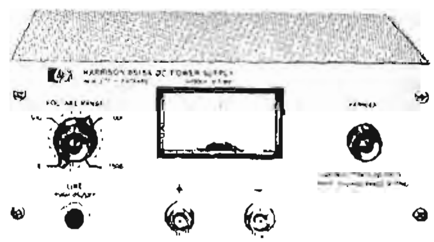
Dimensions: 7⅜" (18,7 cm) wide x 11½" (31,5 cm) high x 14¼" (38 cm) deep.

Weight: 20 lbs (9,2 kg) net; 26 lbs (11,8 kg) shipping.

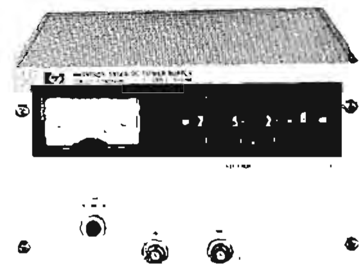
Price: $275.

Option 28: 230 V ac ±10%, single phase input: factory modification consists of reconnecting the multi-tap input power transformer for 230-volt operation. Price, $10.

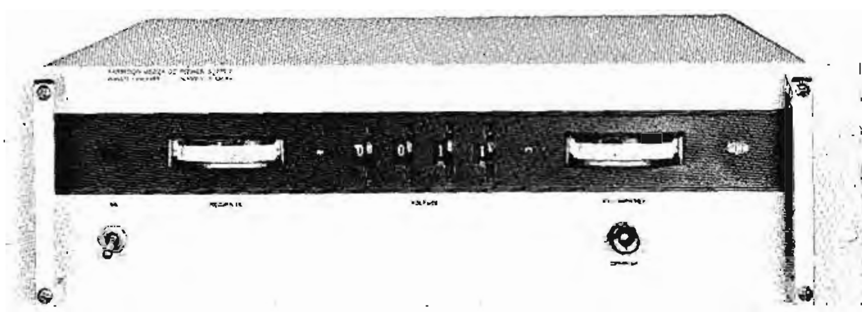
HIGH VOLTAGE SUPPLIES
HVB, HVR Series
Models 6515A—6525A



6515A



6516A



HVR Series

HVB SERIES—This series has two compact, dc regulated bench supplies offering up to 3 KV in moderate currents. These high-voltage supplies offer low cost, portability, and high performance for experimenting and circuit developing at the bench. Low ripple and impedance are achieved by a series regulator feedback circuit using a temperature-compensated zener diode for reference. The design also includes short-circuit protection and current-limiting. Output is floating, giving choice of negative or positive voltages up to 1 KV off ground. High performance design makes these supplies particularly suited for photomultiplier application, as well as for TWT's, CRT's, gas flow tubes, proportional counter tubes, and rapid high-voltage single-trip electrophoresis. Circuits are all solid-state.

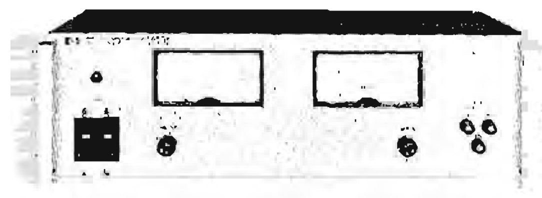
HVR SERIES—These three supplies are all tightly regulated (0.005%) and provide sufficient output current for many devices not capable of being powered from conventional low current, high voltage supplies. Such devices would include power TWT's, Klystrons, continuous wave magnetrons, power gas lasers, and electron beam welding devices. Circuitry includes constant voltage/constant current operation with automatic crossover. Thumbwheel voltage controls give you 0.002% resolution. Two meters—one for voltage, one for current—are standard with each model. As in the HVB Series, these supplies are short-circuit proof. With floating output, you have the option of negative or positive voltages up to 2 KV off ground. Circuits are all solid-state.

		HVB SERIES		HVR SERIES		
Model		**6515A**	**6516A**	**6521A**	**6522A**	**6525A**
DC output	voltage	0–1600 V	0–3000 V	0–1000 V	0–2000 V	0–4000 V
	current	0–5 mA	0–6 mA	0–200 mA	0–50 mA	0–50 mA
AC input		115 V ±10%, 60 Hz	115 V ±10%, 57–63 Hz	115 V ac ±10%, 50–500 Hz		
Load regulation	constant voltage	0.01% +16 mV		0.005% or 20 mV		
	constant current	—		2% or 1 mA		
Line regulation (for a 10% change in voltage)	constant voltage	0.01% +16 mV		0.005% or 20 mV		
	constant current	—		1 mA		
Ripple and noise (peak-to-peak)	constant voltage	2 mV (5 mV p-p)		1 mV		
	constant current	—		2 mA	1 mA	500 μA
Temperature coefficient	constant voltage	0.02% +2 mV			0.012% + 1 mV	
	constant current	—		0.2% +0.2 mA	0.2% +0.1 mA	0.2% +0.06 mA
Stability	constant voltage	0.05% +5 mV			0.036% +3 mV	
	constant current	—		0.25% +0.5 mA	0.25% +0.2 mA	0.25% +0.12 mA
Meters		0–1800 V	0–3500 V	0–1 kV and 0–200 mA	0–2 kV and 0–200 mA	0–4 kV and 0–50 mA
Controls		100 V steps with intermediate vernier for 100 mV resolution.	4-digit thumbwheel, to 1-Volt resolution.	voltage control—3 decade thumbwheel switches plus thumbwheel vernier with 0.002% resolution, current control—single-turn potentiometer.		
Dimensions		3½" (8.9 cm) H x 8½" (21,6 cm) W x 11-13/16" (30 cm) D.	5¼" (12,7 cm) H x 8½" (21,6 cm) W x 16" (40,6 cm) D.	5¼" H x 18" D x 19" W (13,3 x 45,7 x 48.3 cm)		
Options		28 (p. 561)	05,13			
Weight (net/shipping)		12/15 lbs (5,44/6,8 kg)	17/20 lbs (7,71/9,07 kg)	50/60 lbs (22,5/27 kg)		
Price		$235	$295	$750	$750	$750

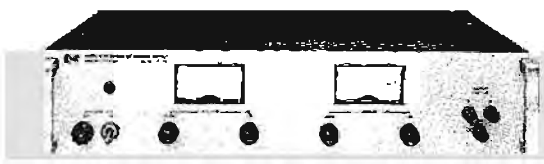
Note: See Model 6110A on p. 566.

COMPACT SCR REGULATED

SCR-1P Series
Models 6427B-6448B



Models 6428B, 6434B, 6439B, 6448B



Models 6427B, 6433B, 6438B, 6443B

The SCR-1P Series consists of eight regulated dc power supplies utilizing silicon-controlled rectifiers in series with the transformer primary. Controlled by the output voltage and current settings, these supplies accomplish the desired regulation using Harrison's unique "Ramp-Lock" phase control circuit. This circuit technique permits a reduction in the overall size and weight of the power supply and results in up to 75% efficiency at full output. Four models with output ratings of approximately 300 watts are packaged in a 3½" high rack mounting cabinet, while the four models with approximately 900 watt output power capability are 5¼" high. All supplies may also be used on the bench (attachable rubber feet for bench use available on request). These second generation SCR regulated power supplies also feature lower output ripple, tighter load and line regulation, and Constant Voltage/Constant Current operation with automatic crossover, and all-silicon circuitry.

Advantages:

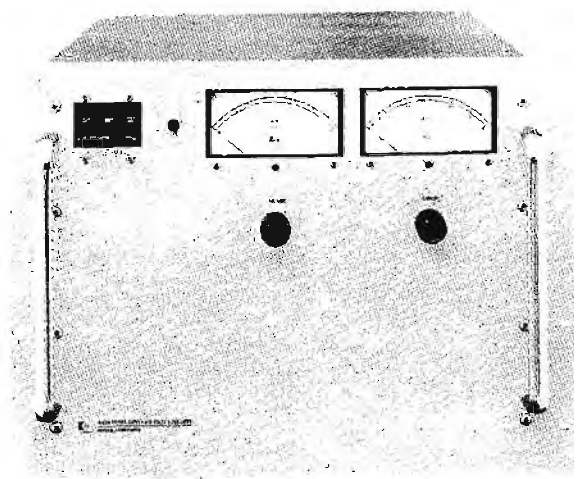
Output continuously variable to zero in either voltage or current mode
Efficiency up to 75% at full output
Excellent line transient immunity

Specifications

Model		6427B	6428B	6433B	6434B	6438B	6439B	6443B	6448B
DC output	volts	0-20	0-20	0-36	0-40	0-60	0-60	0-120	1-600
	amps	0-15	0-45	0-10	0-25	0-5	0-15	0-2.5	0-1.5
AC power in	volts	115 V ac ± 10%, 57-63 Hz							
	amps	6 5	17	7	19	6.5	17	6 5	16
	watts	450	1200	450	1300	400	1200	400	1200
Line regulation: For a 10% change in the nominal ac line voltage.	constant voltage	10 mV	20 mV	18 mV	18 mV	30 mV	60 mV	60 mV	600 mV
	constant current	150 mA	450 mA	100 mA	200 mA	50 mA	150 mA	25 mA	15 mA
Constant voltage load regulation: for a change in output current from no load to full load or full load to no load.		20 mV	40 mV	36 mV	40 mV	60 mV	120 mV	120 mV	600 mV
Constant current load regulation: for a change in output voltage from no load to full load or full load to no load.		150 mA	450 mA	100 mA	200 mA	50 mA	150 mA	25 mA	15 mA
Full scale meter readings: meters have 2% accuracy: all units have meter calibrating potentiometers.		24 V & 18 A	24 V & 50 A	40 V & 12 A	50 V & 30 A	70 V & 6 A	70 V & 18 A	150 V & 3 A	700 V & 1.8 A
*Transient recovery time: <200 ms for output recovery to within "A" mV; transient amplitude less than "B" volts/amp for any load change between 20% and 100% of rated output current.		A = 200 B = 0 35	A = 200 B = 0.15	A = 200 B = 0.5	A = 200 B = 0.3	A = 300 B = 1.0	A = 600 B = 0.4	A = 600 B = 4 0	A = 3000 B = 20
*Ripple and noise: rms maximum		40 mV	40 mV	36 mV	40 mV	120 mV	60 mV	240 mV	600 mV
Remote programming	constant voltage	200 ohms/volt	200 ohms/volt	200 ohms/volt	200 ohms/volt	300 ohms/volt	300 ohms/volt	300 ohms/volt	300 ohms/volt
	constant current	15 ohms/amp	5 ohms/amp	25 ohms/amp	10 ohms/amp	50 ohms/amp	15 ohms/amp	100 ohms/amp	170 ohms/amp
Size: W x H x D	inches	19 x 3½ x 17	19 x 5¼ x 16¾	19 x 3½ x 17½	19 x 5¼ x 16¼	19 x 3½ x 17½	19 x 5¼ x 16¼	19 x 3½ x 17½	19 x 5¼ x 16¼
	centimeters	48,3 x 8 9 x 44	48,3 x 14 x 43,7	48,3 x 8,9 x 44,4	48,3 x 14 x 43,7	48,3 x 8,9 x 44,4	48,3 x 14 x 43,7	48,3 x 8,9 x 44,4	48,3 x 14 x 43,7
Weight (net/shipping)	pounds	36/51	67/76	33/48	67/76	31/46	61/70	31/46	61/70
	kilograms	16,3/23,1	30,4/34,4	14,9/21,7	30,4/34,4	14/20.8	27,6/31,7	14/20,8	27,6/31,7
Price		$380							
Options: refer to page 561 for descriptions.									

3 KW REGULATED SUPPLIES
SCR-3 series
Models 6453A, 6456B, 6459A

The SCR-3 Series of regulated supplies are suitable for high-power applications which require up to 200 amps output current and up to 3.6 kilowatts output power. These supplies can be connected in auto-series and auto-parallel for higher power applications. In this series of supplies, silicon-controlled rectifiers perform simultaneously the rectifying and regulating functions with resulting voltage regulation of less than 0.3%.



6450A

Advantages:

- Constant voltage/constant current
- Minimum size, reduced weight
- Continuously variable to zero volts
- Excellent line transient immunity
- 50 millisecond recovery for load current changes
- Short-circuit-proof
- Remote programming
- Remote error sensing
- Auto-series and auto-parallel operation
- 75% efficiency at full load

Model		6453A	6456B	6459A
DC volts out		0 to 15 V	0 to 36 V	0 to 64 V
DC amps out		0 to 200 A	0 to 100 A	0 to 50 A
AC power in		208/230/460±10%, 3 phase, 57 to 63 Hz; 14 amps per phase		
Combined load and line regulation	cv	0.2% +10 mV	0.2% +10 mV	0.2% +10 mV
	cc	1% or 2 A	1% or 1 A	1% or 500 mA
†Ripple and noise (rms max., specified as percent of max. output voltage)		1%	0.5%	0.25%
Remote programming (all programming terminals located on rear barrier strips)	cv	200 ohms/volt	200 ohms/volt	300 ohms/volt
	cc	1 ohm/amp	2 ohms/amp	4 ohms/amp
†Transient recovery time (less than 50 ms required for output voltage recovery to within A mV of nominal output voltage following a load change from full load to half load or half load to full load)		A = 150	A = 300	A = 600
Meters		20 V and 200 A	40 V and 100 A	80 V and 50 A
Input terminals		4-terminal twist lock connector		
Output terminals		tapped rectangular bus bars		
Cooling		internal fan		
Dimensions		19" W, 14" H, 18¼" D (48,3 x 35,6 x 46,4 cm)		
Weight (net/shipping)		225/262 lbs (107/124 kg)	238/275 lbs (107/124 kg)	238/275 lbs (107/124 kg)
Price: Option 01, 02, or 03 must be specified when ordering		$1375	$1275	$1275
Options: Refer to page 561 for description		06-$350	06-$300	06-$300
		01-208 V ac input—no charge, 02-230 V ac input—no charge, 03-460 V ac input—no charge.		
		05-$25, 10-$195, 31-$40, 32-$40		

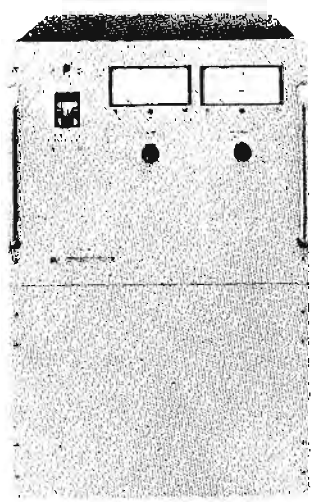
cc = constant current, cv = constant voltage

†Use of supply at 50 Hz input (possible only with option 05) results in a 20% increase in transient recovery time and ripple.

10 KW REGULATED SUPPLIES

SCR-10 Series
Models 6463A—6483B

The SCR-10 Series of all silicon, 10 kilowatt regulated supplies are intended for high power applications which require a fixed or variable dc source with a moderate degree of regulation. Silicon-controlled rectifiers in series with the transformer primary, and controlled by the output voltage and current settings, accomplish the desired regulation using Harrison's "Ramp-Lock" phase control circuit. This circuit technique permits a reduction in the overall size and weight of the power supply and results in up to 75% efficiency at full output. All features of the SCR-10 Series are the same as given for the SCR-3 Series, except that auto-series and auto-parallel operation is not possible.



6472A

Specifications

Controls: a single control allows continuous adjustment of output voltage over the entire output range. A single control allows continuous adjustment of output current over the entire output range. Models 6475A, 6477A, 6479A, and 6483B have 10-turn voltage controls.

Input terminals: a 4-pin jack and mating connector are supplied.

Output terminals: tapped rectangular bus bars.

Cooling: internal fan.

Size: standard 19 inch (483 mm) relay rack mounting, 26¼ inches (669 mm) and 22½ inches (572 mm) deep.

Weight: 420 lbs (191 kg) net, 500 lbs (227 kg) shipping weight.

Finish: light gray front panel with dark gray case.

Model		6463A	6464A	6466A	6469A	6472A	6475A	6477A	6479A	6483B
DC output	volts	0-4	0-8	0-16 or 0-18	0-36	0-64	0-110	0-220	0-300	0-440 or 0-500 or 0-600
	amps	0-2000	0-1000	0-600 or 0-500	0-300	0-150	0-100	0-50	0-35	0-15 or 0-20 or 0-25
AC Input	volts	208/230/380/400/460 ±10% 3 Phase 57–63 Hz Specify by option number see below								
	amps	less than 50 amps per phase at 230 V ac								
Combined line and regulation constant voltage: for a change in output current from no load to full load or full load to no load combined with a ±10% change in line voltage.		50 mV	25 mV	0.2% plus 10 mV	0.2% plus 10 mV	0.2% plus 100 mV	0.2% plus 100 mV	0.2% plus 100 mV	0.2% plus 100 mV	0.5% plus 100 mV
Combined line and load regulation constant current: for a change in output voltage from no load to full load or full load to no load combined with a ±10% change in line voltage.		20 A	10 A	6 A	3 A	1.5 A	1 A	0.5 A	0.3 A	0.2 A
Full scale meter readings: meters have 2% accuracy; all units have meter calibrating potentiometers.		5 V & 2400 A	10 V & 1200 A	18 V & 700 A	40 V & 350 A	80 V & 180 A	125 V & 120 A	250 V & 60 A	350 V & 40 A	600 V & 25 A
†Transient recovery time: less than 50 milliseconds is required for output voltage recovery to within A millivolts of the nominal output voltage following a load change from full load to half load or half load to full load, or a change of 100 amperes, whichever is less.		—	A = 150	A = 150	A = 500	A = 600	A = 1 V	A = 2 V	A = 3 V	A = 5 V
Ripple and noise: rms/p-p (dc to 20 MHz); at any line voltage and load condition within rating		280 mV/1V	80 mV/1V	180 mV/1V	180 mV/1V	160 mV/2V	220 mV/2V	330 mV/2V	300 mV/2V	600 mV/2V
Temperature coefficient: output change per degree centigrade change in ambient following 30 minutes warmup.	cv	0.05% plus 2 mV								
	cc	12 A	6.0 A	3.6 A	1.8 A	0.9 A	0.6 A	0.3 A	0.2 A	0.1 A
Stability: under constant ambient conditions, total drift for 8 hours following 30 minutes warmup.	cv	0.25% plus 10 mV								
	cc	60 A	30 A	18 A	9 A	4.5 A	3 A	1.5 A	1 A	0.6 A
Remote programming (Accuracy 1%)	cv	200Ω/V	200Ω/V	200Ω/V	200Ω/V	300Ω/V	300Ω/V	300Ω/V	300Ω/V	300Ω/V
Remote programming (Accuracy 10%)	cc	0.1Ω/A	1/5Ω/A	⅓Ω/A	⅔Ω/A	1.5Ω/A	2Ω/A	4Ω/A	6Ω/A	10Ω/A
Price: Option 01, 02, 03, 31 or 32 must be specified when ordering.		$3500	$3300	$2600	$2300	$2600	$2600	$2600	$2600	$2600
Options: refer to page 561 for descriptions.	06	—	—	$500	$450	$400	$400	$300	$300	$300
		01-208 V ac input-no charge, 02-230 V ac input-no charge, 03-460 V ac Input- $200, 04-$85, 05-$25, 10-$225 31–380 V ac input-$275, 32–400 V ac input-$275.								

cv = constant voltage cc = constant current

†Use of supply at 50 Hz Input (possible only with option 05) results in a 20% increase in transient recovery time and ripple

MODULAR SLOT SUPPLIES
Adjustable within ±20% band
Models 60063A - 60246B

The SLOT series of modular power supplies is intended for applications requiring a fixed constant voltage source of dc.

The output voltage can be selected by adjusting the rear panel screwdriver control. The nominal output voltage is offset from the design center, used in the output rating charts at right, by up to 2 volts. The output voltage can be varied ±10% of the design center without derating the output current; above ±10%, the output current is derated as illustrated in the graphs below.

The mechanical and electrical design have been accomplished with a view toward simplicity, without any compromise in component quality or manufacturing technique. The result is a low cost, yet reliable power supply which can be bolted directly to standard rack panels (with only four screws) or included as a power module in a larger chassis. All supplies are fully rated to 55°C, and require no additional heat sinks.

A temperature compensated zener diode is employed as the reference element in an all-silicon series regulator feedback circuit which monitors and controls the output voltage. The resulting low ripple and low output impedance permit these supplies to be used in critical applications where less well regulated supplies are not suited.

All supplies are short circuit proof and will not be damaged by any overload regardless of how long imposed. If the output current exceeds the rated value, the cut back circuit is triggered and reduces the output current to a safe limit. When the overload is removed, the supply returns to normal operation.

The output is floating—thus any supply can be used as either a positive or negative source.

Specifications

MODEL	DC OUTPUT (Refer to Derating Charts)		AC INPUT			RIPPLE & NOISE		SIZE	PRICE		
	NOMINAL VOLTS	AMPS	VOLTS	AMPS	WATTS	RMS	P-P (mV) dc to 20 MHz		1–9	10–19	20–49
60063A	6	1.5	115 V ac ± 10%, 48-440 Hz	0.3	26	1 mV or 0.006%, whichever is greater	3	3	$ 87	$ 85	$ 81
60065A	6	3		0.75	63		3	5	$110	$107	$103
60066A	6	8		1.5	150		6	6	$110	$107	$103
60122B	12	0.5		0.16	15.7		3	2	$ 72	$ 70	$ 68
60123B	12	1		0.3	26		3	3	$ 79	$ 77	$ 74
60125B	12	2.2		0.75	62		4	5	$100	$ 97	$ 94
60126B	12	6		1.75	153		6	6	$179	$174	$169
60242A	24	0.25		1.5	15.5		3	2	$ 72	$ 70	$ 68
60243B	24	0.5		0.3	26		3	3	$ 79	$ 77	$ 74
60244B	24	1		0.5	45		3	4	$ 88	$ 85	$ 83
60245B	24	1.5		0.75	65		9	5	$100	$ 97	$ 94
60246B	24	3.5		2	160		12	6	$179	$174	$169

If chart does not include a SLOT supply to fill your needs, ask your HP Sales Engineer for the Custom SLOT Series data sheet.

Specifications

Load regulation: less than 0.05% from no load to full load.

Line regulation: less than 0.05% for 10% change in nominal line voltage.

Temperature coefficient: output voltage change per °C is less than 0.025% after 30-minute warmup.

Stability: the total drift for eight hours (after 30 minutes warmup) at a constant ambient is less than 0.1%.

Temperature rating: operating: 0 to 55°C; storage: −40 to +85°C.

Output impedance: less than 0.3 ohms to 100 kHz; less than 3 ohms to 1 MHz.

Transient recovery time: less than 25 μs for output voltage recovery to within 10 mV of the nominal output voltage following a full load or 5 amp load change, whichever is less.

Overload protection: the output is current limited (non-adjustable) and is fully rated for operation under any overload condition including a direct short circuit, regardless of how long maintained. Supply will automatically restore to normal operation upon overload removal.

Terminals: a rear barrier strip includes AC, ACC, GND, + Out, − Out, + Sensing, and − Sensing terminals. Either side of the supply may be grounded or the output may be operated floating at potentials of up to 300 V off ground.

Output control: screwdriver adjust, accessible through hole in end plate.

Mounting: four 8-32 threaded nuts embedded in mounting end plate facilitate assembly of modules to rack panels, chassis, etc.

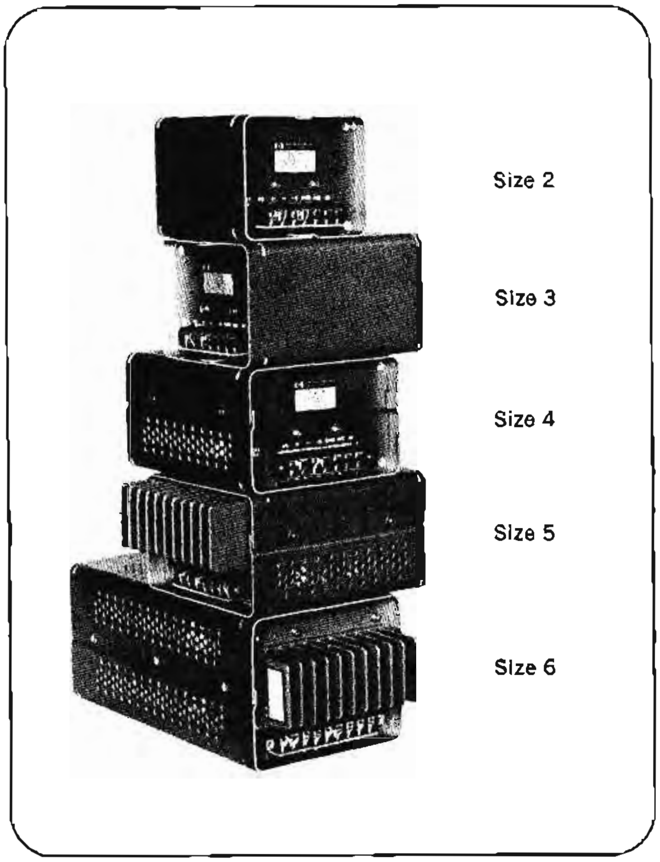
Overall dimensions:

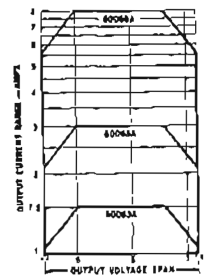
	Mounting face	Module length
Size 2:	3⅜" (8.6 cm) x 4⅛" (10.5 cm)	4⅛" (10.5 cm)
Size 3:	3⅜" (8.6 cm) x 4⅛" (10.5 cm)	6" (15.2 cm)
Size 4:	3⅜" (8.6 cm) x 5⅛" (13 cm)	6" (15.2 cm)
Size 5:	3⅜" (8.6 cm) x 5⅛" (13 cm)	7-5/16" (18.6 cm)
Size 6:	4¼" (10.8 cm) x 5⅛" (13 cm)	11" (27.9 cm)

Weight:

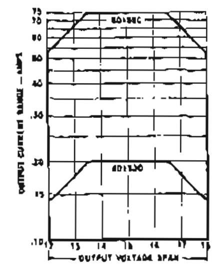
	Net	Shipping
Size 2:	2.1 lbs (0.95 kg)	3.5 lbs (1.6 kg)
Size 3:	2.5 lbs (1.1 kg)	4.0 lbs (1.8 kg)
Size 4:	4.5 lbs (2 kg)	6.5 lbs (2.9 kg)
Size 5:	6.0 lbs (2.7 kg)	8.0 lbs (3.6 kg)
Size 6:	13 lbs (5.9 kg)	15 lbs (6.8 kg)

Options: 06, 17, 18. See page 561 for descriptions.

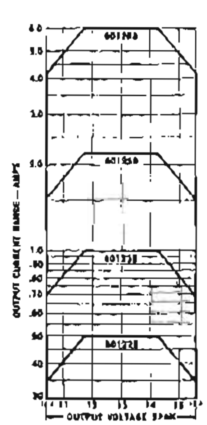




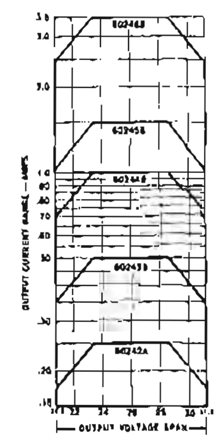
6 V



±15 V



12 V



24V

Dual Slot Supplies

Model 60155C and 60153D are dual output SLOT supplies ideal for powering operational amplifiers. These new supplies provide a positive and negative 15 V dc output referenced to a common terminal and are internally connected for auto-tracking "rubber-band" operation. With the slave (−) supply tracking the master (+) supply, any change of the internal reference source (e.g. drift, ripple) will cause an equal percentage change in the outputs of both the master and slave supplies.

The degree by which the slave supply varies as a percentage from the master supply is defined as "tracking error." The tracking error is less than 30 mV for each 1 V change in the master. For example, if the master supply output voltage drifted more negative by 0.5 V, the slave supply output voltage would become more positive by 0.5 V ±15 mV.

The features are identical to the standard units in the SLOT Series as listed on page 584.

Specifications

Unless otherwise indicated, the specifications are identical to the single output SLOT power supplies on the preceding page.

Dual output: 60155C: ±15 V dc, 0 - 0.75 A; 60153D: ±15 V dc, 0 - 0.2 A.

Output current capability: as illustrated, the output voltage can be varied from 12 to 18 volts; but with output current rated according to chart above.

Input: 115 V ac ±10%, 48 - 440 Hz.

Load regulation: less than 0.03% output voltage change for a load current change equal to the rating of the supply.

Line regulation: less than 0.01% for 60155C, 0.03% for 60153D output voltage change for a 10% change in line voltage.

Ripple and noise: less than 300 μV rms, 2 mV p-p (dc to 20 MHz).

Temperature coefficient: output voltage change per degree centigrade after 30-minute warmup.
Master supply: less than 0.025%.
Slave supply: less than 0.015%.

Stability: total drift for 8 hours (after 30-minute warmup) at a constant ambient temperature.
Master supply: less than 0.1%.
Slave supply: less than 0.06%.

Slave tracking error: less than 30 mV for each IV change in the master output voltage.

Terminals: a rear barrier strip includes AC, ACC, +, −, common, + sensing, − sensing, and common sensing terminals. Either side of the supply may be grounded or the output may be operated floating at potentials 300 V off ground.

Weight: (net/shipping) 60155C: 5.25 lbs (2,4 kg), 7.25 lbs (3,2 kg); 60153D: 2.5 lbs (1,1 kg), 4.0 lbs (1,8 kg).

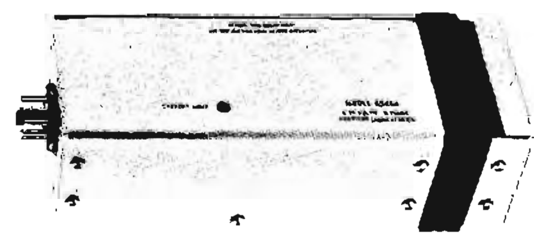
Size: 60155C, size 5; 60153D, size 3. Refer to dimensions under single SLOT specifications.

Price:	1-9	10-19	20-49
60155C	$133	$129	$125
60153D	97	93	91

MODULAR PLUG-IN SUPPLIES
MOD Series, 801C
Models 6343A - 6357A, 801C

The MOD Series of plug-in modular power supplies was designed to meet the need for well-regulated, inexpensive chassis-mounting supplies. All input, output and control connections are made through the 11-pin plug at the base of the module. Depending upon techniques and values of resistance employed to connect these pins to controls, a designer can vary output over the complete voltage range of the supply, employ remote sensing, or use remote programming.

Current limit can be set at any value from zero to a value slightly greater than the current rating of the supply. A screwdriver adjustment slot permits readjustment of the current limit value without removing the module cover. This gives protection against any overload problem, including shorts across the output.



Model 6346A

Specifications, MOD Series

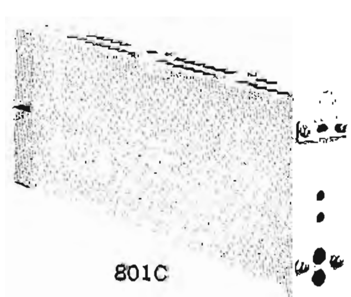
Model	6343A	6344A	6346A	6347A	6354A	6357A
DC output	0 to 18 V 0 to 300 mA	0 to 18 V 0 to 1 A	0 to 36 V 0 to 150 mA	0 to 36 V 0 to 500 mA	0 to 160 V 0 to 400 mA	0 to 320 V 0 to 200 mA
AC input	115 Vac ± 10% 48 to 440 Hz	115 Vac ± 10% 48 to 63 Hz	115 Vac ± 10% 48 to 440 Hz	115 Vac ± 10% 48 to 63 Hz	115 Vac ± 10% 48 to 63 Hz	115 Vac ± 10% 48 to 63 Hz
Load regulation	3 mV or 0.03%	3 mV or 0.03%	3 mV or 0.02%	3 mV or 0.02%	0.005% +2 mV	0.005% +2 mV
Line regulation	3 mV or 0.03%	3 mV or 0.03%	3 mV or 0.02%	3 mV or 0.02%	0.005% +1 mV	0.005% +1 mV
Ripple and noise	Less than 1 mV rms for any combination of line voltage, output voltage and load current.					
Stability	Less than 0.1% plus 10 mV total drift for 8 hours (after 30 minutes warm-up) at a constant ambient.					
Temperature coefficient	Less than 0.033%, plus 2 mV/1°C.					
Size	A	B	A	B	C	C
Weight (lb/kg)	3/5 lbs (1,4/2,3 kg)	7/10 lbs (3,2/4,5 kg)	3/5 lbs (1,4/2,3 kg)	7/10 lbs (3,2/4,5 kg)	13/19 lbs (5,9/8,6 kg)	13/19 lbs (5,9/8,6 kg)
Price	$120	$165	$120	$165	$259	$259
Options	05–$10 28–$10	05–$10 28–$10	28–$10	05–$10 28–$10	05–$10 28–$10	05–$10 28–$10

*Refer to page 561 for descriptions.

NOTE: Size "A" is 8" H x 3" W x 2⅜" D; Size B is 9" H x 5" W x 3" D; Size C is 9" H x 6¼" W x 5" D.

Strain gage supply

Designed to operate primarily as a power supply for strain gage application, the 801C is a solid-state power supply with greater than 10,000 megohms to ground or ac input and less than 1 pF capacity from output terminals to input power line. See page 561 for rack kits. (Connections by barrier strip.)



801C

Specifications

Output: 0 to 25 volts at 0 to 0.2 amp.

Load regulation: less than 2 mV change, no load to full load.

Line regulation: less than 2 mV change, for a change in line voltage from 105 to 125 volts.

Ripple and noise: less than 100 μV rms.

Maximum ambient operating temperature: 50°C.

Stability: less than 0.1% +5 mV total drift for 8 hours after 30-minute warmup.

Overload protection: current limiter protects supply from all overloads including direct shorts.

Controls: coarse and vernier for continuous voltage control.

Remote error sensing: at rear terminals.

Power: 105 to 125 V ac, 55-65 Hz.

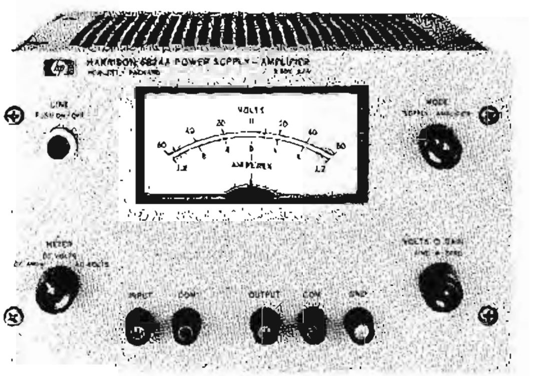
Dimensions: 5" high, 14⅞" deep, 1⅜" wide.

Weight: net 4 lbs; shipping 8 lbs.

Price: 1 to 9, $149 each; 10 to 49, $145 each; 50 to 99, $140 each; 100 and more, $135 each.

DC POWER SUPPLY/AMPLIFIER

PS/A series
Models 6823A, 6824A



6824A

Models 6823A and 6824A are dual-purpose dc regulated power supplies and direct-coupled amplifiers. Two or more of these units can be connected in Auto-Series to obtain greater voltage capability. High speed constant current operation can be obtained by simply adding an external resistor in series with the load and making minor changes in the rear barrier strapping.

Two temperature-compensated zener diodes are employed as reference elements in a series regulator feedback circuit which monitors and controls the output voltage. The resulting low ripple and low output impedance permit these instruments to be used in critical power supply applications. Low internal dissipation assures reliability.

As a power amplifier, both instruments offer a signal-to-noise ratio of 80 dB at full output with low distortion and 20 dB gain from dc-20 kHz (kc); making them useful in a wide variety of applications. The output is inverted. Rack mounting hardware is available for mounting singly or in pairs in 3½" or 5¼" of rack height.

Advantages:

Power supply
- Output adjustable through zero
- High-speed programming
- Short-circuit-proof
- Low ripple and noise
- Fast transient recovery
- No overshoot for turn-on, turn-off, or power removal

Power amplifier
- Variable gain
- High signal-to-noise ratio
- Low distortion
- Frequency response — dc to 20 kHz

Applications

As a dc Power Supply, Models 6823A or 6824A can be controlled from the front panel, or remotely programmed with resistance or voltage. The low output drift and noise combined with high speed programming adapt this supply to a wide variety of laboratory and production testing applications.

As a dc coupled Power Amplifier, the unusually low output impedance, distortion, ripple and noise make the 6823A or 6824A useful in servo system, as a pulse or oscillator amplifier, and for motor control. Constant Current output is readily achieved by connecting a current monitoring resistor to the rear terminal barrier strip—makes an ideal driver-amplifier for deflection coils!

For more information, refer to Application Note 82, Power Supply/Amplifier Concepts and Modes of Operation, available free of charge from your local Hewlett-Packard field sales office.

Specifications

MODEL 6823A

High speed programming dc power supply	10 watt peak output dc power amplifier
Output: —20 to +20 V dc @ 0-0.5 A	Output: 40 volts p-p @0-0.5 A
Load regulation: 0.02% +5 mV	Voltage gain: Variable 0-10 (20 dB) output inverted.
Line regulation: 0 02% +5 mV	Frequency response; at full output, ±3 dB from dc to 20 kHz.
Ripple & noise: 2 mV rms	
Transient recovery time: less than 100 μs to within 5 mV +0.02% of the nominal output.	Max. phase shift. dc —180° 100 Hz —181° 1 kHz —183° 10 kHz —205° 20 kHz —225°
Remote programming: 500 ohms/V. Also voltage programming.	Distortion: <0.02% at 1 kHz and full output.
Programming speed: less than 50 μs are required for programming between —20 V and +20 V. Typically the programming time between 0 and 90% of the maximum voltage span is 20 μs.	Input impedance: 2k ohms approx. Input terminals: front and rear.

AC Input: 115 V ac ±10%, single phase, 50-440 Hz; 0.33 amp, 24 watts max.
Meter: Dual purpose with selector switch; —24 to +24 volts, —0.6 to +0.6 amps.
Size: 3½" H x 8½" W x 13" D (8.9 cm H x 21.8 cm W x 33 cm D).
Weight: 16 pounds (7.26 kg) net, 20 pounds (9.07 kg) shipping.
Price: $194.
Rack mounting kits: refer to page 561.
14513A: mounts one 3½" high unit—add $20.00
14523A: mounts two 3½" high units—add $10.00

MODEL 6824A

High speed programming dc power supply	50 watt peak output dc power amplifier
Output: —50 to +50 V DC @ 0-1.0 A	Output: 100 volts p-p @ 0-1.0 A
Load regulation: 0.02% +5 mV	Voltage gain: variable, 0-10 (20 dB), output inverted.
Line regulation: 0.02% +5 mV	Frequency response; At full output, ±3 dB from dc to 20 kHz
Ripple & noise. 10 mV rms.	
Transient recovery time: less than 100 μs to within 5 mV +0.02% of the nominal output.	Max. phase shift: dc —180°, 100 Hz —180.7°, 1 kHz —182.9°, 10 kHz —205°, 20 kHz —225°
Remote programming: 500 ohms/V. Also voltage programming.	Distortion: <0.02% at 1 kHz and full output
Programming speed: less than 50 μs are required for programming between —50 V and +50 V. Typically, the programming time between 0 and 90% of the maximum voltage span is 20 μs.	Input impedance: 2k ohms approx. Input terminals: front and rear.

AC Input: 115 V ac ±10%, single phase, 50-60 Hz, 1.3 amps, 96 watts max.
Meter: triple purpose with selector switch; —60 to +60 volts, —1.2 to +1.2 amps, 0 to 60 V rms
Size: 5¼" H x 8¼" W x 13" D (14 cm H x 21 .8 cm W x 33 cm D).
Weight: 17 pounds (7.7 kg) net, 21 pounds (9.55 kg) shipping.
Price: $350
Rack mounting kits: refer to page 561.
14515A: mounts one 5¼" high unit —add $23.00
14525A: mounts two 5¼" high units —add $13.00

Other specifications for both models

Temperature ratings: operating: 0 to 50°C. Storage +20 to 85°C.

Temperature coefficient: 0.015% +1 mV per °C.

Stability: 0.075% +5 mV for 8 hrs. (after ½ hr. warm-up); ambient temperature variation held to 3°C.

Overload protection: the unit is completely protected for all overload conditions including a short circuit applied directly across the output terminals.

Output terminals: both front and rear terminals are provided.

Option 28: 230 V ac ±10%, single phase input. Factory modification consists of reconnecting the multi-tap input power transformer for 230-volt operation. See page 561.

FREQUENCY AND TIME MEASURING INSTRUMENTATION

Electronic counters have proven to be the most accurate, flexible, and convenient instruments available for making both frequency and time interval measurements. Since the introduction of the first high-speed counter (the 10 MHz HP Model 524A) more than 15 years ago, Hewlett-Packard has developed a broad range of counters with a wide variety of features. The counters and associated equipment can measure frequencies from dc to 40 GHz, and time intervals from 10 nanoseconds to more than 100 days.

The electronic counter is an instrument which compares an unknown frequency or time interval to a known frequency or a known time interval. The counter's logic is designed to present this information in an easy-to-read, non-ambiguous, numerical display. The accuracy of this measurement depends primarily upon the stability of the known frequency, which usually is derived from the counter's internal oscillator or, in the lowest cost counters, from the ac power line frequency. The oscillators in HP counters are designed and built by HP for optimum stability in each price class.

The decision as to which electronic counter is best suited for a specific application depends upon the range and type of measurements to be made. See the Electronic Counter Selection Guides on pages 593 and 594.

To go with this very complete line of electronic counters Hewlett-Packard also offers many input and output accessories. Included are digital recorders for automatic recording of measurements; digital clocks which control measurement intervals and supply time information for simultaneous recording; digital-to-analog converters for high resolution analog records of digital measurements; and scanners which can receive the outputs from several electronic counters for entry into a single recording device. Hewlett-Packard also manufactures magnetic and optical tachometers for rps measurement inputs to low-frequency electronic counters, and accurate analog frequency meters which also serve as highly linear, wide-band, FM discriminators.

Counter elements

All electronic counters have several basic functional sections in common. These are interconnected in a variety of ways to perform the different counter functions. The most important components are: (1) the decade counting assemblies (DCA's) with visual numerical readouts to totalize and display the count; (2) the main gate, which controls count start and stop with respect to time, (3) the time base, which supplies the precise increment of time to control the gate for a frequency or pulse train measurement and (4) decade divider assemblies (DDA's) which allow variation of gate time. Other sections include: Schmitt trigger for signal shaping, display control, and logic control. The logic control interconnects the proper circuits for the desired measurement, selects the appropriate measurement units for display and initiates the measurement cycle. The various modes of electronic counter operation are described in the following paragraphs, and accuracy is discussed on page 592.

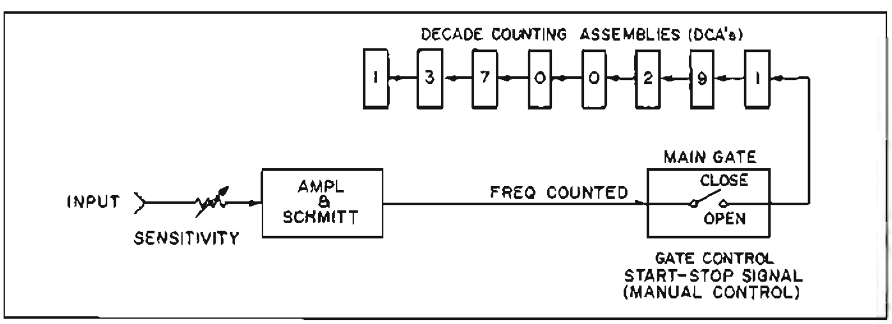


Figure 1. Function switch set to manual Start and Stop to determine interval input signal.

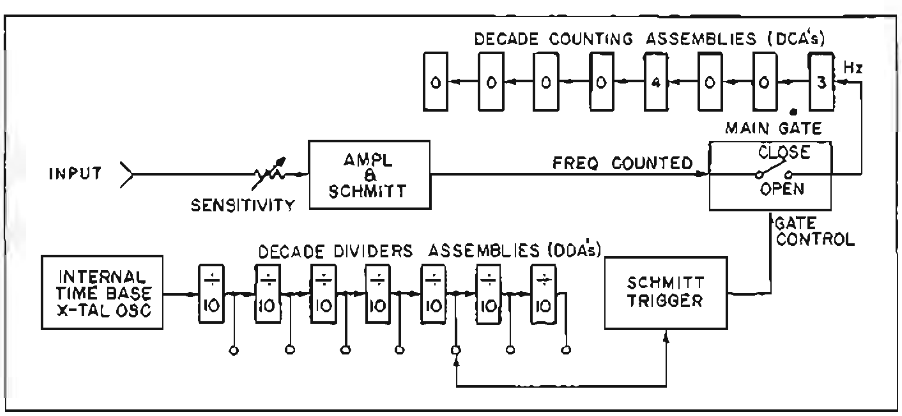


Figure 2. Function switch set to Frequency and gate time selected by time base switch.

Totalizing

Electronic counters can be operated in a totalizing mode with the main gate flip-flop controlled by a manual start-stop switch as shown in Figure 1. With the switch in Start (gate open), the decimal counter assemblies totalize the input pulses until the main gate is closed by the switch being changed to Stop. The counter display then represents the input pulses received during the interval between manual Start and manual Stop. Generally, totalizing can also be remotely controlled.

Reversible counting

The unique feature of a reversible counter is each decade's ability to totalize in either a positive or negative direction. Signals on one input are added, while signals on the other input line are subtracted; alternately, signals on the first input line may be added or subtracted, when information regarding the direction of count is supplied to the second input line. The HP 5280A can reverse its direction of count in 250 ns.

Frequency measurements

For direct frequency measurements (Figure 2) the input signal is first converted to uniform pulses by the Schmitt signal shaper. These pulses are then routed through the main gate and into the decade counting assemblies (DCA's) where the pulses are totalized. The number of pulses totalized during the "gate open" interval is a measure of the average input frequency for that interval. The count obtained, with the correct decimal point, is displayed and retained until a new sample is ready to be shown. The Sample Rate Control determines the time between samples, resets the counter and initiates the next measurement cycle.

The time base selector switch selects the gating interval, positions the decimal point and selects the appropriate measurement units.

Measurement accuracy is discussed on page 592. For measurement of low level signals (down to 1 mV rms), HP manufactures a video amplifier plug-in (the model 5261A) for the HP plug-in counters. When using the 5261A on the most sensitive ranges, precaution should be taken to exclude the presence of stray radiation from the immediate measurement area because of its high sensitivity. A front panel meter indicates whether the input level is adequate for the measurement.

High frequency measurements are discussed later.

Period measurements

Period is the inverse of frequency ($P = 1/f$). Therefore period measurements are made with the input and time base connections reversed. This is shown in Figure 3. The unknown input signal controls the main gate time, and the time base frequency is counted in the DCA's. The input shaping circuit selects the positive-going zero axis crossing of successive cycles of the unknown as trigger points for opening and closing the gate.

Low frequencies may be determined more accurately by measuring period rather than frequency directly. This is true because the longer period of a low frequency allows more counts to accumulate in a period measurement; therefore, resolution and accuracy are both improved. This is discussed in more detail on page 592. For example, a frequency measurement of 100 Hz on the 8-digit 5248L Counter with a 10-second gate time will be displayed as 0000.1000 kHz. A 10 period average measurement of 100 Hz on an HP 5248L with 100 MHz as the counted frequency, would be displayed as 100000.00 μs. Thus, resolution is increased by a factor of 10^4 and measurement time decreased by 100.

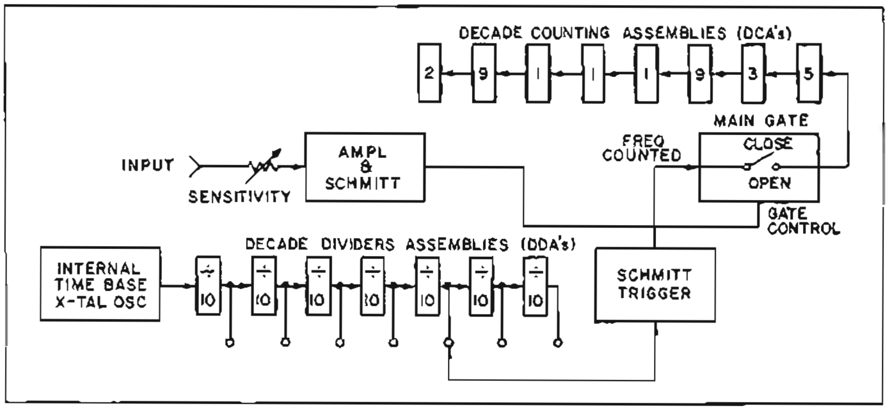


Figure 3. Function switch set to Period and counted frequency selected by time base switch.

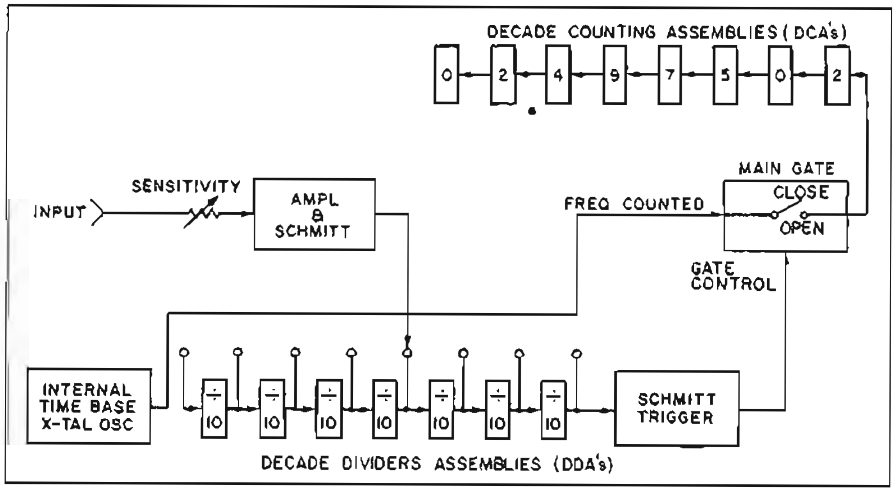


Figure 4. Function switch set to Period Average. Input signal controls gate for counting time base frequency.

Multiple period averaging

Multiple period averaging is a simple method for reducing error and improving resolution in period measurements. Accuracy is discussed thoroughly on page 592 where it is shown that the more periods over which a signal is averaged, the better the accuracy.

The number of periods of the unknown to be averaged is selected by a front panel switch. The HP 5325A can average up to 10^8 periods and several other HP counters can average up to 10^6 periods. In the low-frequency measurement example above, the counter would display 10000.000 μs for a 10 period average. (The selector switch automatically shifts the decimal point in the display to show the correct reading for a single period.)

Ratio measurements

The ratio of two frequencies is determined by using the one signal for the gate control while the other signal is counted (Figure 5). With proper transducers, ratio measurements may be applied to any phenomenon which may be represented by pulses or sine waves. Gear ratios and clutch slippage, as well as frequency divider or multiplier operation, are some of the measurements which can be made using this technique.

The accuracy may be improved by using the multiple period averaging technique by counting for 10^N cycles of the gate control signal. Sources of error are discussed on page 592.

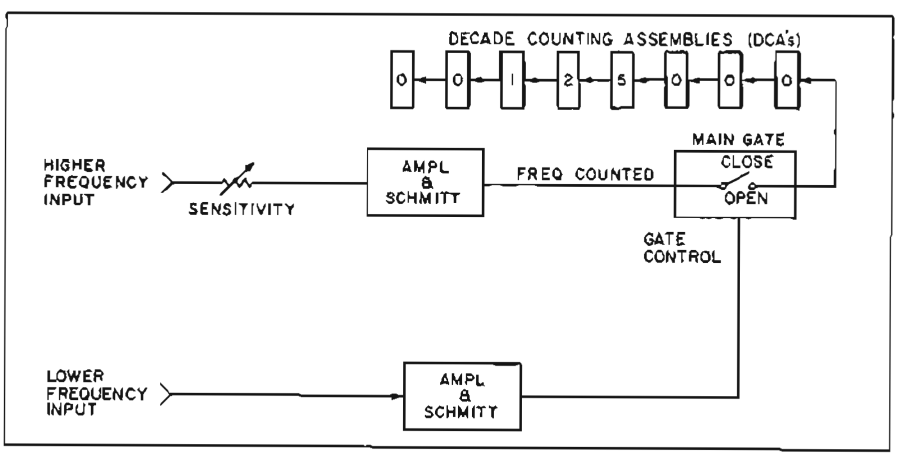


Figure 5. Ratio measurement. Function switch set to Period and time base switch to Ext. Lower frequency controls gate, while higher frequency replaces time base as counted frequency.

Rate measurements

With a preset counter or a counter with a preset plug-in, frequency measurements can be normalized automatically to rate measurements by appropriate selection of the gate time. The counter will then display a readout in the desired unit of measurement. For example: the HP 5214L Preset Counter or the HP 5248L Counter with the 5264A Preset Plug-in can be set to a gate time of 600 milliseconds to cause the input from a 100-pulse-per-revolution tachometer to be displayed directly in revolutions per minute.

Scaling

Several HP counters can scale (divide) an input by powers of 10 up to 10^9. The scaled output is available from the rear of the counter.

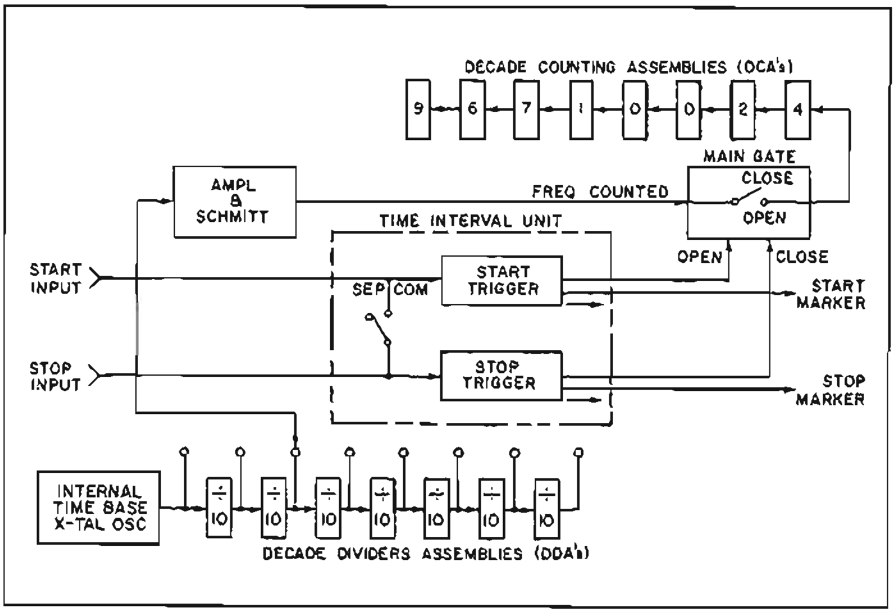


Figure 6. Start and stop signals derived from two sources or from different points of same waveform as selected by Com-Sep switch.

Time interval measurements

Counters vary greatly in their time interval measuring capability. Some counters only measure the duration of an electrical event, others measure the interval between the start of two pulses, but the most versatile models, known as "universal counters," have separate inputs for the start and stop commands and have separate trigger controls which permit setting the trigger level amplitude, polarity, slope and type of input coupling (ac or dc) for the start and stop channel. Since stop and start commands can originate from common or separate sources, this type of instrument can measure the interval from one point on a waveform to another point on the same waveform. Examples of universal counters are HP 5325A, 5223L and 5233L Counters and 5267A, or 5262A Time Interval Plug-in in an HP 5245, 5246, 5247, or 5248 Counter. Figure 6 is a generalized diagram of these versatile models. Time is displayed in μs, ms or s. Accuracy is affected by the same factors which affect period measurements. See page 592 for a detailed discussion of accuracy.

The HP 5267A Time Interval Plug-in offers the greatest versatility in measuring time interval from 100 ns to 10^{4} s. Resolution is 10 ns from 100 ns to 1 s. The full complement of trigger controls, 100 mV sensitivity and constant input impedance of 1 MΩ/35 pF on all ranges permits measurements of any waveshape and from high or low impedance circuits. The 5262A Plug-in offers less versatility and 100 ns resolution. The 5275A is a special purpose counter for time interval measurement only, it will measure from 10 ns to 0.1 s with 10 ns resolution.

Measurement of the time required for a number of random events to occur is possible with the 5214L Preset Counter. This instrument's decade dividers may be preset to close the gate on the Nth input pulse, where N is any number from 1 to 100,000.

High-frequency measurements

The frequency range of a counter can be extended with heterodyne converters, transfer oscillators or automatic dividers and for frequencies up to 350 MHz prescaling is available.

The unique capabilities of each will now be briefly described.

Heterodyne converters measure the average frequency of CW signals (even when FM'd) and give the greatest resolution for a given counter gate time of any frequency extension technique. Resolution is 1 Hz in 1 s, 10 Hz in 0.1 s, 100 Hz in 0.01 s, etc. (exception: Models 5255A and 5256A require four times longer). Hewlett-Packard manufactures a series of heterodyne converter plug-in units (see pages 608, 609) which convert the unknown high frequency to a related frequency which is within the counter's basic range. Measurements to 18 GHz are possible.

As an example we shall refer to the HP 5255A Plug-in Unit (see Figure 7). The tuning cavity selects the 200 MHz harmonic that gives a beat frequency output. After prescaling by a factor of four, the difference frequency is within the 50 MHz counting capability of the 5245M. At the same time

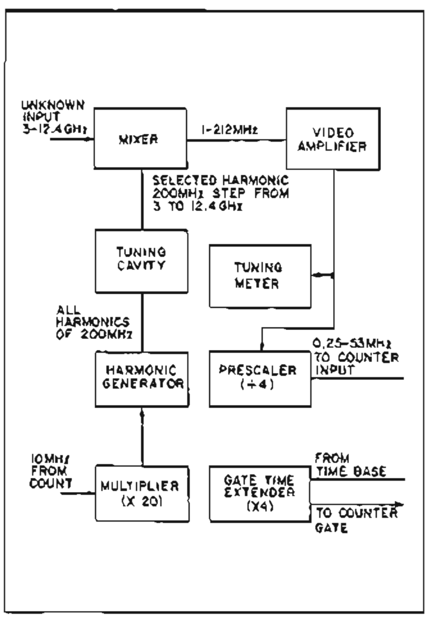


Figure 7. Frequency measurement with heterodyne converter; counter measures difference frequency (diagram is of HP 5255A Converter).

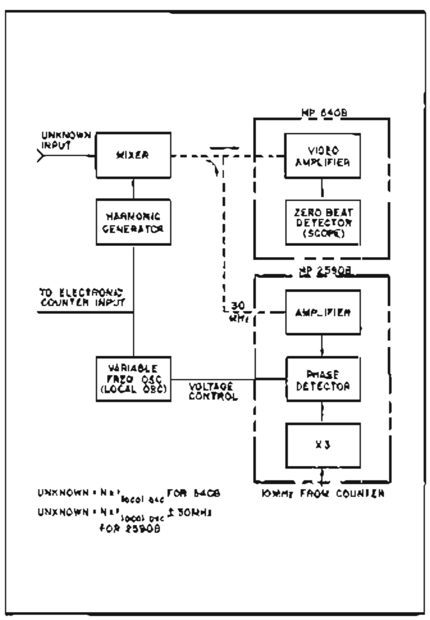


Figure 8. Frequency measurement with conventional transfer oscillators; counter measures oscillator frequency (diagram is of HP 540B and 2590B).

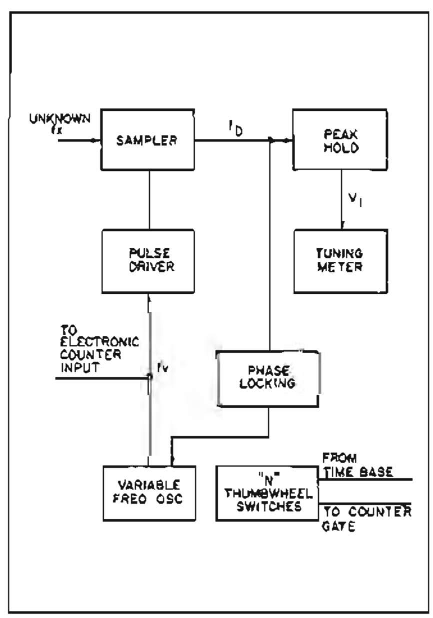


Figure 9. Frequency measurement with HP 5257A Transfer Oscillator using new transfer oscillator principle: counter measures sampling frequency of sampler.

the 5245M gate time is automatically extended by a factor of 4 so that direct readout on the 5245M is achieved. The frequency reading on the counter is then added to the setting on the tuning dial to give the unknown frequency.

Transfer oscillators, on the other hand, can measure pulsed signals as well as CW signals. They also have a wider bandwidth than heterodyne converters. Possible drawbacks of transfer oscillators, when compared to converters, are that they require more operator skill and time for initial set-up (because calculations of harmonic number might be needed), and a longer gate time is needed for equivalent resolution.

In operation, the transfer oscillator generates a variable frequency, which is adjusted so a harmonic of that frequency zero beats with the unknown signal (see Figure 8). The transfer oscillator frequency is then measured on the counter and multiplied by the appropriate harmonic number to give the unknown frequency. In the HP 2590B, zero beat is obtained by an automatic phase lock loop after one of the nearest subharmonics has been manually tuned. Measurements to 18 GHz are possible with the HP 5257A, and to 40 GHz with the HP E40-5245L System or the HP 540B Transfer Oscillator with related instruments.

The model 5257A is HP's newest transfer oscillator. It plugs into the front panel of the HP 5245, 5246, 5247, and 5248 Counters and extends counter range so that continuous coverage from 50 MHz to 18 GHz is achieved in a very compact, convenient, easy-to-use package. It is a new concept in frequency extension using a broadband sampler in place of both the harmonic mixer and phase detector. It operates without an offset frequency; thus, once the harmonic number has been dialed into the 5257A thumbwheel switches and the VFO tuned for phase-lock, frequency is read directly from the counter with no further calculation. It also measures pulsed RF frequencies. A simple tuning meter replaces the conventional "zero beat" oscilloscope with no sacrifice in accuracy. The broadband sampler offers high sensitivity over the entire 50 MHz to 18 GHz range and permits tuning by a single knob instead of requiring several auxiliary stub tuners to optimize sensitivity.

The 5257A operates in a manner analogous to a stroboscope which uses a flashing lamp for measuring vibrational or rotary speeds. That is, if the 5257A variable frequency oscillator output frequency (Figure 9) is set to any sub-harmonic (N) of the unknown input frequency f_x, then V_1 will be a dc voltage (otherwise it's ac) because the input waveform will be sampled at the same point each time the sampler is gated open. Thus, if we manually tune the VFO until $f_D = 0$ (indicated by tuning meter) and measure f_v with an electronic counter, the counter reading will be the frequency of some subharmonic of f_x. The frequency of f_x can then be determined by multiplying the counter reading by the harmonic number N. Dialing the number N into the thumbwheel switches on the 5257A performs this multiplication by extending the counter gate time by a factor of N. Since there is no offset frequency to add or subtract from the reading, the counter displays f_x directly. "Zero beats" occur at intervals of N f_v across the VFO dial. The VFO dial need only be used as an approximate indicator of VFO frequency since the electronic counter rapidly measures VFO frequency and displays up to 8 significant figures.

Tuning the 5257A is an uncritical operation. For CW signals, once the VFO is tuned through the proper frequency, it becomes automatically and securely phase-locked to it. Phase-locking does not occur for pulsed RF signals. Therefore, as in all transfer oscillators, accuracy is not as great when measuring the frequency of pulsed carriers as it is for CW signals. Tuning is also simple for pulsed carriers because zero beat is indicated by a maximum reading on the front panel meter.

See the HP Journal, Feb., '68, for a complete description of the 5257A.

In all transfer oscillators, harmonic number is calculated from the VFO frequency measured at two adjacent lock-points ("zero beat"). If the transfer oscillator operates with an offset (IF frequency), calculation is lengthier.

Automatic frequency dividers provide automatic measurement and direct readout of a wide range of CW frequencies, and furnish 1000 Hz resolution is 1 s. Some FM can be tolerated. Measurements from 0.3 GHz to 12.4 GHz can be achieved using the HP 5260A with a suitable counter or the HP 5240A Frequency Meter. The 5240A and 5260A zero beat with the input automatically and without offset and then provide a frequency input to the counter equal to exactly 1/100 or 1/1000 of the unknown frequency depending upon the division ratio switch setting.

Prescaling is accomplished by means of frequency division of the input signal. If the gate time is extended with the scale factor, the correct frequency will appear on the counter readout. The HP Model 5252A Prescaler plug-in unit has three selectable scale factors: ÷8, ÷4, and ÷2 and is dc coupled which makes it very useful for counting of random pulses or events. Because the Prescaler is a wideband instrument, it is more susceptible to noise than tuned instruments like the heterodyne converters. An adjustable trigger-level control on the Prescaler can be used to discriminate against unwanted signals. The accuracy of the Prescaler is the same as that of the counter although the measurement takes 2, 4, or 8 times as long time, depending on the scale factor.

For very low signal levels, HP manufactures a Sensitive Prescaler (Model 5258A) with a maximum sensitivity of 1 mV rms and a frequency range of 1 MHz to 200 MHz. The scale factor is fixed at ÷4. For simplicity of operation, a meter indicates the input signal level.

Digital to analog conversion

In many measurement applications analog recordings can be of great value. In general it is not possible to make analog recordings directly from a counter. Most of Hewlett-Packard's electronic counters will provide the measurement data in BCD form. Using this BCD output and an HP Model 580A or 581A Digital to Analog (D/A) Converter, an analog recorder output is then available from the D/A converters. The 580 Series offers resolutions to 1 part in 10^5.

A case where the D/A converters prove very useful is in the evaluation of the stability of quartz crystal oscillators. By combining a counter, a D/A converter, and a strip chart recorder it is possible to obtain a plot of fractional frequency deviation.*

In general, when data must be monitored continuously over a long period of time, the use of D/A converters in connection with electronic counters becomes very useful.

Counter accuracy

There are 3 main sources of error in counter measurements: ±1 count ambiguity, time base instability, and trigger error. The causes and the effects of these errors are discussed below. ±1 COUNT AMBIGUITY. The ±1 count ambiguity is inherent in all electronic counter measurements because the input signal and the time base are normally not synchronized. As shown in Figure 10, the count registered during the gating time t_g may be either 6 or 7 depending on the moment at which t_g begins. Thus, in any measurement, the counter's display may be incorrect by one count.

*This and other stability measurements are described in greater detail in the HP Application Note AN-52, available without charge from the Hewlett-Packard Company.

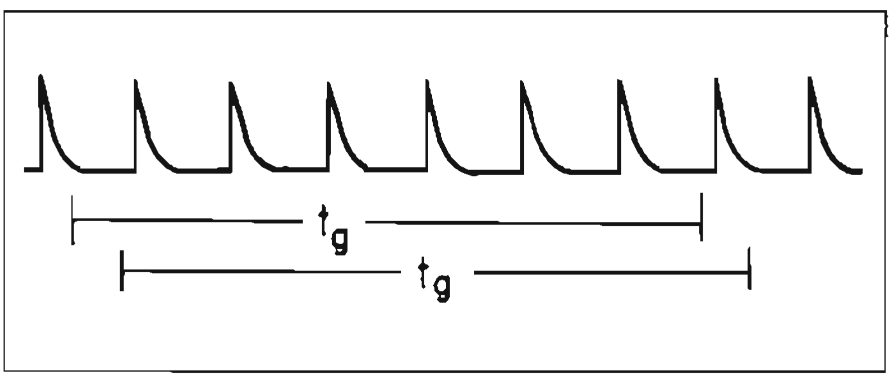


Figure 10. An error of ±1 count can occur because gate may open and close between input pulses. With gate open for upper tg interval, 6 counts occur; 7 counts occur for lower interval.

The fractional effect of the ±1 count ambiguity is:

$$\frac{1}{\text{total events counted}}$$

Obviously, the more events counted, the smaller this error becomes. This explains why long gate times result in better accuracy in frequency measurements.

TIME BASE STABILITY. When the crystal is in a precision oven, Hewlett-Packard separately specifies crystal aging rate, short-term stability, temperature change and line voltage change as sources of time base error.

Crystal aging rate (also called long-term stability or drift rate) refers to slow, but predictable, variation in average oscillator frequency with time due to changes occurring in the quartz crystal itself. After an initial period of rapid change when the oscillator is turned on, aging in a good crystal becomes quite slow and assumes a predictable linear characteristic. The slope of this line is the aging rate of the oscillator.

Since aging is cumulative, it is necessary to periodically calibrate the oscillator. Calibration methods are discussed in HP Application Note 52 which is available upon request.

Short-term stability specifications indicate the effects of noise generated internally in the time base oscillator on the average frequency over a short time, usually one second.

Short-term effects are so small that the spec is listed for only the very most stable time base oscillators in precision ovens. In the less stable oscillators, other errors make the short-term spec insignificant.

When comparing short-term stability specifications, it is important to remember that the averaging time used will determine how good the spec *appears* to be. A long averaging time will hide large frequency variations. Hewlett-Packard always specifies rms short-term stability over the realistically short period of 1 second.

Line voltage and *temperature* specifications should be self-explanatory. The total inaccuracy due to the time base is the sum of the aging, short-term, line voltage, and temperature errors.

TRIGGER ERROR. Trigger error arises from noise on the gate-control signal. This noise causes the gate to open or close at incorrect times and results in an erroneous count.

Significant trigger error can occur only when an external signal controls the gate; that is, when period, ratio, and time interval measurements are being made.

Absolute trigger error is stated in time units and the fractional effect is given by:

$$\frac{\text{error in time}}{\text{total time gate is open}}$$

This equation explains why multiple period averaging is such a good method for reducing period measurement error (because it extends the gate time). As more periods are averaged, the effect of both trigger error and the 1 count ambiguity are reduced proportionally.

For the best HP counters, trigger error is <0.3% for one period if the signal is a sine wave with 40 dB signal-to-noise ratio, and if triggering occurs at zero volts on the signal, and if the signal amplitude is at the specified sensitivity limit of the counter (generally 100 mV rms). Trigger error is less than 0.3% if signal-to-noise ratio is improved, or if the input amplitude or rise time increased. For clean, fast rise time pulses, trigger error can be very low.

TOTAL MEASUREMENT ERROR. To calculate the error in any counter measurement, simply sum the individual errors discussed above.

In frequency measurements trigger error is zero, so the total error equation becomes:

$$\text{error}_{freq} = S_{LT} + S_{ST} + T_e + V + C,$$

where S_{LT} = long-term instability,
S_{ST} = short-term instability,
T_e = temperature variation error,
V = line voltage error,
and C = ±1 count error = 1/ total events counted.

For Period, Ratio, and Time Interval measurements trigger error must be included and the error equation is: $\text{error}_{period,\ ratio,\ ti} = S_{LT} + S_{ST} + T_e + V + C + Tr$, where Tr = trigger error in time/total gate time.

Figure 11 presents a good summary of this accuracy discussion. Notice how error decreases as frequency is measured over longer gate times and also how multiple period averaging is used to increase period accuracy. The minimum error in the figure, 2×10^{-7}, is equal to the total time base instability.

In the section titled "Period Measurements" (page 589) it was mentioned that low frequencies are determined more accurately by measuring period than frequency directly. This is proven in Figure 11. The intersection points of the frequency and period error curves indicate the frequency below which better accuracy is obtained by the Multiple Period Average technique.

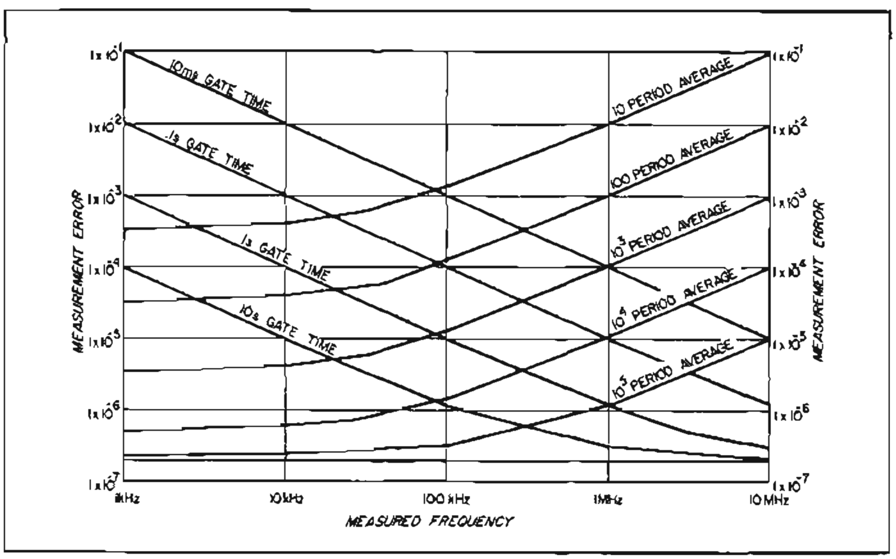


Figure 11. Comparison of error vs measured frequency for frequency measurements (plots labeled "gate time") and period measurements. Example is for HP 5325A Counter. Total time base error assumed to be 2×10^{-7}. Note that low frequencies are best measured by multiple period averaging.

Counter display

If a long gate time is used when a high frequency is counted, the entire answer will not be seen on the counter because the readout capacity will be exceeded. To determine what part of the answer will be visible, one must realize that counting starts with the rightmost digit in the readout, progresses to the next digit to the left after a count of 9 has been reached, and so forth until all digits read 9. Next, account for the effect of gate time: If .9 MHz is counted for 1 s, a total of 900,000 counts will be gated into the counting circuits and a 6-digit counter will display 900,000 but a 5-digit counter will display 00000. In the most versatile 8 digit counters having gate times from 1 μs to 10 s, the entire answer can always be made visible by suitable gate time selection. The convenient table below shows the maximum readout capacity (counting rate can be much greater) for low cost counters having fewer digits and a more limited gate time selection than more expensive units.

Gate	4-digit	5-digit	6-digit
.01 s	.9999 MHz	9.9999 MHz	99.9999 MHz
.1 s	99.99 kHz	.99999 MHz	9.99999 MHz
1 s	9.999 kHz	99.999 kHz	.999999 MHz
10 s	.9999 kHz	9.9999 kHz	99.9999 kHz

Lowest frequency measured

Counters can have ac or dc coupled inputs or both, the desired input coupling being selected by a front panel switch. As the name implies, dc coupled inputs will pass input waveforms regardless of rise time. Ac coupled inputs discriminate against slow rise times; the frequency range specified defines sine wave frequencies for which the snsitivity specification will be met (typically, 100 mV rms for frequencies down to several Hz). Most ac coupled counters will count sine waves below the minimum frequency specified but a higher input amplitude will be needed; they will count events of extremely low repetition rate if the input waveshape counted has a fast rise time. Where contact closures are being counted beware of spurious counts caused by contact bounce.

Summary of Electronic Counters

	Instrument	Range	Functions*	Readout Digits	BCD Out	Time base Aging Rate and (Gate Times)	Model	Price	Page
50 MHz AND HIGHER	Versatile, ultra-stable, fast warmup, accepts plug-ins	0 Hz to 135 MHz	F, P, MPA, R, MR, T†	8 in-line	Std.	$\pm 5 \times 10^{-10}$/day (1 μs–10 s)	5248M	$3300	598
		0 Hz to 50 MHZ					5245M	$3100	595
	Ultra-stable, 135 MHz, fast warmup, accepts plug-ins	10 Hz to 135 MHz‡	F†	8 in-line	Opt.	$\pm 5 \times 10^{-10}$/day (1 μs–10 s)	5247M	$3150	601
	Versatile, accurate, accepts plug-ins	0 Hz to 135 MHz	F, P, MPA, R, MR, T†	8 in-line	Std.	$\pm 3 \times 10^{-9}$/day (1 μs–10 s)	5248L	$2900	598
		0 Hz to 50 MHz					5245L	$2480	595
	Economical, accepts plug-ins	0 Hz to 50 MHz	F, R, MR TI	6 in-line (7 or 8 opt.)	Opt.	$\pm 2 \times 10^{-7}$/month, $\pm 3 \times 10^{-9}$/day opt. (1 μs–1 s)	5246L	$1800	602
	Economical, 50 MHz, does not accept plug-ins	0 Hz to 50 MHz	F, P, MPA R, MR, T	7 in-line	Std.	$\pm 2 \times 10^{-7}$/month (1 μs–10 s)	5244L	$1900	615
	12.4 GHz automatic digital frequency meter	0.3 to 12.4 GHz	F	8 in-line	Std.	$\pm 2 \times 10^{-7}$/month (0.1 s, 1.0 s)	5240A	$4750	611
		10 Hz to 12.5 MHz	F, R						
INTEGRATED CIRCUIT MODELS	Versatile, economical	3 Hz to 12.5 MHz‡	F, P, MPA R, MR, T	7 in-line leading zeros blanked	Std.	$\pm 2 \times 10^{-6}$/month (0.01s–10 s)	5216A	$985	622
	Economical, 10 MHz	5 Hz to 10 MHz‡	F, R, MR, T	5 in-line (6 opt.) zero blanking	Std.	$\pm 1 \times 10^{-6}$/month (0.01 s–10 s)	5221B	$775	620
							5321B	$775	
	Most economical, 10 MHz	5 Hz to 10 MHz‡	F, T	4 in-line (5 or 6 opt.) zero blanking	Not avail.	Power line (0.1 s, 1.0 s)	5221A	$425	620
							5321A	$425	
	Economical, reads out to 11.0000 or 9.99999 MHz	5 Hz to 11 MHz‡	F, T	6 in-line zero blanking	Not avail.	$\pm 1 \times 10^{-6}$/month (0.01 s–0.1 s)	H01-5321A	$705	620
	Universal counter	0 Hz to 12.5 MHz	F, P, MPA, R, MR, TI, T	7 in-line zero blanking	Std.	$\pm 3 \times 10^{-7}$/month (0.1 μs–10 s)	5325A	$1300	616
LOW TO MEDIUM FREQUENCY MODELS	Universal counters	0 Hz to MHz	F, P, MPA, R, MR, TI, T	6 in-line	Std.	$\pm 2 \times 10^{-7}$/month (10 μs–10 s)	5233L	$1675	618
		0 Hz to 300 kHz	F, P, MPA, R, MR, TI, T	5 in-line	Std.	$\pm 2 \times 10^{-6}$/week (10 μs–10 s)	5223L	$1325	
	Versatility at moderate cost	2 Hz to 1.2 MHz	F, P, MPA R, MR, T	6 in-line	Std.	$\pm 2 \times 10^{-7}$/month (0.01 s–10 s)	5532A	$1450	623
				6 columnar			5232A	$1350	
		2 Hz to 300 kHz	F, P, MPA R, MR, T	5 in-line	Std.	$\pm 2 \times 10^{-6}$/week (0.01 s–10 s)	5512A	$1050	623
				5 columnar			5212A	$950	
	Low cost, low frequency	2 Hz to 300 kHz	F, R, T	4 in-line	Std.	Power line (0.01 s–10 s)	H22-5211B	$850	623
							5211B	$750	
				4 columnar	Std.	Power line (0.1 s, 1.0 s)	5211A	$650	623
SPECIAL PURPOSE MODELS	Preset counter/controller	0 Hz to 2 MHz	T, C	4 in-line (4 or 6 opt.)	Std.	None	5331A/B	$950–1050	625
			F, R, T, C			$\pm 0.5 \times 10^{-6}$/month	5332A/B	$1100–1200	
	Reversible counter, versatile, high speed	0 Hz to 2 MHz	Add, subtract, 1 or 2 inputs	6 in-line (7 or 8 opt.)	Std.	External (Internal optional)	5280A (5285A)	$1600 ($500)	630
	Preset counter, normalizes count, versatile	2 Hz to 300 kHz	Rate, R, C, time for N events	5 in-line	Std.	$\pm 2 \times 10^{-6}$/week	5214L	$1300	628
	Time interval counter	10 ns to 0.1 s	TI	7 columnar	Std.	External	5275A	$2450	636
	Preset scaler, timer	10^6 counts, 10^5 min or s	Preset T, time	6 in-line (7 opt.)	Std.	Total error $< \pm 5 \times 10^{-5}$	5590A	$1675	79

*F—Frequency, P—Period, MPA—Multiple Period Average, R—Ratio, TI—Time Interval, C—Control Signal, T—Totalize.
†Accepts plug-ins for wide variety of other measurements. **See page M54-5245L for version meeting Mil Std for RFI and drip proof.
‡Specified for full sensitivity and sine wave input; counts repetition rate of pulses down to 0 Hz.

ELECTRONIC COUNTERS

50 MHz and 135 MHz plug-in counters

5245 Series

Hewlett-Packard's most accurate and versatile counters—and the plug-ins that go with them—are described on the next 15 pages. All 8 counter models have been developed from HP's 5245L—the industry standard for quality since its introduction in 1961.

For your convenience in comparing these instruments, a summary of the various counters is given below.

Comparison and Summary of 50 and 135 MHz Counters (Models 5245-46-47-48)

Model	5245L, M54–5245L (pp. 595, 600)	5248L (p. 598)	5248M (p.598)	5245M (p.595)	5247M (p. 601)	5246L (p. 602)	5244L (p. 615)
Basic Measurement range	0 to 50 MHz	0 to 135 MHz		0 to 50 MHz	10 Hz–135 MHz	0–50 MHz	0–50 MHz
Digits in readout	8				8	6 (7 or 8 optional)	7 (8 optional)
Measurement Functions F=freq., R=ratio, P=period, S=input scaling, M=multiple	F, P, R, MP, MR, S				F	F, R, MR	F, P, R, MP, MR, S
Time base Aging rate	$<3 \times 10^{-9}$/24 hours	$<5 \times 10^{-10}$/24 hours			$<5 \times 10^{-10}$/24 hrs.	$<2 \times 10^{-7}$/mo.[1]	$<2 \times 10^{-7}$/mo.[1]
Time base Warm-up	Normal	Rapid			Rapid	Room Temp. xtal[1]	Room Temp. xtal[1]
Input impedance	1 MΩ/25 pF				1 MΩ/25 pF	1 MΩ/25 pF	10 K/100 K/1 MΩ; 40/15/15 pF
Gate times	1 μs–10 s				1 μs–10s	1 μs–1 s	1 μs–10 s
Time base outputs (in decade steps)	0.1 Hz to 10 MHz	0.1 Hz to 10 MHz, Fixed 5 MHz[2]			Fixed 5 MHz[2]	Fixed 1 MHz (10 MHz special order)	0.1 Hz–1 MHz
BCD output	Yes				Optional	Optional	Yes
Remote programming	Optional				Not Available	Not Available	Not Available
Input coupling	ac or dc				ac only	ac or dc	ac or dc
Input attenuator	Yes				Not Required	No	Yes
Trigger level adjustment	Yes				Not Required	No	No
Freq. ratio Measurement (f_1/f_2); range, sensitivity, input resistance — f_1	0–50 MHz; 0.1 V, 1 MΩ	0 to 135 MHz; 0.1 V, 1 MΩ		0–50 MHz; 0.1 V, 1 MΩ	None	0–50 MHz; 0.1 V, 1 MΩ	0–50 MHz; 0.1 V, 100 KΩ/volt
Freq. ratio Measurement (f_1/f_2); range, sensitivity, input resistance — f_2	0 to 1 MHz; 0.1 V, 1 MΩ				None	100 Hz–1 MHz; 1 V, 500 Ω	0–1 MHz; 0.1 V, 100 KΩ
Compatible 5245 series plug-ins	All (on pages 603 to 609)				Transfer Osc., Freq. Converters, Prescalers, Video Amp.	All[3] (on pages 603 to 609)	None
Price	5245L: \$2480.00 M54–5245L \$2880.00	5248L: \$2900.00	5248M: \$3300.00	5245M: \$3100.00	\$3150	\$1800	\$1900

[1] Oven enclosed crystal ($<3 \times 10^{-9}$/day aging rate) optional.
[2] 5 MHz output has high spectral purity; 5×10^{-11} (rms for 1 s averaging time) short term stability; is available whenever counter is connected to ac line.
[3] Six digits restricts time interval range to 10^6 s (7, 8-digits optional). In 5246L, Preset Unit 5264A will only multiply and divide frequencies by N and preset count.

ELECTRONIC COUNTERS
Versatile 50 MHz plug-in counters
Models 5245L, 5245M

Advantages:

- Accept 13 plug-ins for wide variety of measurements
- High input impedance on all ranges
- Ac or dc coupling
- Two-mode trigger level control
- Readout storage; BCD output
- Ultra-stable time base in 5245M

These solid-state counters, which are identical except for their internal time bases, measure frequency, period, multiple period average, ratio, and multiple ratio. They can also be used to scale (divide) a frequency by decades. Plug-ins, which go directly into the front panel, extend frequency measurements to 18 GHz, permit time interval measurements, and will perform a variety of other functions. The basic counters (without plug-ins) offer a counting rate of 50 MHz with 8-digit resolution.

Ultra-stable time base

Several years ago the time base oscillator in the 5245L, with its $<3 \times 10^{-9}$/day aging rate, represented the state of the art in counter time bases, and it still serves as a secondary frequency standard in many applications today. But recently HP developed a compact, ultra-stable, rapid warm-up time base for use where even better performance is required. This new time base is installed in Model 5245M.

Compared to standard electronic counter time bases available previously, the 5245M's ultra-stable 5 MHz oscillator has a significantly better short-term stability ($<5 \times 10^{-11}$ rms for 1 s averaging) and long-term stability ($<5 \times 10^{-10}$/day aging rate), and significantly less frequency change due to variations in line voltage, external load and temperature. The time base has rapid warm-up, excellent spectral purity, and the same usefulness as costly secondary frequency standards. These advancements mean greater precision, lower investment for counter calibration equipment, and greater versatility because of excellent performance and convenience when employed as a secondary frequency standard. The very low aging rate of the ultra-stable oscillator extends the time between calibrations, thereby keeping the counter in use longer and reducing the time and money spent on calibration.

For maximum accuracy, the 5245M's time base is kept energized as long as the counter power cord is plugged into an energized power receptacle, whether the front panel switch is ON or OFF. The counter has a separate, internal, regulated power supply to permit operation of the oscillator when the remainder of the counter is turned off. The 5 MHz time base output is usable while the counter is being used for measurements.

Display storage

Both models have readout storage, which provides a continuous display of the most recent measurement. This display is held even while the instrument is gated for a new count. If the new count differs from the stored count, the display will shift to the new reading directly. Storage can be disabled.

Sample rate

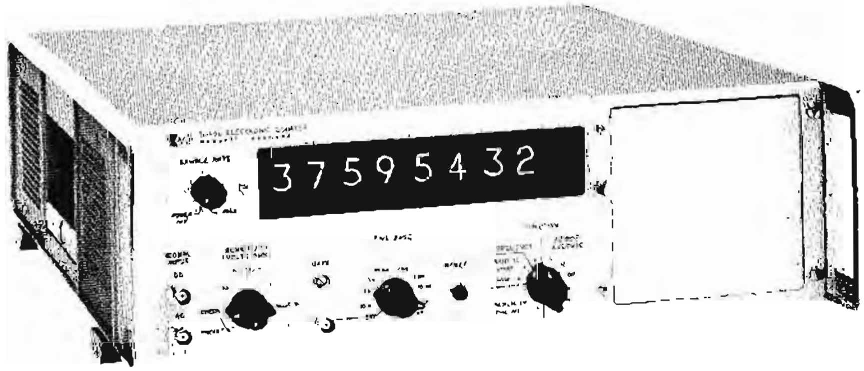
A sample rate control is provided which determines the length of time following the gate closure during which the gate may not be reopened. When the Function Selector is set to Frequency, the Sample Rate adjusts the time between gates from less than 0.2 sec. to at least 5 seconds and is independent of gate time. The control may also be set to hold a display indefinitely.

Input amplifier

A dual FET input amplifier provides 1 meg/25 pF input impedance, independent of attenuator setting and frequency up to 50 MHz. Therefore, one needs not be concerned about input impedance changes affecting the signal source when the input attenuator switch is rotated. Also, low VSWR is more easily attainable. High impedance probes (e.g., HP 10000 Series) may be directly connected to the input and used in the same manner as with high frequency oscilloscopes.

Basic counter operation

The 5245L/M (without plug-ins) measure frequencies and repetition rates of periodic or random pulses from 0 to



5245L

Versatile 50 MHz plug-in counters
Models 5245L, 5245M

50 MHz. Gate times from 1 μs to 10 seconds are selected with a front panel switch. Multiple period and multiple averaging ratio to 10^5 periods is obtained without need for a separate plug-in. This capability makes possible accurate frequency determination at low and intermediate frequencies. The increase in accuracy over that possible in single period or ratio is a direct result of division of the trigger error by the averaging factor, as well as the result of increased resolution. Ratios of frequencies that are almost identical can be accurately resolved.

The basic counter will also scale (divide) an input frequency as high as 50 MHz in decade steps by factors up to 10^9. For example a 14 MHz signal can be divided to 0.014 Hz. A rear panel BNC connector and switch provide a choice of nine output frequencies.

Input signal triggering

Models 5245L and M have a front panel trigger level control with both preset and adjustable modes. In PRESET, trigger level is optimum for signals which are symmetrical about ground; it is useful for most applications, and is automatically selected when plug-ins are used (without moving the TRIGGER control to PRESET). In ADJUSTABLE, the control can be rotated for counting positive or negative pulses, or for unusual signal conditions.

Electrical readout and remote control

Four-line BCD code output is provided and is suitable for systems use or for output devices, such as Model 562A or 5050B Digital Recorder, and Model 580A or 581A Digital to Analog Converter. Other codes and remote control of front panel switches are optional.

Specifications, 5245L, 5245M

Frequency measurements

Range: dc coupled, 0 to 50 MHz; ac coupled, 25 Hz to 50 MHz (typical response of input amplifier <±1 dB over entire range).

Gate time: 1 μs to 10 seconds in decade steps.

Accuracy: ±1 count ± time base accuracy.

Readout: kHz or MHz with positioned decimal point; units annunciator in line with digital display.

Self-check: counts 10 MHz for the gate time chosen.

Period average measurements

Range: Single Period .... 0 to 1 MHz.
Multiple Period .... 0 to 300 kHz.

Periods averaged: 1 period to 10^5 periods in decade steps.

Frequency counted:

1 and 10 Period .... 1 Hz to 10 MHz in decade steps.
100 Period .... 10 Hz to 10 MHz.
1,000 Period .... 100 Hz to 10 MHz.
10,000 Period .... 1 kHz to 10 MHz.
100,000 Period .... 10 kHz to 10 MHz.

Accuracy: ±1 count ± time base accuracy ± trigger error.*

Readout: s, ms, or μs, with positioned decimal point; units annunciator in line with digital display.

Self-check: checks operation from 1 period to 10^5 periods.

Ratio measurements

Displays: (f_1/f_2) times period multiplier; multiplier: $1\text{-}10^5$.

Range: f_1:0 to 50 MHz. f_2:0 to 1 MHz in single ratio, 0 to 300 kHz in multiple ratio; ratios averaged 1 to 10^5 in decade steps.

Sensitivity: 0.1 V rms, each input (max).

Accuracy: ±1 count of f_1 ± trigger error* of f_2. f_1 is applied to the decimal counters (enters "Ext." jack on front panel); f_2 is applied to decade dividers (enters Signal Input jack).

Readout: dimensionless; decimal point positioned for number of periods averaged.

Self-check: Period Average Self-check applies.

Scaling

Frequency range: 0 to 50 MHz.

Factor: by decades up to 10^9, switch selected on rear panel. For ÷2, ÷4, ÷8, add HP 5252A Prescaler.

Input: front panel. Signal Input jack.

Output: in place of time base output frequencies.

General

Display: 8 digits in-line with rectangular Nixie® tubes; 99,999,999 maximum display; total width of display including units annunciator and auto-positioned decimal point indication does not exceed 7 inches.

Display storage: holds reading between samples; rear panel switch overrides storage.

Sample rate: time following a gate closing during which the gate may not be reopened is variable from less than 0.2 s to 5 s in Frequency mode, independent of gate time; display can be held indefinitely.

Signal input

Maximum sensitivity: 100 mV rms.

Coupling: ac or dc, separate BNC connectors. AC coupling has 600 V dc, 0.022 μF capacitor (−3 dB at approx. 7 Hz).

Impedance: 1 MΩ in parallel with approx. 25 pF, all ranges.

Attenuation: step attenuator (SENSITIVITY switch) provides nominal sensitivities of 0.1, 1, and 10 V rms.

Trigger level adjustment (min.): front panel control has ±0.3 V trigger level range on 0.1 V position, ±3 V range on 1 V position, ±30 V range on 10 V position. A PRESET position automatically centers trigger level at 0 V.

Overload protection: diodes protect input circuit for up to 120 V rms (<1 kHz) on 0.1 V range, 240 V rms on 1 V range, 500 V rms on 10 V range. Input resistance for overload conditions (input amplitude > ten times SENSITIVITY) is 100 kΩ on 0.1 V range, and is approximately 1 MΩ on other ranges.

Pulse measurements: front panel TRIGGER LEVEL adjustment allows counting positive or negative pulses.

External input (selected by front panel Time Base switch):

Maximum sensitivity: 100 mV rms.

Impedance: 1 MΩ, approx. 20 pF, dc coupled.

Overload: diodes protect input circuit up to 120 V rms.

Digital output: 4-line BCD 4-2-2-1, "1" state positive; includes decimal point and measurement unit. 8-4-2-1 available as Option 02 ("1" state positive) and Option 03 ("1" state negative); decimal point remains 4-2-2-1 (see J35- and J36- options below).

"0" STATE LEVEL: −8 V. "1" STATE LEVEL: +18 V.

Impedance: 100 kΩ, each line.

BCD reference levels: approximately +17 V, 350Ω source; approximately −6.5 V, 1000Ω source.

Print command: +13 V to 0 V step; dc-coupled.

Hold-off requirement: +15 V min., +25 V max. from chassis ground (1000Ω source).

Cable connector: Amphenol 50-pin 57-30500-375, HP Part No. 1251-0086, 1 required.

Operating temperature range: −20°C to +65°C.

Power supply: 115 or 230 volts ±10%, 50 to 60 Hz; 95 watts. (5245M only: 150 W maximum during approximately first 2 minutes after power line is energized.) 50 to 1000 Hz operation, price on request.

Weight: net, 32 lbs (14,4 kg) with blank plug-in panel. shipping, 40 lbs (18,2 kg).

Connectors: BNC (except remote program and BCD out).

Accessories furnished: *10503A Cable, 4 ft. (120 cm)* long, male BNC connectors. Detachable power cord, 7½ ft. (200 cm) long, NEMA plug. Circuit Board Extender, rack mount conversion parts.

Dimensions: 5¼" high, 16¾" wide, 16⅜" deep (133 x 425 x 416 mm).

Prices: Model 5245L, $2,480.00.
Model 5245M, $3,100.00.

Optional and special features

Option 02. 4-line BCD 8-4-2-1, "1" state positive (for digits only) in lieu of 4-2-2-1 (identical in other respects to above specifications), add $10.00.

Option 03. 4-line BCD 8-4-2-1, "1" state negative (for digits only) in lieu of 4-2-2-1 (identical in other respects to above specifications), add $10.00.

J35-5245L/M: similar to Option 02, except has 8-4-2-1 output, "1" state positive for measurement units and decimal point as well as digits. (Note: M47-562A/AR and 5050A Option 01 Printers are especially suitable for J35-5245L/M.)

Prices: J35-5245L, $2,510.00; J35-5245M, $3,130.00.

J36-5245L/M: similar to Option 03, except has 8-4-2-1 output, "1" state positive for measurement units and decimal point as well as digits. (Note: P64-562A/AR and 5050A Option 02 Printers are especially suitable for J36-5245L/M.)
Prices: J36-5245L, $2,480.00; J36-5245M, $3,130.00.

Electromagnetic compatibility: Models H60-5245L/M meet the requirements of military specification MIL-I-6181D. (Plug-in model numbers must also be prefixed H60.)
Prices: available on request.

Remote operation: all functions which may be controlled from the front panel controls (in normal use) may be programmed from a remote location except for the "Sample Rate" (as defined above) and the sensitivity and trigger control setting. Mating half of the control connectors (2 required) is Amphenol 36 pin 57-30360.
Prices: H65-5245L, $2,595.00.
H65-5245M, $3,215.00.

M07-5245L/M: have "GHz" added to readout and are controlled from 5260A Option 02 Automatic Frequency Divider. Readout is inhibited when 5260A "searches." All remote capabilities of H65-5245L/M are included (see above).
Prices: M07-5245L, $2,615.00; M07-5245M, $3,235.00.

Time Base, Model 5245L

Crystal frequency (internal): 1 MHz.

Stability

Aging rate: <3 parts in 10^9 per 24 hours.†

Short term: <2 parts in 10^{10} rms with measurement averaging time of one second under constant environmental and line voltage conditions.

Temperature: <2 parts in 10^{10} per °C from −20°C to +55°C.

Line voltage: <±5 parts in 10^{10} for 10% change in line voltage from 115 V or 230 V rms.

Adjustment: fine frequency adjustment (range approximately 4 x 10^{-8}) and medium frequency adjustment (range approximately 1 x 10^{-6}) are available from the front panel through the plug-in hole. Coarse frequency adjustment (range approximately 1 x 10^{-5}) is available at the rear of the instrument.

Output frequencies

1. **At rear panel:** 0.1 Hz to 10 MHz in decade steps, selected by rear panel switch. All frequencies available in manual function without interruption at reset except 100 Hz, 10 Hz, 1 Hz, and 0.1 Hz which are interrupted by manual reset; 10 kHz to 10 MHz available continuously in all functions; 1 kHz available continuously for all functions except 10^8 period average; stability same as internal time base. Output is: 5 volts p-p rectangular wave with 1000 Ω source impedance at 1 MHz and lower; 1 V rms sine wave with 1000 Ω source impedance only at 10 MHz.
2. **At front panel:** 0.1 Hz to 1 MHz in decade steps; available at "Ext." jack, selected by Time Base switch; availability same as in paragraph 1 (above); stability same as internal time base; 1 V peak-to-peak.

External standard frequency: 1 MHz, 1 V rms into 1000 Ω. Can be substituted for internal time base via rear panel EXT. STD. FREQ. connector.

Time Base, Model 5245M

Crystal frequency (internal): 5 MHz.

Stability

Aging rate: <5 parts in 10^{10} per 24 hours after warm-up.**

Short term (rms fractional frequency deviation): better than 5 parts in 10^{11} for 1 second averaging time.

Temperature: <5 parts in 10^{11}/°C from 0°C to 50°C (<2.5 parts in 10^9 within the entire span of 0°C to 50°C).

Line voltage: <±1 part in 10^{10} for 10% change in line voltage from 115 V or 230 V rms.

Load stability: typically <±2 parts in 10^{11} for any of the following loads: open, short, 50 Ω resistive, 50 Ω inductive, 50 Ω capacitive.

Warm-up: for "off" periods up to approximately 24 hours: 1 hour typical to reach 5 parts in 10^9 of the frequency that existed when turned off. The 5 MHz crystal oscillator operates whenever the power cord is connected.

Adjustment: fine frequency adjustment, range approx. 5 x 10^{-8}, 16-turn control accessible through plug-in accessory compartment in front panel. Coarse frequency adjustment, range approx. 1 x 10^{-6}, 20-turn control at rear panel.

Output frequencies

1. **At rear panel:** 5 MHz sine wave, 1 V rms into 50 Ω. Available at all times whenever power line cord is energized, whether front panel power switch is ON or OFF. Stability is as defined above. Signal-to-Noise Ratio typically >87 dB below rated output. Harmonic Distortion typically >40 dB below rated output. Non-harmonic components typically >80 dB below rated output.
2. **At rear panel:** 0.1 Hz to 10 MHz in decade steps; switch selected on rear panel; all frequencies available in manual function without interruption at reset except 100 Hz, 10 Hz, 1 Hz, and 0.1 Hz which are interrupted by manual reset; 10 kHz to 10 MHz available continuously in all functions; 1 kHz available continuously for all functions except 10^8 period average; stability same as internal time base; 5 V p-p rectangular wave with 1000 Ω source impedance at 1 MHz and lower; 1 V rms sine wave with 1000 Ω source impedance only at 10 MHz.
3. **At front panel:** 0.1 Hz to 1 MHz in decade steps; available at "Ext." jack, selected by Time Base switch; availability same as in paragraph 2 (above); stability same as internal time base; 1 V peak-to-peak.

External standard frequency: 5 or 10 MHz, 1 V rms, into 1000 Ω. Can be substituted for internal time base via rear panel EXT. STD. FREQ. connector.

*Trigger error is <(±0.3% of one period ÷ periods averaged) for signals with 40 dB or better signal-to-noise ratio, and 100 mV rms amplitude; error decreases as signal-to-noise ratio and input level increase.

†72 hours of continuous operation.

**Up to 72 hours continuous operation may be required to reach this aging rate after transportation or lengthy "off" periods.

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ELECTRONIC COUNTERS

New 135 MHz plug-in counters

Models 5248L, 5248M

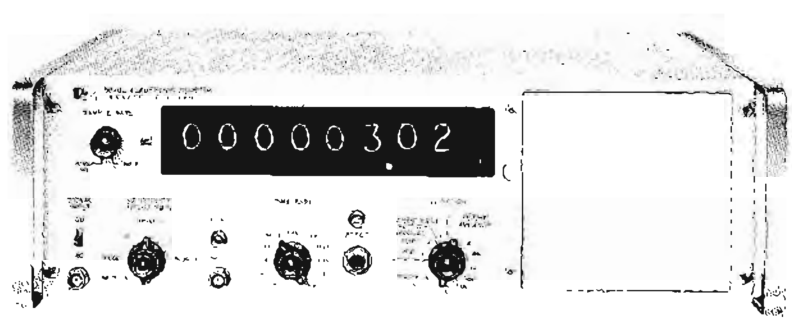
Advantages:

- 0-135 MHz basic ranges
- Ultra-stable time base in 5248M
- Accept all plug-ins for 5245 Series

These new counters have the accuracy, plug-in accessory versatility and field-proven circuitry of the 5245L and M, and also introduce several additional major features. The most important additions are extension of the basic frequency range to 135 MHz; period measurement resolution of 10 ns; and, with the new HP 5267A Time Interval plug-in, time interval resolution of 10 ns.

Except for time base characteristics, the 5248L and M are identical. The 5248M, like the 5245M, has a rapid warm-up, ultra-stable (<5 parts in 10^{10} per day aging rate) time base having a high degree of spectral purity. Its performance rivals that of many high-quality quartz oscillators now being used as secondary frequency standards. The 5248L has the same excellent time base used in the 5245L with an aging rate of <3 parts in 10^9 per day.

Another notable feature of the 5248L/M counters is their single input connector for both ac and dc coupling. A front panel switch selects the desired coupling. Also, scaling can be performed on input signals as high as 135 MHz by decades up to 10^9. Minimum sample time is ≈ 0.05 s.



5248L, 5248M

Specifications

Frequency measurement

Range: dc coupled, 0 to 135 MHz
ac coupled, 25 Hz to 135 MHz (typical response of input amplifier ±1 dB over entire range.)

Gate time: 1 μs to 10 seconds in decade steps.

Accuracy: ±1 count ± time base accuracy.

Readout: kHz or MHz with positioned decimal point; units annunciator in line with digital display.

Self-check: counts 100 MHz for the gate time chosen.

Period average measurements

Range: single period .... 0 to 1 MHz
multiple period .... 0 to 300 kHz

Periods averaged: 1 period to 10^5 periods in decade steps.

Frequency counted:

1 and 10 Period .... 1 Hz to 100 MHz in decade steps
100 Period .... 10 Hz to 100 MHz
1,000 Period .... 100 Hz to 100 MHz
10,000 Period .... 1 kHz to 100 MHz
100,000 Period .... 10 kHz to 100 MHz

Accuracy: ±1 count ± time base accuracy ± trigger error.*

Readout: s, ms, μs, with positioned decimal point; units annunciator in line with digital display.

Self-check: checks operation from 1 period to 10^5 periods.

Ratio measurements

Displays: (f_1/f_2) times period multiplier; multiplier: 1-10^5.

Range: f_1: 0 to 135 MHz. f_2: 0 to 1 MHz in single ratio, 0 to 300 kHz in multiple ratio; ratios averaged 1 to 10^6 in decade steps.

Sensitivity: 0.1 V rms, each input (max).

Accuracy: ±1 count of f_1 ± trigger error* of f_2. f_2 is applied to the decade dividers (enters ratio jack on front panel), f_1 is frequency applied to decimal counters (enters Signal Input jack).

Readout: dimensionless; decimal point positioned for number of periods averaged.

Self-check: period average self-check applies.

Scaling

Frequency range: 0 to 135 MHz; 50 MHz max., for ÷ 10 step.

Factor: by decades up to 10^9, switch selected on rear panel. For ÷2, ÷4, ÷8, add HP 5252A Prescaler.

Input: front panel, Signal Input.

Output: in place of time base output frequencies.

General

Display: 8 digits in-line with rectangular Nixie® tubes; 99,999,999 max. display; total width of display including units annunciator and auto-positioned decimal point indication does not exceed 7 inches.

Display storage: holds reading between samples; rear panel switch overrides storage.

Sample rate: time following a gate closing during which the gate may not be reopened is variable from less than 0.05 s to 2 s in Frequency mode, independent of gate time; display can be held indefinitely.

Signal input

Maximum sensitivity: 100 mV rms.

Coupling: ac or dc, selected by front panel switch. Ac coupling has 600 V dc, 0.022 μF capacitor (−3 dB at approx. 7 Hz).

Impedance: 1 meg. parallel with approx. 25 pF, all ranges.

Attenuation: step attenuator (SENSITIVITY switch) provides nominal sensitivities of 0.1, 1, and 10 V rms.

Trigger level adjustment (min.): front panel control has ±0.3 V trigger level range on 0.1 V position, ±3 V range on 1 V position, ±30 V range on 10 V position. A PRESET position automatically centers trigger level at 0 V.

Overload protection: diodes protect input circuit for up to 120 V rms (<1 kHz) on 0.1 V range, 250 V rms on 1 V range, 500 V rms on 10 V range. Input resistance for overload conditions (input amplitude > ten times SENSITIVITY) is 100 kΩ on 0.1 V range, and is approximately 1 MΩ on other ranges.

Pulse measurements: front panel TRIGGER LEVEL adjustment allows counting positive or negative pulses.

Ratio input (front panel):

Maximum sensitivity: 100 mV rms.

Impedance: 1 MΩ, approx. 20 pF, dc coupled.

Overload: diodes protect input ckt. up to 120 V rms.

Digital output: 4-line BCD 8-4-2-1, "1" state positive; includes decimal point and measurement unit. "0" STATE LEVEL: −8 V. "1" STATE LEVEL: +18 V. For "1" state negative, order Option 03.

Impedance: 100 kΩ, each line.

BCD reference levels: approximately +17 V, 350 Ω source; approximately −6.5 V, 1000 Ω source.

Print command: +13 V to 0 V step, dc coupled.

Hold-off requirement: +15 V min., +25 V max. from chassis ground (1000 Ω source).

Cable connector: amphenol 50-pin 57-30500-375, HP part no. 1251-0086, 1 required.

Operating temperature range: −20°C to +65°C.

Power supply: 115 or 230 volts ±10%, 50 to 60 Hz; 125 watts ±10%. (50 to 1000 Hz operation, price on request.)

Weight: net, 31 lbs (14 kg) with blank plug-in panel. shipping, 37 lbs (17 kg).

Connectors: BNC (except remote program and BCD out).

Accessories furnished: 10503A cable, 4 ft. (120 cm) long, male BNC connectors. Detachable power cord, 7½ ft. (200 cm) long, NEMA plug. Circuit board extender, rack mount conversion parts.

Dimensions: $5\frac{7}{32}$" high x 16¾" wide x 16⅜" deep (133 x 425 x 416 mm).

Prices: Model 5248L, $2900.00; Model 5248M, $3300.00

Optional and special features (at added cost):

Option 03. 4-line BCD 8-4-2-1, "1" state negative in lieu of "1" state positive (identical in other respects to above output data).

Electromagnetic compatibility: H60-5248L/M meet military specification MIL-I-6181D. Price on request.

Remote operation: H65-5248L/M, same as "Remote Operation" in 5245L/M specs. Price on request.

M07-5248L/M: same as M07-5245L/M. Price on request.

Time Base, Model 5248L

Crystal frequency (internal): 1 MHz.

Stability

Aging rate: <3 parts in 10^9 per 24 hours.†

Short term: <2 parts in 10^{10} rms with measurement averaging time of one second under constant environment and line voltage conditions.

Temperature: <2 parts in 10^{10} per °C from −20° to −55°C.

Line voltage: <±5 parts in 10^{10} for 10% change in line voltage from 115 V or 230 V rms.

Adjustment: fine frequency adjustment (range approximately 4 x 10^{-8}) and medium frequency adjustment (range approximately 1 x 10^{-6}) are available from the front panel through the plug-in hole. Coarse frequency adjustment (range approximately 1 x 10^{-5}) is available at the rear of the instrument.

Output frequencies

At rear panel: 0.1 Hz to 10 MHz in decade steps, switch selected on rear panel. All frequencies available in manual function without interruption at reset except 100 Hz; 10 Hz, 1 Hz, and 0.1 Hz which are interrupted by manual reset; 10 kHz to 10 MHz available continuously in all functions; 1 kHz available continuously for all functions except 10^5 period average; stability same as internal time base. Output is 5 volts p-p rectangular wave with 1000 Ω source impedance at 1 MHz and lower; 1 V rms sine wave with 1000 Ω source impedance only at 10 MHz.

Separate BNC gives 100 MHz sine wave, 100 Ω source.

External standard frequency: 1 MHz, 1 V rms into 1000 Ω. Can be substituted for internal time base via rear panel EXT. STD. FREQ. connector.

Time Base, Model 5248M

Crystal frequency (internal): 5 MHz.

Stability

Aging rate: <5 parts in 10^{10} per 24 hours after warm-up.**

Short term (rms fractional frequency deviation: better than 5 parts in 10^{11} for 1 second averaging time.

Temperature: <5 parts in 10^{11}/°C from 0°C to 50°C (<2.5 parts in 10^9 within the entire span of 0°C to 50°C).

Line voltage: <±1 part in 10^{10} for 10% change in line voltage from 115 V or 230 V rms.

Load stability: typically <±2 parts in 10^{11} for any of the following loads: open, short, 50 Ω resistive, 50 Ω inductive, 50 Ω capacitive.

Warm-up: for "off" periods up to approximately 24 hours: 1 hour typical to reach 5 parts in 10^9 of the frequency that existed when turned off. The 5 MHz crystal oscillator operates whenever the power cord is connected.

Adjustment: fine frequency adjustment, range approx. 5 x 10^{-7}, 16-turn control accessible through plug-in accessory compartment in front panel. Coarse frequency adjustment, range approx. 1 x 10^{-6}, 20-turn control at rear panel.

Output frequencies

1. **At rear panel:** 5 MHz sine wave, 1 V rms into 50 Ω. Available at all times whenever power line cord is energized, whether front panel power switch is ON or OFF. Stability is as defined above. Signal-to-Noise Ratio typically >87 dB below rated output. Harmonic Distortion typically >40 dB below rated output. Non-harmonic Components typically >80 dB below rated output.
2. **At rear panel:** 0.1 Hz to 10 MHz in decade steps; switch selected on rear panel; all frequencies available in manual function without interruption at reset except 100 Hz, 10 Hz, 1 Hz, and 0.1 Hz which are interrupted by manual reset; 10 kHz to 10 MHz available continuously in all functions; 1 kHz available continuously for all functions except 10^5 period average; stability same as internal time base; 5 V p-p rectangular wave with 1000 Ω source impedance at 1 MHz and lower; 1 V rms sine wave with 1000 Ω source impedance only at 10 MHz.

   Separate BNC gives 100 MHz sine wave, 100 Ω source.

External standard frequency: 5 or 10 MHz, 1 V rms, into 1000Ω. Can be substituted for internal time base via rear panel EXT. STD. FREQ. connector.

*Trigger error is <(±0.3% of one period ÷ periods averaged) for signals with 40 dB or better signal-to-noise ratio, and 100 mV rms amplitude; error decreases as signal-to-noise ratio and input level increase.

® Burroughs Corporation.

**Up to 72 hours continuous operation may be required to reach this aging rate after transportation or lengthy "off" periods.

†After 72 hours of continuous operation.

ELECTRONIC COUNTER

High performance, plug-in, dc to 50 MHz operation

Model M54-5245L

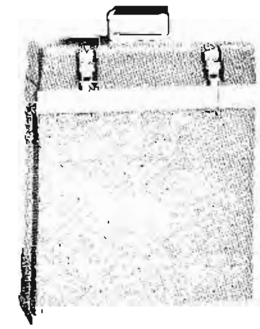
Advantages:

- New enclosure meets MIL specification for RFI and drip proofing
- Operationally identical to 5245L counter
- Meets MIL specification for temperature, humidity, vibration, shock, altitude
- Easily carried and handled

The functional performance of the M54-5245L, and most of its circuits, are identical to that of the 5245L. It is a dc to 50 MHz plug-in counter which can perform a wide range of functions with great accuracy. Refer to page 596 for the full operating specifications of the M54-5245L.

The frequency range of the M54-5245L can be extended to 18 GHz by the use of plug-in units. It accepts all of the plug-in units for the 5245L (see pages 603-609). The plug-in units must have the H60 modification in order to meet the MIL RFI specification (MIL-I-6181D).

The environmental resistance of the rugged 5245L has been increased by encasing it in a tough, fiberglass enclosure. The main improvements are drip proofing and improved RFI specifications. The fiberglass enclosure includes a detachable front panel cover with a conveniently located carrying handle (as shown in the photograph).



Fiberglass enclosure for M54-5245L Counter.

Environmental specifications

RFI: (MIL-I-6181D) meets all four sections of the specification—limits on radiated and conducted interference generation and on susceptibility to radiated and conducted interference.

Enclosure: meets MIL-STD-108D section on drip proof enclosures.

Operating temperature: operating range of −20°C to +55°C meets and exceeds MIL-E-4158C for indoor equipment and MIL-E-16400, Class 4.

Non-operating temperature: meets all classes of MIL-E-16400F. −62°C to +85°C.

Humidity: meets MIL-E-16400F for Class 3 and 4 equipment. 95% RH over operating temperature range.

Vibration: when operating in cabinet configuration, it meets MIL-T-21200 for Class 2 and 3 equipment.
5-15 Hz at 0.06 inch double amplitude
15-25 Hz at 0.04 inch double amplitude
25-55 Hz at 0.02 inch double amplitude

Shock: meets MIL-T-21200F for all classes of equipment. Three impact shocks of 30 G's applied to each of the six sides. Each shock has a duration of 11 ms ±1 ms and a half sine wave shape.

Operating altitude: operation at 15,000 ft. meets and exceeds MIL-E-4158C up to at least +25°C (consult HP regarding higher temperatures).

Non-operating altitude: exposure to 50,000 ft. altitude without ill effect; meets and exceeds MIL-E-4158C. If additional environmental data are needed, please consult HP.

Operating specifications

(Except for those listed below, Operating Specifications are same as for the 5245L given on page 596.)

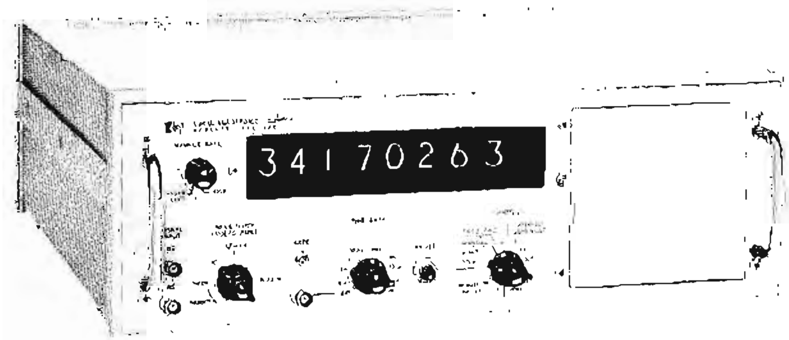
Power supply: 115 or 230 volts ±10%, 50 to 400 Hz; 95 watts.

Weight: net, 37 lbs (15,5 kg).

Accessories furnished: fiberglass front panel cover. Detachable power cord, 7½ feet (200 cm) long, NEMA plug.

Dimensions: 5⅞" high, 16-15/16" wide, 16½" deep (14,9 x 43 x 42 cm) without front panel cover; 21⅛" (53,8 cm) deep with front panel cover.

Price: Model M54-5245L, $2,880.00.



M54-5245L

ELECTRONIC COUNTERS
Ultra-Stable Counting to 135 MHz
Model 5247M

Advantages:

- 10 Hz to 135 MHz basic range
- Ultra-stable, fast warm-up time base
- Plug-ins for measurements to 18 GHz
- Wide input voltage range without level adjustment
- 8 digit readout

The 5247M performs frequency measurements over a very wide frequency range with great accuracy and stability. It's rapid warm-up, ultra-stable crystal time base is the same as that used in the 5248M Counter, ensuring high accuracy soon after the counter is energized. The 5 MHz time base output frequency stability and spectral purity qualify it as a highly precise secondary frequency standard.

The same plug-in heterodyne converters, transfer oscillators and prescalers used in the 5245L/M and 5248L/M and 5246L Counters can be used in the 5247M. Thereby, the frequency range can be extended to 18 GHz. Other plug-ins for 5245L cannot be used in the 5247M.

The 5247M has a unique input section which accepts any input voltage level between 100 mV and 10 V rms without adjustment. This feature enables unskilled people to use it for routine measurements on non-complex waveforms without attending to trigger level control adjustment. It's also useful where voltage levels vary widely and rapidly (e.g. when using tachometer generators). However, where a general purpose counter is needed, or where complex waveforms are to be counted, the trigger level controls of the HP 5248M Counter are usually required.

Specifications

Frequency measurement

Range: 10 Hz to 135 MHz (ac coupled).

Gate time: 1 μs to 10.0 seconds in decade steps.

Accuracy: ±1 count ± time base accuracy.

Readout: MHz, kHz or Hz with positioned decimal point; units annunciator in line with digital display.

Time base

Crystal frequency: 5 MHz.

Stability

Aging rate: <5 parts in 10^{10} per 24 hours after warm-up (after 72 hours of continuous operation).

Short term: <5 parts in 10^{11} for 1 second average (rms fractional frequency deviation).

Temperature: <5 parts in 10^{11} per °C from 0° to 50°C; <2.5 parts in 10^{8} within the entire span of 0° to 50°C.

Line voltage: <±1 part in 10^{10} for 10% change in line voltage from 115 V or 230 V rms.

Load stability: typically ±2 parts in 10^{11} for any of the following loads — open, short, 50Ω resistive, 50Ω inductive, 50Ω capacitive.

Warm-up: for "off" periods up to approximately 24 hours: 1 hour typical to reach 5 parts in 10^{9} of the frequency that existed when turned off (30 min., typical, to 1 part in 10^{8}). Time base operates whenever power cord is connected.

Output frequencies: rear panel: 5 MHz sine wave. 1 V rms into 50Ω. Available at all times whenever power line cord is energized, whether front panel power switch is ON or OFF. Stability as defined above. Signal-to-Noise Ratio typically >87 dB at rated output. Harmonic Distortion typically >40 dB below rated output. Non-harmonic Components typically >80 dB below rated output.

General

Display: 8 digits in-line; rectangular display tubes and display storage.

Signal Input

Sensitivity: 100 mV rms to 10 V rms (maximum) without level adjustment. Voltage exceeding ±100 V dc may cause damage.

Impedance: 1 MΩ shunted by 25 pF.

Connectors: BNC type.

Operating temperature range: 0°C to +60°C.

Power requirements: 115 or 230 volts ±10%, 50 to 60 Hz; 95 W, except is 150 W, max., during approx. the first 2 minutes after power line is first energized.

Weight: net 30 lbs (13.6 kg) with blank plug-in; shipping 36 lbs (16,4 kg).

Accessories furnished: HP 10503A Cable, 4 feet long, male BNC connectors. Detachable power cord, 7½ ft. (200 cm) long, NEMA plug. Circuit Board Extender. Rack mount conversion parts.

Price: Model 5247M, $3150.00.

Dimensions: 16¾" (425 mm) wide, 5-7/32" (133 mm) high, 16⅜" (416 mm) deep.

Chassis connectors: BNC type.

Options: digital output (Options 1 and 2):

Code: *Option* 2: 8-4-2-1 + ("0" level: −8 V; "1" level: 18 V; impedance: 100 KΩ). Option 1: 8-4-2-1 − ("0" level: 18 V; "1" level: −8 V; impedance: 100 KΩ).

Reference level: +17 V, 350Ω; −6.5 V, 1 kΩ.

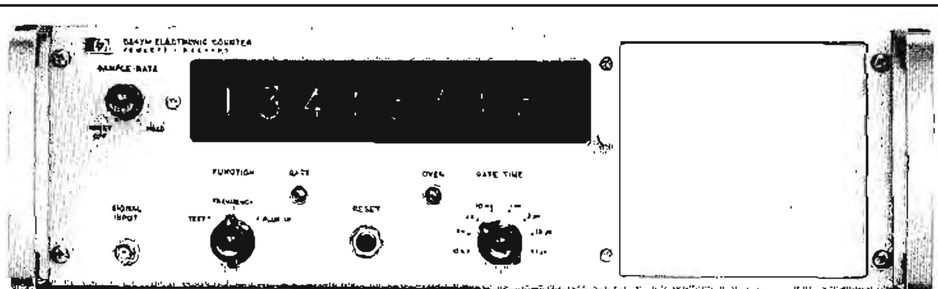
Print command: +13 V to 0 V step, dc coupled.

Hold-off requirements: +15 V minimum, +25 V maximum from chassis ground (1000Ω source).

Price: Option 01 or 02, add $85.

Option 3: rear terminal input in addition to front panel input; specifications are the same as front panel input.

Price: Option 03, add $75.



5247M

ELECTRONIC COUNTER

Economical 50 MHz plug-in counter

Model 5246L

The 5246L offers the basic 0-50 MHz range, many of the circuit benefits, and plug-in accessory features of the 5245L. Although, in the interest of economy, some of the 5245L capabilities are omitted from the 5246L, versatility can be increased by optional features.

The 5246L has display storage, a 6-digit readout (7 and 8 digits optional), and without any plug-ins will measure frequency and frequency ratio. BCD output and a higher stability ($<3 \times 10^{-9}$/day) crystal time base are optional. A dual field-effect transistor input amplifier offers almost constant 1 megohm/25 pF input impedance, and HP 10000 Series Probes can be used.

Frequency ratio (f_1/f_2) is measured by connecting signal f_2 (100 Hz to 1 MHz) in place of the counter's time base (BNC at rear), and connecting f_1 (up to 50 MHz) to the SIGNAL INPUT. Multiple ratios can be measured from 10 to 10^4 in decade steps.

Specifications

Frequency measurement

Range: dc coupled, 0 to 50 MHz.
ac coupled, 25 Hz to 50 MHz (typical response of input amplifier $<\pm 1$ dB over entire range).

Gate time: 1 μs to 1.0 second in decade steps.

Accuracy: ±1 count ± time base accuracy.

Readout: kHz or MHz with positioned decimal point; units annunciator in line with digital display.

Time base

Frequency (internal): 1 MHz.

Stability

Aging rate: less than 2×10^{-7} per month.

Temperature: less than ±2 parts in 10^6 (+10° to +50°C) ±2 parts in 10^5 (0°C to 65°C).

Line voltage: less than ±1 part in 10^7 for 10% change from 115 V or 230 V rms.

Output frequency: 1 MHz, >3 V p-p into 1 kΩ.

External input: sensitivity: 1 volt rms into 500 ohms, 1 kHz to 1 MHz; 2 V rms into 500Ω, 100 Hz to 1 kHz.

General

Display: 6 digits in-line with rectangular Nixie tubes and display storage: 999,999 max. display.

Display storage: holds reading between samples; rear panel switch overrides storage.

Sample rate: time following a gate closing during which the gate may not be reopened is continuously variable from less than 0.2 s to 5 s in Frequency mode, independent of gate time; display can be held indefinitely.

Signal input

Maximum sensitivity: 100 mV rms.

Coupling: ac or dc, separate BNC connectors. Ac coupling has 600 V dc, 0.022 μF capacitor (−3 dB at approximately 7 Hz).

Impedance: 1 MΩ shunted by 25 pF.

Overload: diode clamps in series with 100 kΩ and 0.001 μF protect input circuit for up to 120 V rms (<1 kHz). Input resistance for overload condition (beyond approx. 1 V) is approximately 0.1 MΩ.

Self-check: counts 10 MHz for the gate time chosen by the time base selector switch.

Operating temperature range: 0°C to +65°C.

Power supply: 115 or 230 volts ±10%, 50 to 60 Hz; 95 W (50 to 1000 Hz operation, price on request).

Weight: net, 28 lbs (12,8 kg) with blank plug-in.
shipping, 36 lbs (16,4 kg).

Accessories furnished: HP 10503A Cable, 4 ft. (120 cm) long, male BNC connectors. Detachable power cord, 7½ ft. (200 cm) long, NEMA plug. Circuit board extender. Rack mount conversion parts.

Dimensions: 5-7/32" high x 16¾" wide x 16⅜" deep (133 x 425 x 416 mm).

Price: Model 5246L, $1800.00.

Options

Option 01: 7 digit readout, add $100.00.

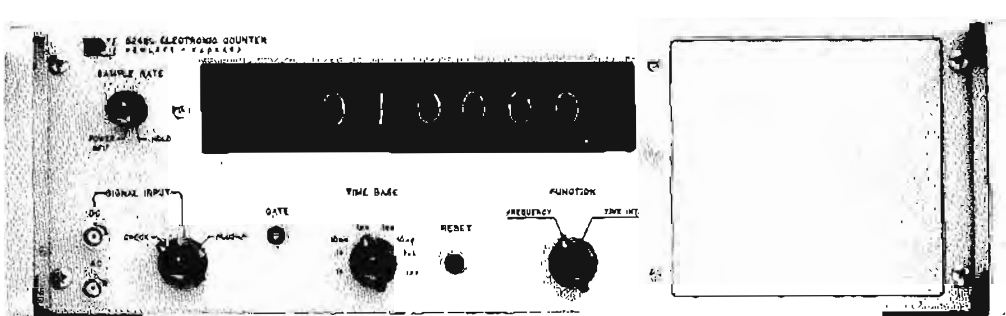
Option 02: 8 digit readout, add $200.00.

Option 03: 4-2-2-1 "1" state positive 4-line BCD output.
"0" State Level: −8 V.
"1" State Level: +18 V.
Impedance: 100 K ohms, each line.
BCD Reference Levels:
Approximately +17 V, 550Ω source.
Approximately −6.5 V, 1000Ω source.
Print Command: +13 V to 0 V step, dc coupled.
Hold-off Requirement: +15 V min., +25 V max. from chassis ground (1000Ω source).
Cable Connector: Amphenol 57-30500-375 (HP No. 1251-0086), 1 required.
Price: Option 03, add $75.00.

Option 04: similar to Option 03 except output is 8-4-2-1 "1" state negative 4-line BCD. Add $85.00.

Option 05: similar to Option 03 except output is 8-4-2-1 "1" state positive 4-line BCD. Add $85.00

Option 06: high-stability time base oscillator. "Stability" specifications for Model 5245L Time Base apply (see page 597). Also, External input: 1 V rms into 1000Ω, 1 MHz; (2 V rms, 100 Hz to 1 kHz; 1 V rms, 1 kHz to 1 MHz into 1000Ω available on special order). External input must be 1 MHz for readout in kHz or MHz. For frequency ratio measurements, external input can be 100 Hz to 1 MHz with the above sensitivities. Frequency and voltage specifications apply for sine wave inputs. Price: Option 06, add $300.00.



5246L

PRESCALER; DIGITAL VOLTMETER

Increase capability of 5245L/M, 5248L/M, 5246L

Models 5252A, 5258A, 5265A

5252A Prescaler

The direct-counting frequency of the HP 5245L/M, 5248L/M, 5246L and 5247M Counters is extended to 350 MHz using the Model 5252A Prescaler Plug-in. Prescaling is accomplished with transistor binary dividers which operate over the frequency range dc to 350 MHz. No tuning is required. A trigger level adjustment permits counting when unusual measurement conditions are encountered.

Prescalers divide the input frequency by a factor of 2, 4 or 8, and at the same time adjusting the counter's time base to provide a direct reading in frequency.

Specifications, 5252A*

Operating frequency range: dc to 350 MHz.
Accuracy: same as the basic counter.
Input sensitivity: 100mV rms.
Maximum input: 2 volts, +20 dBm, or 100 mW.
Input impedance: 50 ohms (nominal).
Operating temperature range: −20°C to +55°C.
Scaled output: >100 mV rms into 50 ohms is available at the AUX A BNC connector of the basic counter.
Weight: net 2.2 lb (1 kg); shipping 4 lb (1,8 kg).
Price: HP 5252A, $685.

5258A Sensitive Prescaler

5258A installation, use and operation are similar to the 5252A. It is also useful as a video amplifier.

Specifications, 5258A*

Operating frequency range: 1 MHz to 200 MHz.
Accuracy: same as the basic counter.
Input sensitivity: 1 mV/10 mV/0.2 V rms as selected by front panel switch.
Resolution: 1 Hz in 4 s, 10 Hz in 0.4 s, etc.
Maximum input: 3 V, +22.5 dBm, or 180 mW.
Input impedance: 50Ω.
Operating temperature range: −20°C to +65°C.
Scaled output: 100 mV rms into 50Ω is available at the Aux A output BNC connector of the basic counter.
Weight: net 5 lb (2,3 kg); shipping 7 lb (3,2 kg).
Price: HP 5258A, $825.

5265A Digital Voltmeter

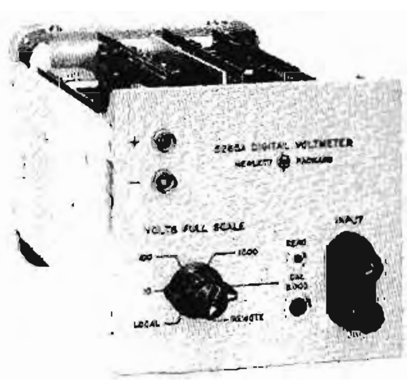
The HP 5265A Digital Voltmeter Plug-in quickly converts your 5245L/M, 5248L/M or 5246L Electronic Counter to an accurate dc digital voltmeter. Operation is straightforward—simply set range switch, connect the voltage to be measured and read.

A Local-Remote switch permits remote selection of the DVM mode or the regular electronic counter functions when used with an H65-5245L/M or H65-5248L/M Counter (remote control option).

Specifications, 5265A**

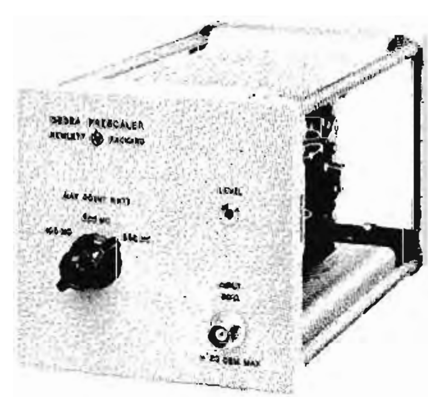
Voltage range: 6-digit presentation of 10.0000, 100.000, and 1000.00 V full scale with 5% overrange capability.
Registration: on electronic counter.
Reads in: dc volts with decimal point positioned by range switch; automatic polarity indicator.
Accuracy (0° to +50°C): ±0.1% of reading; ±0.01% of fs <1/10 fs (within 24 hrs and ±10°C temperature change since last front-panel calibration adjustment and within 6 mos. of calibration of internal zener reference).
Range selection: manual.
Sample rate: 5 per second. Has storage.
Input resistance: 10.2 megohms to dc on all ranges.
Input filter:
- **AC rejection:** 30 dB at 60 Hz, increasing at 12 dB per octave.
- **Response time:** less than 450 ms to a step function to within 0.05% of final value.
- **Accessory furnished:** 5060-0630 22-pin extender board.
- **Weight:** net 2½ lb (1,1 kg); shipping 5 lb (2,3 kg).
- **Price:** HP 5265A, $625.

*When used with HP 5245L (serial prefixed 402 and above) 5245M, 5248L/M, 5247M or 5246L Electronic Counters.
**When used with HP 5245L/M, 5248L/M, or 5246L Electronic Counter.



5265A

5258A

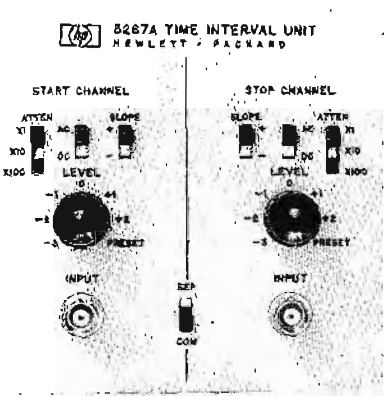


5252A

10 ns TIME INTERVAL UNIT

Highly versatile, 10 ns resolution

Model 5267A



5267A

Advantages:

- Resolution to 10 ns
- High, constant input impedance
- Versatile trigger controls
- Trigger point markers
- Measure time interval or pulse length, spacing or delay
- Will measure interval between pulses on single or dual inputs

Model 5267A Time Interval Plug-in converts the 135 MHz HP Models 5248L and 5248M Counters into highly versatile, highly accurate time interval counters with a resolution of 10 nanoseconds from 100 ns to 1 s (total range is 10^5 s). Resolution of this order is of special importance in time interval measurements involving projectiles, explosives, shock waves, laser pulses, and other fast phenomena (light travels only 10 feet in 10 nanoseconds). Among other applications, 10 ns resolution is also valuable for measuring pulse length, spacing and delay when calibrating pulse generators, and for measuring cable length using pulse transmission or pulse reflection techniques.

The 5267A will measure the length of or spacing between electrical events regardless of polarity or wave shape; it is not limited to pulse measurements, but will handle sine waves, triangular waves, etc. Measurements are made in a precise straightforward manner, even where the events occur in two different circuits. Steering circuitry in the 5267A permits measuring intervals between the starts of consecutive events, even when the events are of like polarity and occur on a single input line (the older 5262A Plug-in cannot do this).

Time is read directly on the counter with the units and decimal indicated. Since the counted signal is derived from its precise oscillator, counter time base accuracy is retained. High input impedance (constant on all ranges) and high sensitivity permit measurements on high-impedance, low-voltage circuits.

Marker pulses, generated each time the input signal crosses the threshold set by the dual trigger level controls, are available on the rear panel of the counter for oscilloscope intensity (Z-axis) modulation. These marker dots identify the measured interval on the displayed input waveform.

By combining all the above capabilities in one relatively inexpensive plug-in, the 5267A offers a flexibility that was previously unavailable in most special-purpose time interval counters and counter plug-ins.

The 5267A can be also used in HP 5245L or M, M54-5245L or M, and 5246L Counters. It brings all the above features to those models except that the minimum interval is 1 μs and maximum resolution is 100 ns.

Operation

The count is started by a signal applied to the "Start" channel of the 5267A and is stopped by a signal applied to the "Stop" channel. To ensure maximum versatility in time interval measurement, the 5267A has separate threshold controls for each channel. These controls select the magnitude and polarity of the voltage as well as the slope of the signal required to actuate the channels. In addition, either two separate waveforms or the same waveform can operate the channels since separate input connectors are provided for the "Start" and "Stop" channels. The inputs can be connected together, when preferred, by a front panel SEP-COM switch on the 5267A.

Specifications

Range:
100 ns to 10^5 s with HP 5248L or M Counter.
1 μs to 10^5 s with 5245L, 5245M, M54-5245L or M, or 5243L Counter.
1 μs to 10^6 s with 6-digit 5246L Counter.

Maximum resolution:
10 ns for intervals from 100 ns to 1 s with HP 5248L or M Counter; 0.1 μs for intervals from 1 μs to 10 s with 5245L, 5245M, M54-5245L or M, 5246L, or 5243L Counter.

Input repetition rate: 5 MHz, max.

Input coupling: ac or dc (front panel switch for each channel).

Standard frequency counted: 100 MHz to 1 Hz* in decade steps from counter or externally applied frequency up to 135 MHz** in HP 5248L or M Counter.

Input sensitivity: 0.3 V p-p (min.) x ATTENUATOR setting.

Input impedance: 1 MΩ/35 pF for peak input voltages up to 3 times the ATTENUATOR setting.

Maximum input:
120 V rms for X1 ATTEN. setting.
250 V rms for X10 ATTEN. setting.
500 V rms for X100 ATTEN. setting.

Accuracy (pulse): ±1 period of standard frequency counted ± time base accuracy.

Registration: on counter.

Start-stop: independent or common channels.

Trigger slope: positive or negative on Start and Stop channels, independently selected.

Trigger amplitude: both channels adjustable from −300 to +300 V peak.

Markers: separate output pulses coincident with Start and Stop trigger points on input waveforms; −10 volt amplitude, 0.7 μs width, from source impedance of approximately 1.5 kΩ; available at rear panel of counter.

Reads in: μs, ms, sec, with measurements unit indicated and decimal point positioned.

Accessories furnished: 10503A Cable Assembly, male BNC to male BNC, 48 inches (122 cm) long.

Weight: net, 1.5 lb (750 gms), shipping 3.5 lb (1,6 kg).

Price: Model 5267A, $400.00.

*10 MHz to 1 Hz in HP 5245L or M, M54-5245L or M, 5246L, or 5243L Counter.
**50 MHz in HP 5245L or M, M54-5245L or M, 5246L, or 5243L Counter.

T. I. UNIT; VIDEO AMPLIFIER
0.1 μsec resolution; 1 mV sensitivity
Models 5262A, 5261A

5262A Time Interval Unit

The economical HP 5262A increases the versatility of HP plug-in counters by making possible accurate time interval measurements with 0.1 μs resolution. Time is read directly from the counter display with units and decimal point also indicated. Counter time base accuracy is retained, since the counted signal is derived from the time base oscillator. The HP 5262A measures from 1 μs to 10^8 s with the 5245L/M, 5248L/M or 8-digit 5246L; to 10^6 s with the standard 5246L. It measures pulse length, pulse spacing and delays, and triggers from separate or common signals. The 5262A may be used as an amplitude discriminator which permits counting only signals meeting requirements set by trigger level controls. The newer 5267A has many features not present in the 5262A, but cannot be used as an amplitude discriminator.

Specifications, 5262A*

Range: 1 μs to 10^8 s (8-digit counter); 1 μs to 10^6 s (6-digit counter).
Standard frequency counted: 10^7 to 1 Hz in decade steps from HP counter or external frequency.
Accuracy (pulse): ±1 period of standard frequency counted ± time base accuracy.
Registration: on electronic counter.
Input voltage: 0.3 volt, p-p, minimum, direct-coupled input.
Input Impedance and overload: input impedance (constant up to 40 volts times Multiplier setting).

Multiplier	Input Impedance		Max. Input
	Resistance	Capacitance	
X0.1 X0.2 X0.3	10 k 10 k 30 k	80 pF 80 pF 40 pF	50 V rms ±150 V peak
X1 X3	100 k 300 k	20 pF 20 pF	150 V rms ±250 V peak
X10 X30 X100	1 M 3 M 10 M	20 pF 20 pF 20 pF	±250 V peak

Start-stop: separate or common channels.
Trigger slope: positive or negative on start and stop channels, independently selected.
Trigger amplitude: both channels adjustable, −250 to +250 V.
Frequency range: 0 to above 2 MHz when used as input signal discriminator.
Markers: (HP 5245L/M, 5248L/M only) separate output voltage steps, 0.5 volt peak-to-peak from source impedance of approximately 7 k, 100 pF; available at rear panel of counter with negative step coincident with trigger points on input waveforms for positive slope and positive step coincident for negative slope.
Reads in: μs, ms, s with measurements unit indicated and decimal point positioned.
Accessories furnished: 10503A Cable Assembly, male BNC to male BNC, 4 feet (1220 mm) long.
Weight: net 2.5 lb (1,1 kg); shipping, 4 lb (1,8 kg).
Price: HP 5262A, $250.
Model 5263A: Similar to 5262A but available only in Europe. Please consult your local European HP office for details.

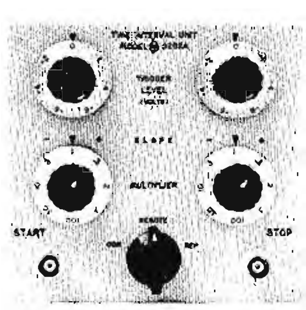
5261A Video Amplifier

The HP 5261A plug-in increases the sensitivity of HP plug-in counters to 1 mV over the range of 10 Hz to 50 MHz. The output level meter indicates when the signal level to the counter is acceptable for stable count. The auxiliary 50-ohm output permits monitoring the unknown input signal to the counter with a scope. A 10 megohm 10:1 divider probe is available to facilitate frequency measurements in high-impedance circuits.

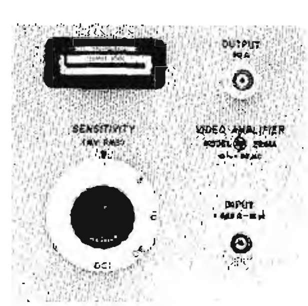
Specifications, 5261A*

Bandwidth: 10 Hz to 50 MHz.
Input sensitivity: 1 mV to 300 mV rms.
Max. input: 100 V dc; 5 V rms (ranges: 1, 3, 10, 30, 100 mV).
Input impedance: approximately 1 megohm, 15 pF shunt.
Output level meter: shows acceptable signal level.
Accuracy: retains accuracy of electronic counter.
Auxiliary output: front-panel BNC for oscilloscope monitoring or driving external equipment; 50-ohm source impedance; on amplifier's most sensitive attenuator range, 1 mV rms at input results in at least 100 mV rms at auxiliary output into 50-ohm load; maximum undistorted output is 300 mV rms into a 50-ohm load.
Accessory furnished: 10507A Low Microphonic 50-ohm Cable, 4 feet (1220 mm) long, BNC connectors.
Accessories available: 10003A 10:1 Probe, 10 pF shunt, 600 V max., $30; 10100A 50-ohm Feed-Thru Termination, $15.
Weight: net 2 lb (0,90 kg); shipping 4 lb (1,8 kg).
Price: HP 5261A, $325.

*When used with HP 5245L or M, 5248L or M, M54-5245L or M, or HP 5246L Electric Counters. 5261A can be used with 5248L or M and 5247M up to 50 MHz.



5262A



5261A

PRESET UNIT

Normalized readings; div. by N; count N events

Model 5264A

The HP Model 5264A Preset Unit extends the versatility of the time bases of the HP 5245L/M, 5248L/M and 5246L Counters, and the counters retain their basic functions and measurement range. Decade dividers in the preset unit control the counter gate; N may be any integer between 1 and 100,000. The 5264A makes possible the following:

N x frequency measurements: gate time is controlled by the preset decades (N) and the counter's Time Base switch. The gate is held open for N periods of the time base setting.

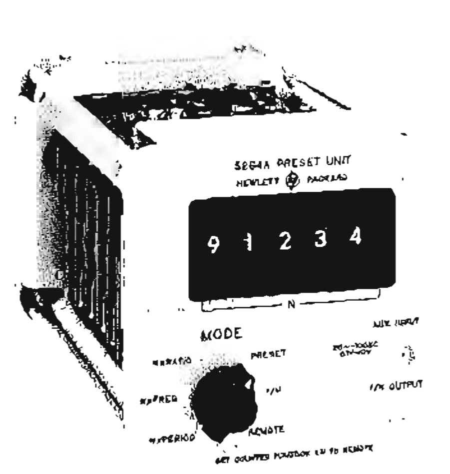
This selectable gate time makes possible normalized readings or conversion of frequencies into practical units. The long gate times that are available (5245L/M and 5248L/M —10^6 s; 5246L —10^5 s) permit accurate measurement of low frequencies.

N x period measurements (5245L/M and 5248L/M only): measures the time for N events to occur in increments of 0.1 μs (5245) or 10 ns (5248) to 10 seconds, depending on the setting of the counter's Time Base switch. Period and multiple period measurements are also easily made. Period average is determined by dividing the time reading by N.

Ratio, N x ratio measurements (5245L/M, 5248L/M only): measures ratio with choice of normalizing factors from 1 to 100,000 in one-digit steps. Counter displays $Nf_1 \div f_2$; f_1 is counted for N periods of f_2.

Dividing by N: permits division by N of any input frequency up to 100 kHz. The counter's prescaling capability (up to 10^9 in decade steps) allows frequencies as high as 50 MHz in 5245L/M and 135 MHz in 5248L/M to be divided by a five-digit number, provided that the frequency supplied the preset units (from the counter) does not exceed 100 kHz.

Preset Counting: N events are counted. The first event opens the gate; the Nth closes it. This feature is useful in batching, and the gate signal can be used to control external circuitry or relays.



5264A

Specifications, 5264A*

N x frequency (counter Signal Input)

Range: 0 to 50 MHz (to 135 MHz in 5248L/M).
Maximum sensitivity: 0.1 V rms.
Input impedance: 1 megohm shunted by 25 pF.
Gate time: (set by counter Time Base and "N" switches)
10 μs to 1 s in 10 μs steps
100 μs to 10 s in 100 μs steps
1 ms to 100 s in 1 ms steps
10 ms to 10^3 s in 10 ms steps
0.1 s to 10^4 s in 0.1 s steps
1 s to 10^5 s in 1 s steps
†10 s to 10^6 s in 10 s steps
Accuracy: ±1 count ± time base accuracy (5245L/M, 5246L) ±1 count ± time base accuracy ±0.02 μs gate uncertainty (5248L/M).

†N x period (counter signal input)

Input frequency range: 0 Hz to 100 kHz.
Maximum sensitivity: 0.1 V rms.
Input impedance: 1 megohm shunted by 25 pF.
Time units: 0.1 μs (5245) to 10 s in decade steps or 10 ns (5248).
Accuracy: ±1 count ± time base accuracy ± trigger error.**

†N x ratio

Reads: N x f_1/f_2.
Accuracy: ±1 count of f_1 ± trigger error of f_2.

	5248L/M		5245L/M, 5246L	
Freq. range MHz; dc to	f1 135 MHz	f2 100 MHz	f1 50 MHz	f2 100 kHz
Sensitivity V rms	0.1	0.1	0.1	0.1
Input Impedance	1 MΩ/25 pF	1 MΩ/20 pF	1 MΩ/20 pF	1 MΩ/25 pF
Connects to counter BNC:	Signal input	Ratio	Ext. Time base	Signal input

Divide by N (5264A Auxiliary Input, f/N mode)

Frequency range: 20 Hz to 100 kHz (sinusoidal).
Sensitivity: 0.1 V rms.
Input Impedance: 1 megohm, 50 pF shunt.
Overload: signals in excess of 10 V rms may damage the instrument.
†Prescaling: in decade steps to 10^9 of maximum rate of counter; (scaled output frequency ≤100 kHz).
Output: 0.2 V peak to peak centered at 0 volts, into high-impedance load; rise time <1 μs, duration approximately 5 μs.

Preset (5264A Auxiliary input)

Input frequency range: 20 Hz to 100 kHz.
Maximum sensitivity: 0.1 V rms.
Input impedance: 1 megohm, 50 pF shunt.
Overload: signals in excess of 10 V rms may damage the instrument.
Preset range: 1 to 99,999 in steps of one.

Weight: net 3lbs (1,4 kg); shipping 5 lbs (2,3 kg).

Accessory furnished: 10503A cable, 4 ft (1220 mm) long, male BNC connectors.

Price: HP 5264A, $650.

*When used with HP 5245L/M, 5248L/M or HP 5246L Electronic Counters. 5245L with serial no. prefix below 402 requires modification.
**Trigger error (sine wave) <0.3% of one period ÷ N for ≥40 dB signal-to-noise ratio on input signal; trigger error decreases with increased signal amplitude and slope.
†HP 5245L/M or 5248L/M only.

TRANSFER OSCILLATOR
Measures from .05 to 18 GHz; down converter
Model 5257A

Advantages:

Measures CW, FM, or pulsed carriers
Direct readout in frequency—no offset to add
Tuning meter replaces oscilloscope pattern
Automatic phase lock for CW and FM carriers
No readout until tuned (CW inputs)
Simple single dial tuning—no stubs

The HP Model 5257A Transfer Oscillator Plug-in extends the frequency measuring range of HP plug-in counters to 18 GHz. It is designed for use with the following counters: HP Models 5245L, 5245M, 5246L, 5247M, 5248L and 5248M. HP Model 5257A measures CW signals and FM carriers to within the counter's accuracy due to an automatic phase lock circuit (APC). The APC has a wide lock range (approx. ±0.2% of input frequency). It will track a rapidly drifting signal, with intermittent signals it relocks without retuning whenever the signal is present, and it locks to carriers with heavy FM; e.g., 4 GHz carrier with 1 MHz peak deviation at a 10 kHz rate. Pulsed carriers with pulse widths as short as 0.5 μsec may be measured with this instrument. The HP 5257A uniquely uses a tuning meter for this and other non-APC operation without loss of accuracy over CRT indicators. Optionally, a large screen oscilloscope may be connected to monitor zero beat tuning.

Sensitivity

High input sensitivity, even at the higher frequencies, is achieved by the wideband sampler at the input. There are no stubs to tune and the harmonic generator generally used in transfer oscillators is eliminated. By using an external oscilloscope for zero beat indication, and without phase lock, measurements may be made of CW signals down to −70 dBm and of pulsed signals down to −55 dBm.

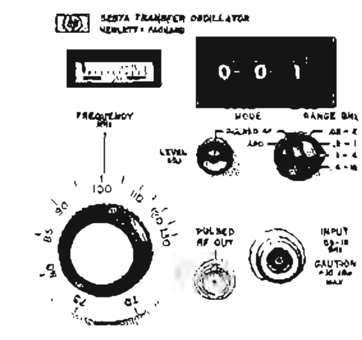
Direct readout

Frequency is read directly on the counter when the proper vfo harmonic number is set on the front panel "N" thumbwheels. Thus, repeated measurements can be made quickly within certain bandwidth restrictions for the same "N". When "N" is unknown it is easily found by taking two measurements and dividing the difference into the second of the two. An inhibit circuit prevents false readings in the APC mode by causing all zeros to be displayed unless the unit is locked into a CW signal.

Down conversion

The HP Model 5257A offers extra value by conveniently providing an 18 GHz hot carrier diode sampler driven by a tunable high stability oscillator from which the frequency converted amplified output is made available for other instrumentation. The carrier of this output is variable from dc to about 1 MHz by tuning the vfo. Input signals from 16.7 MHz to 18GHz can be down converted. Applications include measurement of residual FM, FM deviation and FM modulation linearity, inspection of AM modulation envelopes on an oscilloscope, % AM measurements, and frequency domain measurements with a wave analyzer.

For additional data see HP Journal, Feb. '68.



5257A

Specifications*

Frequency range: 50 MHz to 18 GHz.

Input signal capability: CW Signals. Pulsed RF Signals. Signals with high FM content.

CW measurement accuracy: retains counter accuracy.

Input sensitivity: 100 mV rms (−7 dBm) for input frequencies of 50 MHz to 15 GHz. 140 mV rms (−4 dBm) for input frequencies of 15 to 18 GHz and VFO FREQUENCY of 125-133.3 MHz. Typical sensitivity: −24 to −7 dBm.

Input impedance: 50 ohms nominal.

Maximum input: +10 dBm for CW Signals. 2 volts p-p for Pulsed RF Signals.

APC lock range: approximately ±0.2% of input frequency.

Meter: APC MODE—Indicates loop phase error under locked conditions. PULSED RF MODE—Zero beat indicator.

Pulsed RF out: for external oscilloscope, 0.5 volt p-p. Output frequency range of dc to 1 MHz, approx.

Pulse carrier frequency measurements: minimum pulse width —0.5 μs. Minimum repetition rate—10 pulses per second. Accuracy—0.01 cycle per pulse width (error ±20 kHz or less).

VFO: frequency range—66.7 to 133.3 MHz. Drift—(With constant temperature in operational range of 0° to 55°C) typically ±2 parts in 10^6 per minute immediately after turn on. Typically ±1 part in 10^7 per minute after 2 hours of operation. Temperature variation—typically 1 part in 10^4 per degree C.

Input connector: precision type N female.

Weight: net, 7¼ lb (3,3 kg); shipping, 8 lb (3,6 kg).

Price: $2,100.00.

Option 01: precision type APC-7 input connector, add $25.00.

*When used with HP 5245M, 5245L (serial prefix 402 or above and other serial prefixes when suitably modified), 5248L, 5248M, 5246L, M54-5245L, or 5247M Counters.

FREQUENCY CONVERTERS

Measure to 18 GHz with counter accuracy

Models 5251A, 5253B, 5254B, 5255A, 5256A

Advantages:

- Retains counter accuracy
- Up to 1 Hz resolution in 1 to 4 seconds counter gate time
- Easy to operate—has smooth, backlash-free, spurious-free tuning and a level indicator
- Cover dc to 12.4 GHz with 2 converters (5254B, 5255A); to 18 GHz with 3 converters (add 5256A)
- Sensitivity is high and relatively constant
- AC coupled input in most models

Frequency converters can increase the range of your 5245L/M, 5248L/M, 5246L or 5247M Counter to 18 GHz for CW signals. The stability and accuracy of the basic counter are retained in these higher frequency measurements because the converters use a multiple of the 10 MHz signal from the electronic counter crystal oscillator to beat with the signal to be measured. Operation of the equipment is simple and convenient permitting non-technical personnel to make frequency measurements up to 18 GHz quickly and accurately.

The basic measurement ranges of the counter are retained with the converter installed. Measurements to 50 or 135 MHz are obtained simply by moving the counter Sensitivity control off the "plug-in" position and connecting the input signal directly to the counter input.

The AC coupled inputs of the 5251A, 5253B, and 5254B prevent DC voltages which may be present along with the signal from affecting the measurement sensitivity or damaging the mixer circuits in the converter. The higher frequency AC coupled converters (5253B and 5254B) are unique in that the AC coupling is integrated into the input circuit, so it behaves as a transmission line with good VSWR; this results in relatively constant impedance (and converter sensitivity) over the entire frequency range. Thus, performance of these higher frequency converters is better than if AC coupling were achieved by simply using a series capacitor. VSWRs of the 5255A and 5256A are also excellent.

Models 5253B, 5254B, 5255A, and 5256A are cavity-tuned. Since constant bandwidth cavities are used, tuning peaks and dial "feel" (tuning peak spread) are the same over the entire dial.

Operation

The converter subtracts multiples of 10, 50, or 200 MHz (depending upon converter model) from the CW frequency to be measured and provides the difference to be measured by the counter. For example, if a frequency of 279.25 MHz is to be measured with the 5253B, the operator tunes the converter dial upward until the converter Level Indicator shows an acceptable voltage level. This will occur at a dial reading (mixing frequency) of 270 MHz for a 279.25 MHz input. At this dial setting, the converter will subtract 270 MHz from the input signal and pass 9.25 MHz, which the counter will measure and display. The measured frequency is then the sum of the counter reading and the 5253B dial reading.

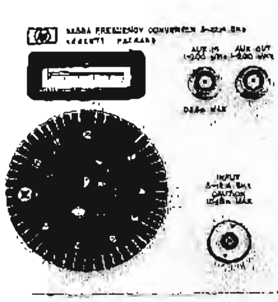
Readout resolution is 1 Hz with the counter gate time set at 1 second, 0.1 Hz at 10 seconds, 10 Hz at 0.1 second, etc. Counter gate time is automatically multiplied by 4 when the 5255A and 5256A are used. A technical article on the 5255A appeared in the Hewlett-Packard Journal, Sept. '66.

Model 5255A and 5256A

The 5256A's high frequency measuring range is unique in the microwave converter field. Previously, only transfer oscillators could make high accuracy measurements up to 18 GHz. Now, the 5255A and 5256A enable frequency measurements through X-band with greater speed, accuracy, and simplicity at comparable price.

The 5255A or 5256A can be used as a prescaler to extend the counting and direct readout range of the counter to 200 MHz. This is because the converters have an internal prescaler which divides both the 0 to 200 MHz heterodyne difference frequency and the counter's time base by a factor of four to achieve direct readout in MHz on the 50 or 135 MHz counter. Prescaler input is available at the AUX IN port; inputs as low as 5 mV between 1 and 200 MHz are prescaled by 4 and displayed in MHz on the counter. 5254B, 5255A and 5256A are also useful as down-converters; the heterodyne difference frequency is available at the AUX OUT port, so that microwave inputs can be beat down to 200 MHz max (5254B, 50 MHz), for oscilloscope observation, etc. Similarly, by adding a detector at AUX OUT, the units serve as receivers.

5256A



5255A

Specifications

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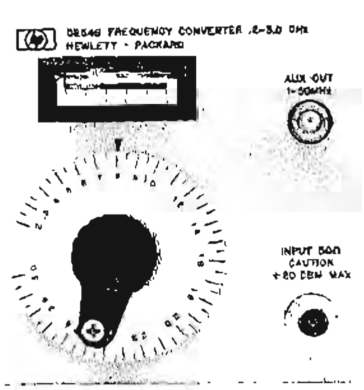
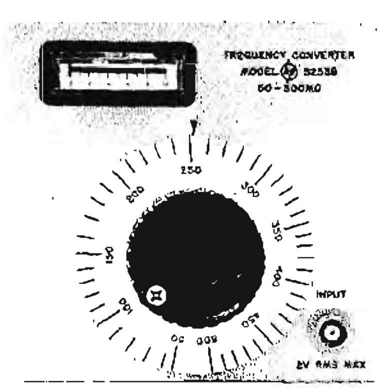
	5256A*	5255A*	5254B*	5253B**	5251A†
RANGE	8 to 18 GHz; as a prescaler, 1 MHz to 200 MHz	3 to 12.4 GHz; as a prescaler, 1 MHz to 200 MHz	0.2 to 3 GHz	50 to 512 MHz	20 to 100 MHz
MIXING FREQUENCIES	8 to 18 GHz in 200 MHz steps	2.8 to 12.4 GHz in 200 MHz steps	0.2 to 3 GHz in 50 MHz steps	50 to 500 MHz in 10 MHz steps	20 to 100 MHz in 10 MHz steps
INPUT VOLTAGE RANGE (min. to max., rms)	100 mV (−7 dBm) to 0.7V (+10 dBm); as a prescaler, 5 mV (−33 dBm) to 0.22 V (0 dBm)	100 mV (−7 dBm) to 0.7 V (+10 dBm); as a prescaler, 5 mV (−33 dBm) to 0.22 V (0 dBm)	50 mV (−13 dBm) to 1 V (+13 dBm)	50 mV (−13 dBm) to 1 V (+13 dBm)	50 mV (−13 dBm) to 1 V (13 dBm); typical sensitivity, 20 mV
MAXIMUM INPUT OVERLOAD	0.7 V rms (+10 dBm) (as a converter or prescaler)	0.7 V rms (+10 dBm) (as a converter or prescaler)	2.2 V rms (+20 dBm); 125 V dc	2 V rms (+19 dBm), 100 V dc	2 V rms (+19 dBm), 100 V dc
NOMINAL INPUT IMPEDANCE	50 ohms nominal	50 ohms	50 ohms	50 ohms	50 ohms
INPUT COUPLING	dc	dc	ac	ac	ac
ACCURACY	maintains counter accuracy				
REGISTRATION	counter display in MHz is added to converter dial reading				
LEVEL INDICATOR	meter aids frequency selection and indicates usable signal level				
INSTALLATION	into front panel plug-in compartment of some HP Electronic Counters (see footnote)				
INPUT CONNECTOR	*Precision Type APC-7 Connector (Precision Type N Optional, no charge)*	*Precision Type N female (APC-7 optional; add $25)*	*Type N female*	*BNC female*	*BNC female*
WEIGHT net / shipping	8¼ lbs. (3,8 kg) / 10 lbs. (4,6 kg)	8¼ lbs. (3,8 kg) / 10 lbs. (4,6 kg)	5 lbs. (2,3 kg) / 7 lbs. (3,2 kg)	5 lbs. (2,3 kg) / 7 lbs. (3,2 kg)	2 lbs. (0,9 kg) / 4 lbs. (1,8 kg)
PRICE	$1,950	$1,850	$825	$500††	$300††

Specifications apply when used with HP Electronic Counter Model No.: *5245L/M, 5248L/M, 5246L, 5247M (5245L with serial no. below 402 will require a minor modification); **5245L/M, 5248L/M, 5246L, 5247M or 5243L; †5245L/M, 5248L/M, 5246L or 5243L, but 5253B is recommended for 5245L/M, 5248L/M and 5246L, 5247M, since 0 to 512 MHz is thereby covered with the one plug-in.
††Accessory furnished: HP 10503A Cable, 4 ft. (122 cm) long, male BNC connectors.



5254B



5253B

5251A

AUTO FREQUENCY DIVIDER
Extends automatic counting range to 12.4 GHz
Model 5260A

Advantages

Automatic measurement, 0.3 GHz to 12.4 GHz
Direct readout, no calculations or offset
Maintains counter accuracy
Essentially constant 100 mV sensitivity

Automatic measurement and direct readout of an unusually wide range of CW microwave frequencies can now be achieved using the HP Model 5260A with a suitable electronic counter. The 5260A divides input signals in the 300 MHz to 12.4 GHz frequency range by 100 or 1000 to provide an output signal in the 1 MHz to 12.4 MHz frequency range. Measurements are rapid and simple, with accuracy the same as for basic counter measurements, the frequency being displayed directly on the electronic counter. There is no ambiguity or offset, and no calculations are needed. Except for selecting the proper division ratio, ALL TUNING IS AUTOMATIC AND NO ADJUSTMENTS BY THE OPERATOR ARE REQUIRED TO OBTAIN THE CORRECT OUTPUT READOUT.

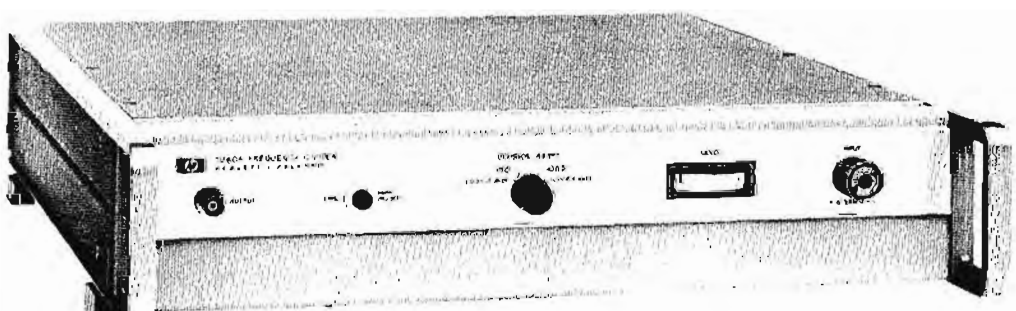
Suitable Electronic Counters (No plug-ins required)

HP 5245L or M, 5248L or M (see page 595, 598)
HP M07-5245L or M, M07-5248L or M (see Option 02)
HP 5246 L (see page 602)
HP 5244L (see page 615)
HP 5247M (see page 601)

Measuring dc to 12.4 GHz

A system for rapid, automatic, direct readout of frequencies from dc to 12.4 GHz can be assembled by combining an HP 5245L or M, 5248L or M, 5247M or 5246L Electronic Counter (dc to 50 or 135 MHz), 5252A Prescaler Plug-in (dc to 350 MHz), and 5260A Automatic Frequency Divider (300 MHz to 12.4 GHz). It is only necessary to select the frequency range desired and read the electronic counter readout; no tuning or calculations are required. Note, however, that the 5252A Prescaler is NOT required for operating the counters from the 5260A. The 5252A Prescaler is only necessary for measurements from 300 MHz down to the top of the counter's basic range.

For theory of operation see HP Journal, April '67.



5260A

Specifications

Range: 0.3 to 12.4 GHz.

Accuracy: retains accuracy of electronic counter.

Input sensitivity: 100 mV rms (−7 dBm).

Input Impedance: 50 ohms nominal.

Input VSWR		
Freq.	Typical	Max.
0.3-8 GHz	1.2:1	1.4:1
8-10 GHz	1.4:1	1.6:1
10-12.4 GHz	1.8:1	2:1

Maximum Input: +10 dBm.

Level Indicator: front panel meter indicates approximate input level, −10 dBm to +10 dBm.

Division ratio: front panel switch selects ÷ 100 (for use up to 1.2 GHz) or ÷ 1000 (from 1 to 12.4 GHz) operation.

Input connector: precision Type N female.

Operation: completely automatic once the DIVISION RATIO switch is positioned.

Output frequency: 1/100 or 1/1000 of input (1 to 12.4 MHz).

Output impedance: designed for 50 ohm (or higher impedance) load.

Output level: 0 dBm, nominal AGC.

Registration: input frequencies from 0.3 to 12.4 GHz are measured by measuring the 5260A output with a counter such as the HP 5245L or M, 5248L or M, 5247M, 5246L or 5244L, and suitably positioning the decimal point. Readout is direct with no offset, ambiguity, or arithmetic processing. See also Option 02, below.

Measurement time: set by electronic counter gate time.

Power supply: 115 or 230 V ±10%, 50 to 60 Hz, 47 watts (52 watts with Option 2). Other frequencies on special order.

Weight: net 29 lbs (13,2 kg); shipping 33 lbs (15 kg).

Dimensions: 16¾" wide, 3-15/32" high, 16⅜" deep (425 x 88 x 416 mm).

Price: Model 5260A Automatic Frequency Divider, $3,700.

Options:

01. Amphenol APC-7 Input Connector, add $25.
02. Provides 5260A with circuitry such that, when used with the HP Model M07-5245L or M07-5248L or M Counter, the decimal point will be automatically positioned for readout in GHz, and the symbol "GHz" will appear in the counter's readout. Readout is inhibited and displays all zeros unless an adequate input signal is present. Add $175.

DIGITAL FREQUENCY METER
Automatic Measurement to 12.4 GHz
Model 5240A

Advantages:

Completely automatic operation in each range
No readout unless phase lock is established
8 digit readout with decimal point and units
BCD output with decimal point and units

Completely automatic measurement and direct readout of frequencies from 0.3 to 12.4 GHz can now be achieved with the HP Model 5240A Digital Frequency Meter. Even an unskilled operator can make fast and accurate measurements since no adjustments or calculations are needed to obtain the correct readout. The only front panel controls are Gate Time and Range switches and a Sample Rate control.

The 5240A consists of an automatic frequency divider (identical to the 5260A on the opposite page) and an integrated circuit counter in a completely self-contained unit. A bonus feature is that low frequency measurements from 10 Hz to 12.4 MHz can be made by using the counter section only.

Correct counting depends on having established phase lock, so the 5240A has been designed to automatically inhibit display and printer output until lock is obtained. This feature is especially useful in automatic systems to greatly reduce erroneous readings.

Time for phase lock acquisition is typically less than 100 ms. Signals with considerable AM and FM can also be accurately counted with this instrument.

5240A

Specifications

Automatic frequency divider

Ranges: 0.3 GHz to 1.2 GHz and 1 GHz to 12.4 GHz.
Input sensitivity: 100 mV (−7 dBm).
Input impedance: 50 ohm nominal.
Input VSWR (type N or APC-7 connectors):

Frequency	Typical	Maximum
0.3 - 8 GHz	1.2:1	1.4:1
8 - 10 GHz	1.4:1	1.6:1
10 - 12.4 GHz	1.8:1	2:1

Maximum input: +10 dBm.
Level indicator: front panel meter indicates approximate input level from −10 dBm to +10 dBm.
Input connector: type N precision female (APC-7 optional).
Operation: completely automatic after RANGE switch is set.
Output frequency: 0.01 or 0.001 of input available from rear panel BNC connector.

Low frequency counter

Frequency measurements:
Range: 10 Hz to 12.5 MHz.
Gate times: 0.1, 1.0 s (10 s available on special order).
Accuracy: ±1 count ± time base accuracy.
Readout: MHz or GHz with positioned decimal point.
Self check: counts and displays 1 MHz for the gate time chosen.

Time base:
Crystal frequency: 1 MHz.
Stability
Aging rate: <2 parts in 10^7 per month.
Temperature: <2 parts in 10^6 over the range −10°C to 50°C; <20 parts in 10^6 over the range 0°C to +65°C.
Line voltage: 1 part in 10^7 for ±10% change in line voltage from 115 V or 230 V.
Output frequency: 1 MHz, 2 V square wave into 6 kΩ available from rear panel BNC connector.
External time base: requires 1 MHz, 2 V square wave into 1 kΩ.

Signal input:
Coupling: ac.
Sensitivity: 100 mV rms.
Maximum input: 2 V rms.
Impedance: 1 megohm shunted by 25 pF.
Remote reset: counter display and internal count reset to zero by grounding center of BNC connector on rear panel.

General:

BCD output: compatible with HP Models 562A and 5050B Digital Recorders with 8-4-2-1 "1" state positive. Printers can record decimal point and measurement units.
Output connector: Amphenol or Cinch Type 57-40500-375. HP part number 1251-0087, 50 pin, female. Mating connector Amphenol or Cinch Type 57-30500-375, HP part number 1251-0086, 50 pin, male.
"0" state level: 0 V.
"1" state level: +5 V.
Impedance: 5 kΩ, each line.
BCD reference levels: ground; ±5 V, 1 kΩ source
Print command: 1.5 V to 10 V step.
Hold-off requirements:
Maximum: +15 V.
Minimum: +7.5 V.
Power: 115 V or 230 V ±10%, 50 Hz to 60 Hz, 90 W.
Weight:
Net: 34 lbs (16,8 kg).
Shipping: 39 lbs (17,8 kg).
Dimensions: 5 7/32" high, 16 3/4" wide, 16 3/8" deep (133 x 425 x 416 mm).
Accessory furnished: detachable power cord, 7½ feet (231 cm) long with NEMA plug.
Price: HP Model 5240A, $4750.
Option:
01. Amphenol APC-7 Input Connector on high frequency input, add $25.

FREQUENCY CONVERTER

Measure frequency to 15 GHz at counter accuracy

Model 2590B

Model 2590B, in a single compact all-solid-state instrument, performs the functions of a transfer oscillator and a transfer oscillator synchronizer. (HP 540B, p. 612, is a transfer oscillator only).

By phase-locking an internal transfer oscillator to the signal frequency, Model 2590B makes CW frequency measurements inherently equal to the accuracy of the external time base used, even on rapidly drifting signals. With the HP 5253B and 5245L or 5246L complete coverage is provided from dc to 15 GHz with attainable accuracy as high as 2 parts in 10^{10}. Permanently phase-locked, the signal frequency's drift may be tracked continuously over long periods.

The 2590B automatic phase-lock is augmented by an automatic search oscillator, to simplify synchronization at system set-up. An automatic gain control eliminates input level adjustments. The instrument incorporates a precision FM discriminator and an envelope detector, for observation and accurate measurement of FM deviation, deviation rate and signal amplitude modulation.

FM and other short-term frequency disturbances can be observed on an oscilloscope while phase-locked to the signal. For signals with carrier frequency sufficiently stable not to require phase-locking, accurate measurements of FM deviation and deviation rate may be made with the precision built-in discriminator. A separate output from the envelope detector provides for oscilloscope observation and measurement of signal AM, in either FM or phase-locked operating modes.

The carrier frequency of pulsed signals can be determined to well within ±4 parts in 10^4 using the 2590B with an oscilloscope. FM on the pulse can also be observed.

Specifications

Frequency range: 0.5 to 15 GHz. Optionally 12 to 18 GHz.

Signal input: minimum level, typically −30 dBm at 0.5 GHz, −40 dBm at 5 GHz, and −15 dBm at 13 GHz. With Option, −15 dBm from 12.4 to 18.0 GHz, typical.

Lock-on range: ±0.15% minimum of signal frequency over entire transfer oscillator range. Track mode increases lock-range to ±0.35% of signal frequency at 240 MHz end of transfer oscillator range, decreasing to ±0.1% at 390 MHz end.

Accuracy: ±stability ±resolution of measurement of transfer oscillator fundamental; stability, same as 10 MHz reference supplied; resolution, ±1 count at transfer oscillator frequency, equivalent to 4.2 to 2.5 parts in 10^9 with 1 sec counter gate or 4.2 to 2.5 parts in 10^{10} with 10 sec gate over 240 to 390 MHz range.

External reference: 10 MHz, 0.1 V min. into 90 ohms.

FM measurement: discriminator characteristics when in FM mode: linearity (max. deviation from straight line through origin), better than ±1% over bandwidth of ±500 kHz, better than ±5% over bandwidth of ±2 MHz; video frequency response; 5 Hz to 1 MHz (3 dB points); center frequency, 30 MHz (nominal); sensitivity, 5 V/MHz (±5%); output impedance, 1.2 k ohm.

AM measurement: output, 200 mV p-p (nominal) for 100% modulation at 1 kHz; frequency response, 30 Hz to 1 MHz, load impedance, 10^6 ohms shunted by 12 pF max.

APC monitor: FM on signal may be monitored when in APC operating mode; sensitivity, ±2 V minimum for frequency deviation of ±0.25%; deviation limits, APC mode can follow frequency deviations to full lock-on range at rates up to 100 Hz; above 100 Hz, deviation decreases at 6 dB/octave; impedance, measuring device should have min. input impedance of 10^6 ohms, shunt capacitance not greater than 150 pF.

Transfer oscillator: fundamental frequency range, 240 to 390 MHz; drift, less than $5/10^4$ per hour immediately after turn-on, less than $1/10^5$ per hour after 3 hours' operation (oscillator automatically corrected for drift in APC mode); residual FM less than 10 Hz rms; dial, 2¼" dia. calibrated in 5 MHz increments.

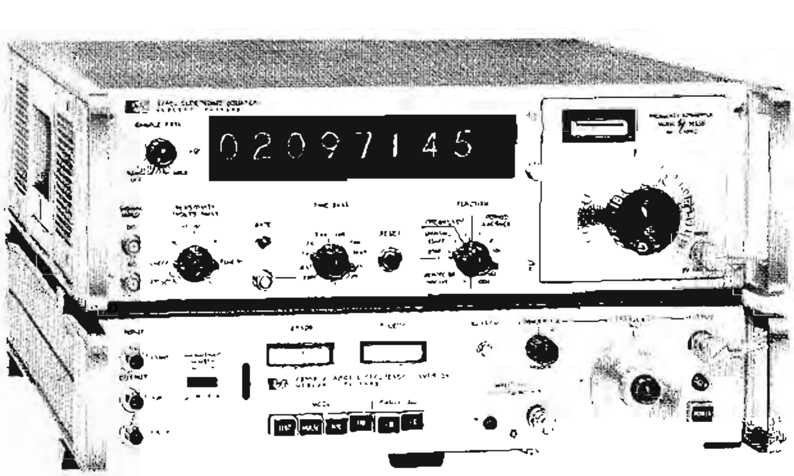
Power: 115/230 V ±10%, 50 to 1000 Hz, approx. 35 W.

Operating conditions: ambient temperatures 0 to 55°C, relative humidities to 95% at 40°C.

Dimensions: 16¾" wide, 3½" high, 16-5/16" deep behind panel (426 x 86 x 414 mm); instrument is fully enclosed for use on bench; may be mounted in 19" rack with side extensions to panel (furnished).

Weight: net 23 lbs (10,4 kg); shipping 30 lbs (13,6 kg).

Price: Model 2590B, $2150.



2590B (lower instrument) shown with 5245L Counter, 5253B Plug-In

TRANSFER OSCILLATOR

Measure to 18 GHz with counter accuracy

Model 540B

USES:

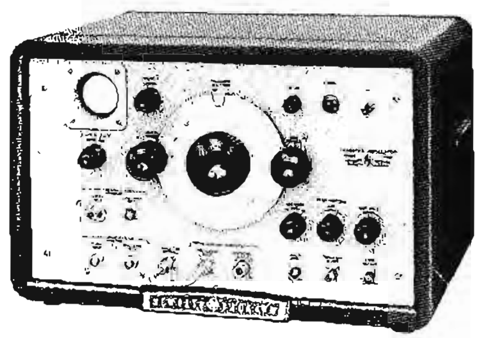
Measure frequency to 12.4 GHz with the 540B Transfer Oscillator plus an electronic counter.

Add a P932A Harmonic Mixer and measure frequency to 18 GHz.

Measure frequency of FM signals.

Determine FM deviation.

Measure signal frequency of pulsed signals.



540B

The HP Model 540B *Transfer Oscillator* provides a straightforward means of extending the frequency measurement range of many Hewlett-Packard Electronic Counters. It makes possible a completely flexible frequency measuring system for laboratory or industrial use. Adding the HP P932A Harmonic Mixer to the system further extends the frequency measuring range to 18 GHz.

The P932A mounts directly in the waveguide system and operates with the counter, mixing generated harmonics with the unknown microwave frequency. The mixer's beat frequency output is applied to the 540B. The measuring procedure is the same as the procedure using the 540B's internal mixer.

The system's accuracy approaches that of the electronic counter on clean cw signals. On pulsed signals, accuracy is governed by carrier frequency and pulse length. On noisy or intense AM signals, the transfer oscillator system with the 540B often provides the only means of accurate measurement. Overall system accuracy is greater than 10 times that of the best microwave wavemeters.

A direct-coupled reactance control circuit in the 540B allows the oscillator to be locked at a sub-multiple of the measured frequency when it is desirable to measure automatically or record drift characteristics of microwave signal sources.

Model 540B may be used with the following:

HP 5245L or M, 5248L or M, 5246L or 5247M Electronic Counters with either a 5253A Frequency Converter or 5252A Prescaler. For greater versatility consider HP 5257A or 2590B.

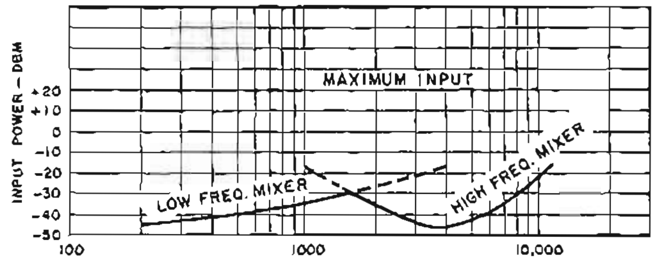
Specifications

Frequency range: 10 MHz to 12.4 GHz.

Input signal: cw, FM, AM or pulse.

Input signal level: varies with frequency and individual crystals. (See chart, upper right.)

Accuracy: cw: approximately 1 part in 10^7 or better.



INPUT FREQUENCY — MHz; 0 REF = 1 mW into 50 ohms.

Oscillator

Fundamental frequency range: 100 MHz to 220 MHz.

Harmonic frequency range: above 12.4 GHz.

Stability: <0.002% change per minute after 30-minute warm-up.

Dial: six-inch diameter, calibrated in 1 MHz increments; accuracy, ±0.5%.

Output: approximately 2 V into 50 ohms.

Amplifier

Gain: adjustable, 40 dB max.

Bandwidth: variable; high frequency: 3 dB point adjustable approximately 1 kHz to 2 MHz; low frequency: 3 dB point switched from 100 Hz to below 10 kHz, then continuously adjustable to above 400 kHz.

Output: 1 V rms maximum into 1000 ohms.

Internal oscilloscope

Frequency range: 100 Hz to 200 kHz.

Vertical deflection sensitivity: 5 mV rms per inch.

Horizontal sweep: internal, power supply frequency with phase control, or external (connection at rear) with 1 V per inch, 20 Hz to 5 kHz.

General

Size: cabinet: 20¾" wide, 12½" high, 15¼" deep (527 x 318 x 387 mm); rack mount: 19" wide, 10½" high, 14¼" deep behind panel (483 x 267 x 362 mm).

Weight: net 42 lbs (19 kg), shipping 51 lbs (23 kg) (cabinet); net 35 lbs (15,9 kg), shipping 48 lbs (21,7 kg) (rack mount).

Power: 115 or 230 V ±10%, 50 to 1000 Hz, approx. 110 W.

Accessories furnished: 10503A Cable Assembly, 4' (1219 mm) long, BNC-to-BNC; a 6" jumper cable (BNC-to-BNC) is included for use between jacks on front panel.

Price: Model 540B (cabinet), $1150.00. Model 540BR (rack mounted), $1150.00.

Auxiliary equipment

5245L or M, 5248L or M, 5247M, 5246L, M54-5245L Electronic Counters (pages 595 through 602).

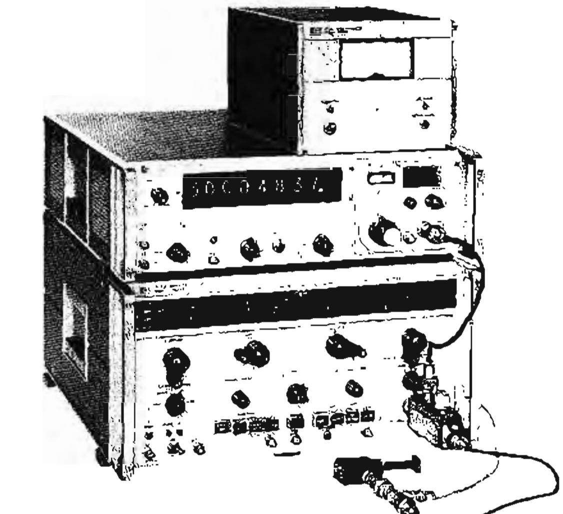
5252A Prescaler (page 606).

5253B Frequency Converter (page 608).

Any suitable HP Oscilloscope.

P932A Mixer, 12.4 to 18 GHz. $250.

DC TO 40 GHz SYSTEM
Versatile, accurate; uses standard instruments
Model E40-5245L



E40-5245L

Advantages:

- Continuous coverage dc to 40 GHz
- Wide phase lock range tolerates 0.1% FM, facilitates tuning
- Calibrated local oscillator (l.o.) speeds measurements
- High l.o. frequency avoids crowded lock points
- Typical sensitivity —30 dBm
- Adjustable l.o. power allows optimizing sensitivity
- Uses standard HP instruments—each useful in many other applications

This versatile dc to 40 GHz frequency measuring system, which consists of standard HP instruments and a monitor tee, gives superior performance and easier operation than previously available special purpose microwave instruments, and the standard HP instruments are fully usable as general purpose instruments outside this system. Owners of some or all of these instruments can build up the system with a saving in initial cost, but with an investment in interconnection and checkout time.

A Model 5245L Counter and 5257A Transfer Oscillator measures dc to 18 GHz. From 12 to 40 GHz, the HP 8690A Sweep Oscillator and H15-8692B Plug-in are the 2-4 GHz local oscillator of a second transfer oscillator (see Figure 1); an 8709A Synchronizer phase locks it to clean or heavily FM'd CW signals. The monitor tee separates out the 20 MHz IF. For pulsed RF input signals the 8709A is not required but an external oscilloscope is needed to display zero beat.

The system's high l.o. frequency (2-4 GHz) spreads out lock points for easy tuning and permits measuring from 20 to 40 GHz using a harmonic number of 10 to facilitate calculation. The system can also measure CW signals to 1% accuracy using the 8690A dial (without using the 5257A).

The minimum input curve of Figure 2 is for 3 consecutive lock points being available across the entire l.o. band (two of these locks find the subharmonic of the unknown and the third is a check). When the input frequency is approximately known, only one lock point is required; then, a more practical sensitivity would be the absolute minimum curve. Sensitivity improves significantly if local oscillator power is adjusted while tuning for phase lock.

Specifications

12.4 to 40 GHz

Input signal capability: CW signals. Signals with high FM content. Pulsed RF signals (using external oscilloscope).

CW measurement accuracy: ±2 parts in 10^7 or better.

Input sensitivity: better than −30 dBm at 12 GHz, −20 dBm at 40 GHz. See Figure 2 for typical sensitivity.

Input impedance: 50 ohms nominal.

Maximum input: 1 mW.

Auto phase control lock range: better than 0.1% of input signal frequency.

Capture range: approximately 20% of Lock Range.

Lock indication: lamp turns off when system phase locks to CW or FM signals; meter indicates phase error.

VFO frequency range: 2 GHz to 4 GHz.

DC to 18 GHz

Specifications of HP 5245L Counter and 5257A Transfer Oscillator apply (listed elsewhere in this catalog).

Price: E40-5245L System, approx. $10,500 depending upon cabinets required.

Accessories available: the waveguide adapter needed to connect to the HP 11517A Mixer is governed by user's waveguide system:
HP 11520A Adapter (26.5-40 GHz), add $75.
HP 11519A Adapter (18-26.5 GHz), add $75.
HP 11518A Adapter (12.5-18 GHz, add $75.

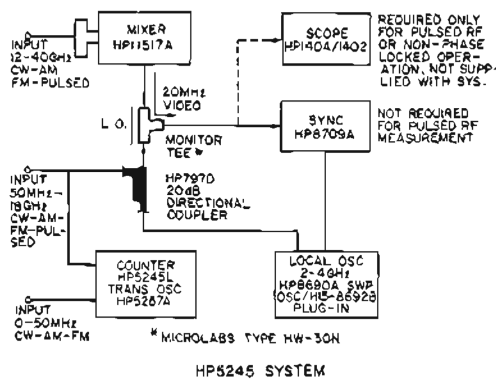


Figure 1. E40-5245L System.

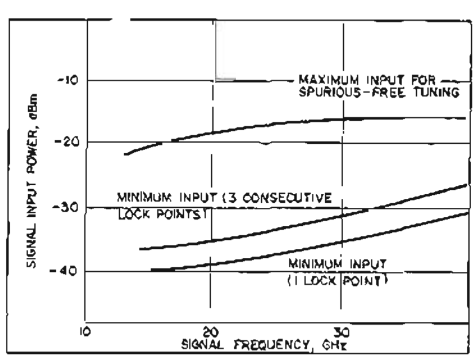


Figure 2. Typical sensitivity using constant local oscillator power.

ELECTRONIC COUNTER

50 MHz counting rate with 0.1 V sensitivity

Model 5244L

The HP 5244L Electronic Counter measures frequency, period, multiple period average, ratio and multiples of ratio with a maximum counting rate of 50 MHz. Rear connectors provide digital output in BCD form. Maximum sensitivity is 0.1 volt rms. The counter time base is a quartz crystal oscillator with an aging rate of less than 2 parts in 10^7 per month. Display storage provides a continuous display of the most recent measurement. With the function switch in "Frequency," the "Sample Rate" control adjusts the time between gates from less than 0.2 second to at least 5 seconds.

Specifications

Frequency measurements

Range: 0 to 50 MHz, dc input; 50 Hz to 50 MHz, ac input.
Input: 100 mV sensitivity; 100 kΩ/v impedance.
Gate time: 1 μs to 10 seconds in decade steps.
Accuracy: ±1 count ± time base accuracy.
Readout: kHz or MHz with positioned decimal point; units annunciator in-line with digital display.
Self check: counts 1 MHz for the gate time selected by time base switch.

Period average measurements

Range: single period, 0 to 1 MHz; multiple period, 0 to 300 kHz.
Input: 100 mV sensitivity; 100 kΩ/v impedance.
Periods averaged: 1 period to 10^5 periods in decade steps.
Accuracy: ±1 count ± time base accuracy ± trigger error.*
Frequency counted: single period, 10^6 to 1 Hz in decade steps; multiple period, 10^6, 10^5 or 10^4 Hz.
Readout: s, ms, μs with positioned decimal point; units annunciator in-line with digital display.
Self check: gate time is 10 μs to 1 s; counts 100 kHz.

Ratio measurements

Displays: f_1/f_2 times Period Average setting—(Range of 1 to 10^5).
Range: f_1: 50 Hz to maximum rate of counter, f_2: 0 to 1 MHz in single period, 0 to 300 kHz in multiple period; periods averaged 1 to 10^5 in decade steps.
Sensitivity: f_1: 1 V rms from 100 Hz to maximum rate of counter, 2 V rms from 50 to 100 Hz; 2500-ohm input impedance; f_2: 0.1 V rms, 100 kΩ input impedance.
Accuracy: ±1 count of f_1 ± trigger error* of f_2, where f_1 is frequency applied to counting binaries (at Time Base Ext. jack) and f_2 is applied to decade dividers (at signal input jack).
Readout: dimensionless units with positioned decimal.
Self check: gate time is 10 μs to 1 s; counts 100 kHz.

Time base

Crystal frequency: 1 MHz.
Stability:**
Aging rate: less than ±2 parts in 10^7 per month.
Temperature: less than ±2 parts in 10^6 for a change from +10° to 50°C, ±20 parts in 10^6 for a change from 0° to 65°C.
Line voltage: less than ±1 part in 10^7 for ±10% line voltage change.

Output frequencies: 0.1 Hz to 1 MHz in decade steps selected by Time Base switch.

General

Display: 7 digits in-line with rectangular Nixie®† tubes and display storage.
Sample rate: time following a gate closing during which the gate may not be reopened is continuously variable in the frequency function from less than 0.1 second to 5 seconds, independent of gate time; display can be held indefinitely.

Signal input

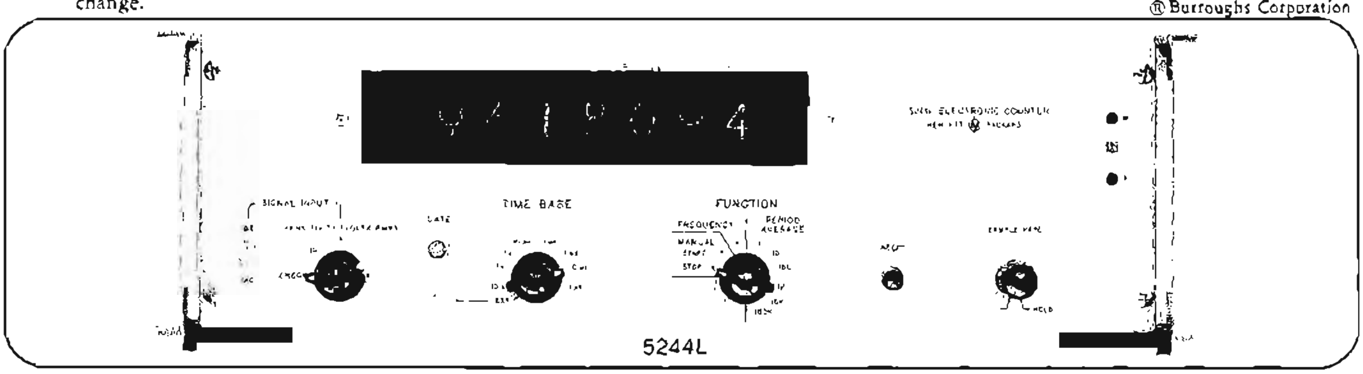
Maximum sensitivity: 100 mV rms.
Coupling: ac or dc.
Impedance: 100 kΩ/V (10 kΩ at 100 mV), approximately 40 pF on 0.1 V range, 15 pF on 1 and 10 V ranges.
Attenuation: step attenuator provides ranges of 0.1, 1 and 10 volts.
Overload: diodes protect input circuit up to 50 V rms on 0.1-volt range, 150 V rms on 1-volt range, 500 V rms on 10-volt range; 600 V dc tolerable.

Operating temperature range: 0°C to +65°C.†
Connectors: BNC type except for BCD output.
Output: 4-line 4-2-2-1 BCD with "1" state positive; 8-4-2-1 optional; "0" state: −8 volts; "1" state: +18 volts; impedance: 100 kΩ each line; reference levels: +17 volts (350-ohm source), −6.5 volts (1000-ohm source); print command: +13 volts to 0 volt step, dc coupled.
Hold-off requirement: +15 volts minimum, +25 volts maximum from chassis ground, 1000-ohm source.
Dimensions: 16¾" wide, 5½" high, 16⅜" deep (425 x 140 x 416 mm).
Weight: net 23 lbs (10,4 kg); shipping 35 lbs (16 kg).
Power: 115 or 230 volts ±10%, 50 to 60 Hz, approximately 80 watts (50 to 400 Hz operation, price on request).
Accessories furnished: 10503A cable assembly, 4 ft (1220 mm), male BNC connectors; detachable power cord 7½ ft (2270 mm) with NEMA plug; printed circuit board extender; rack adapter kit.
Price: HP 5244L, $1900.00.
Options:

01. 8-digit registration, add $100.
02. 8-4-2-1 BCD ("1" state positive) output (7-digit), add $10.
03. 8-4-2-1 BCD ("1" state negative) output (7-digit), add $10.
04. 8-digit registration and 8-4-2-1 BCD ("1" state positive) output, add $110.
05. 8-digit registration and 8-4-2-1 BCD ("1" state negative) output, add $110.

RFI: The counter, modified to meet electromagnetic compatibility specification MIL-I-6181D, may be obtained by specifying H60-5244L. Add $350.

* Trigger error for sine wave input is $\frac{\leq 0.3\% \text{ of one period}}{\text{periods averaged}}$ for signals with 40 dB or more signal-to-noise-ratio.
** The crystal time base (better than ±3 parts in 10^9 per 24 hours and better than 2 parts in 10^{10} rms with 1 second averaging) which is used in the 5245L is available on special order. Specify H15-5244L (add $325).
† −20°C to +65°C on special order or with external time base.
® Burroughs Corporation



ELECTRONIC COUNTERS

Model 5325A

Advantages

- Dual FET differential amplifier inputs
- Differential Schmitt trigger circuits
- Dual trigger level controls
- Remote programming of all functions
- Oscilloscope intensity markers
- Measurement resolution of 0.1 μs
- Minimum 100 μs sample rate
- BCD output with buffer storage
- Readout blanking of undesirable zeros to left of count total
- Very lightweight

Uses:

- Measure frequency
- Measure time interval, period, period average
- Count periodic and random pulses
- Determine ratio and multiple ratio
- With transducers, measure speed, flow rate, and other physical variables
- Scale input signals up to 10^8

Model 5325A Universal Counter is a general purpose 12.5 MHz instrument having dual, level adjustable, high impedance inputs.

Push-button function switches instantly select the desired operating mode. The sample rate is variable from 100 μs to 5 s (including hold) for adjustment to optimum readout speed, and it includes buffer storage (print inhibit holds BCD transfer pulse) to hold information for external use.

Time base pulses are available at a rear panel connector. In start, the pulses are a scaled frequency equal to input A signal divided by the time base/multiplier switch setting.

In check, the 5325A counts its own 10 MHz for the gate times selected.

Dual channel inputs

The HP Model 5325A has dual channel, ac or dc coupled, level controllable differential input amplifiers. Its unique differential Schmitt trigger circuits have a threshold band (error zone) of less than 1 mV to protect against false counting. Trigger level settings are, thus, clear cut and well defined for a count or no count, and undesired signals and noise below the trigger levels are rejected. These controls also select the start-stop points in time interval measurements. A three step attenuator changes the control range maximum in decades of ±1 volt, ±10 volts, and ±100 volts. A separate/common switch allows the inputs to operate from separate input signals or a single input signal. This design results in high stability, high sensitivity, and an input impedance of 1 MΩ shunted by only 35 pF.

Measurements

The 5325A measures frequencies from 0 to 12.5 MHz of either periodic or random signals. The counter's gate time is selectable in decade steps from 0.1 μs through 10 S with the decimal point and units automatically displayed.

Accuracy of 5325A frequency measurements are excellent for its price class. A fast warm-up, oven stabilized, 10 MHz quartz crystal provides a dependable time base with an aging rate of less than 3 parts in 10^7 per month. And the 10 s gate realizes a least significant figure of ±0.1 Hz.

Time intervals of 0.1 μs to 10^9 s can be measured with the 5325A. Rear panel BNC connectors furnish channel A and channel B marker pulses, 0.7 μs wide, for displaying and setting trigger levels with an oscilloscope or they may be used for actuating other circuits. A particularly valuable feature of the 5325A for time interval measurements is the gate pulse, on a rear BNC connector, for intensifying on an oscilloscope the waveform segment between start-stop points.

The 5325A will measure the period of a single input cycle with a selectable resolution of 0.1 μs to 10 s for frequencies from dc to 10 MHz. Periods are fully displayed up to a 7 digit readout; e.g., 999999.9 μs. When the count exceeds the number of digits in the readout an overflow lamp lights on the front panel.

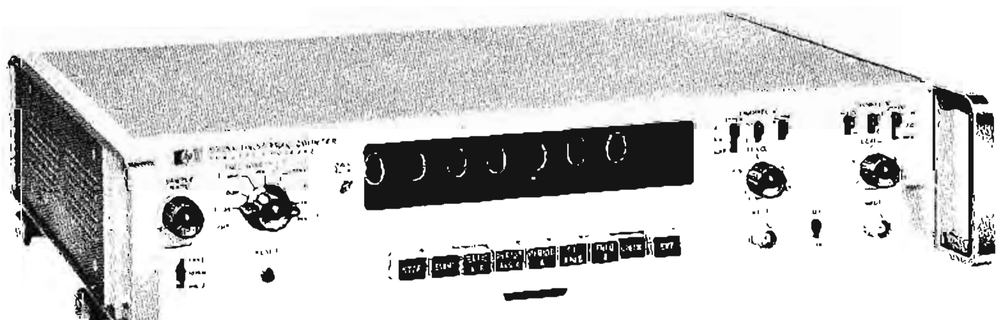
The 5325A offers period average measurements to reduce the effect of trigger error and ± one count ambiguity. Periods averaged are selectable from 1 to 10^5 in decade steps for input rates from 0 to 10 MHz. Period average measurements result in higher accuracy at low frequencies and faster measurements at high frequencies for equivalent resolution.

The 5325A offers frequency ratio measurements with a range of 0-10 MHz. For the ratio of two frequencies, Fa/Fb, the number of cycles of Fa that occur during a period of Fb are counted. The number of periods of Fb can be increased in decade steps to 10^5 periods for an increase in measurement accuracy. Decimal points are automatically positioned to give Fa/Fb, but no units are displayed since ratio is unitless.

Digital output and storage

The 5325A provides 4-line 1-2-4-8 output with "1" state positive. This output is suitable for systems use or output devices such as the HP Model 5050A Digital Recorder. The BCD output is stored after count so that peripheral equipment can examine this information while a new count is being made. This increased the overall speed of a measuring-recording system. Buffer storage on/off choice can be made with a rear panel switch.

Display storage provides a continuous display of the most recent measurement, even while the instrument is gating for a new count. The display changes only when a new count differs from the stored count. Storage may be switched off if desired.



5325A

Specifications

Input channels A and B

Range: dc coupled: 0-12.5 MHz.
ac coupled: 10 Hz-12.5 MHz.
Sensitivity: 0.1 V rms sine wave.
0.5 V p-p pulse, 50 ns minimum pulse width.
Impedance: 1 MΩ shunted by 35 pF.
Maximum input: 120 V rms (<1 kHz) X1 range
250 V rms X10 range
500 V rms X100 range
Overload level: 1.5 V rms X ATTENUATOR settings.
Trigger level:
PRESET to trigger at 0 V, or adjustable:
±1 V X1 range
±10 V X10 range
±100 V X100 range
Trigger threshold band <1.0 mV, referred to input at 12.5 MHz.
Slope: independent selection of positive or negative slope.
Channel inputs: common or separate lines.
Marker outputs: rear panel BNC. −12 V pulse, 0.7 μs width (Marker A and B) at start and stop of gate time.

Start
(Totalizing and scaling)

Frequency range: 0-10 MHz.
Function setting: START push-button.
Factor: $1\text{-}10^4$ selectable in decade steps.
Input: channel A on front panel.
Output: rear panel TIME BASE BNC.
Display: channel A input divided by scaling factor.

Frequency

Range: 0-12.5 MHz.
Input: channel A.
Gate time: 0.1 μs to 10 seconds in decade steps.
Accuracy: ±1 count ± time base accuracy.
Readout: MHz or kHz with positioned decimal point.

Time interval measurement

Range: 0.1 μs to 10^5 seconds.
Input: channels A and B; can be common or separate.
Time base frequency counted: 10 MHz to 0.1 Hz selectable in decade steps.
Accuracy: ±1 count ± time base accuracy ± trigger error.*
Readout: μs, ms, seconds, or 10's of seconds with positioned decimal.

Period

Range: 0-10 MHz.
Input: channel A on front panel.
Frequency counted: 10 MHz to 0.1 Hz selectable in decade steps.
Accuracy: ±1 count ± time base accuracy ± trigger error.**
Readout: μs, ms, seconds, or 10's of seconds with positioned decimal.

Period average

Range: 0-10 MHz.
Periods averaged: $1\text{-}10^5$ selectable in decade steps.
Input: channel A on front panel.
Frequency counted: 10 MHz.
Accuracy: ±1 count ± time base accuracy ± trigger error.**
Readout: ns, μs with positioned decimal.

Ratio

Displays: Fa/Fb x Multiplier (M). M = 1 through 10^4, selectable in decade steps.
Range: channel A 0-12.5 MHz
channel B 0-10.0 MHz
Accuracy: ±1 count of Fa ± trigger error** of Fb.
Readout: dimensionless; positioned decimal point for number of periods averaged.

Time base

Crystal frequency: 10 MHz.
Crystal oven: self regulating solid-state type.
Stability:
Aging rate: less than 3 parts x 10^7/mo.
Temperature: ≤ ±2.5 parts in 10^6, 0° to 50°C.
Line voltage: ≤ ±1 part in 10^7 for ±10% line voltage variation.
Oscillator output: 10 MHz, 1.0 V rms, 50 Ω source impedance at rear panel BNC.

External input: 1 MHz 1.0 V rms
2.5 MHz 1.0 V rms
5 MHz 1.0 V rms
10 MHz 1.0 V rms
Time base output: negative pulses, +4 V to 0 V (open circuit), 100 ns wide. In all functions except START and RATIO, rate is 10 MHz divided by TIME BASE/MULTIPLIER switch setting. Available at rear panel BNC.
Scaling: TIME BASE/MULTIPLIER switch selects division of Channel A frequency in the START function. Available at TIME BASE connector.
Gate output: 0 V while gate open, +4 V while gate closed. Available at rear panel BNC.

General

Display: 7 digits; long-life neon digital display tubes.
Blanking: suppresses display of unwanted zeros left of the most significant digit.
Display storage: holds reading between samples. Rear panel switch overrides storage.
Sample rate: FAST position: Continuously variable from less than 100 μs to approximately 20 ms. NORM position: Continuously variable from less than 20 ms to approximately 5 seconds. HOLD position: Display can be held indefinitely.
Reset: manual.
Overflow: front panel neon indicates when the display range has been exceeded.
Remote programming: all front panel controls are single line programmable except:
SEP-COM (separate-common) switch
Input Attenuators (see Option 01)
AC-DC Input Signal Coupling (see Option 01)
Measurement units and decimal points are each single line programmable
Connector mates with 50-pin Amphenol 57-30500 (HP 1251-0086)
Control signal: single line control for each FUNCTION. Control signal zero (0) volts dc may be a contact closure to ground or electronic or TTL drive.
Digital output (for numerals only)
Code: 4-line 1-2-4-8 BCD, "1" state positive.
"0" state: +0.25 V at −1 mA; +0.4 V at −5 mA.
"1" state: +5 V open circuit, 2.5 kΩ source impedance, nominal.
Print command: +5 V to 0 V, dc coupled; occurs at end of gate.
Storage: buffer storage is provided so BCD output is constant while next measurement is being made.
Inhibit input: inhibits transfer of data to buffer storage when instrument's cycle time is less than time required for external equipment to interrogate BCD outputs. Positive inhibit +5 V.
Chassis connector: special HP manufactured connector assembly. (See Accessories Available below.)
Connectors: all are BNC's except for Remote Programming (Cinch or Amphenol 57-40500-375) and BCD output.
Operating temperature: 0° to 50°C.
Power requirements: 115 or 230 volts ±10%, 50 to 400 Hz, 35 watts maximum. Fast circuit breaker action with internal power reset switch protects supply. Also resets when main power switch is turned off.
Weight: net, 10 lb (4.6 kg); shipping 15 lb (6.8 kg).
Accessories furnished: power cord, 7½ ft HP 10503A, 50 Ω BNC to BNC cable, 4 ft. (122 cm), 2 each. Rack mount kit with P.C. extender board.
Price: $1,300.00.
Dimensions: 16¾" (425 mm) wide, 11¼" (286 mm) deep, 3¹⁵⁄₃₂" (88.2 mm) high.
Accessories available: HP Cable 10513A (6 ft, 183 cm) to connect to HP 5050A Digital Recorder, Price, $65.00.
Option 01: remotely programmable attenuator switch and ac/dc switch. Price: $75.00.

*For any waveshape, trigger error is less than

$$= \frac{0.0025}{\text{Signal Slope (volts/}\mu\text{s)}} \text{ microseconds.}$$

**Trigger error is less than ±0.3% of one period ÷ periods averaged for signals with 40 dB or better signal-to-noise ratio and 100 mV rms amplitude.

ELECTRONIC COUNTERS
Versatile universal counters to 2 MHz
Models 5223L, 5233L

Advantages:

- Trigger level controls usable in all functions
- Bench or rack use, 3½" panel height
- Completely solid state design
- Versatile, yet easy to operate
- More accurate low-frequency measurements with multiple period averages
- Low-level measurements without accessories; 0.1 Volt sensitivity
- Coupling ac or dc
- Display storage

Uses:

- Measure frequency
- Count periodic or random pulses
- Measure period, period average, time interval
- Determine ratio and multiples of ratio
- With transducers, measure speed, flow rate, other physical variables
- Scale inputs

Models 5223L and 5233L are universal electronic counters. They measure time interval, frequency, period, multiple period average, ratio and multiple ratio. The 5223L provides a maximum counting rate of more than 300 kHz and 5-digit resolution, and the 5233L provides a maximum counting rate of more than 2 MHz with 6-digit resolution. Both instrument readouts are in-line displays of rectangular digital tubes.

AC and DC coupling

The 5223L and 5233L offer ac and dc coupling. Dc coupling allows accurate trigger point definition.

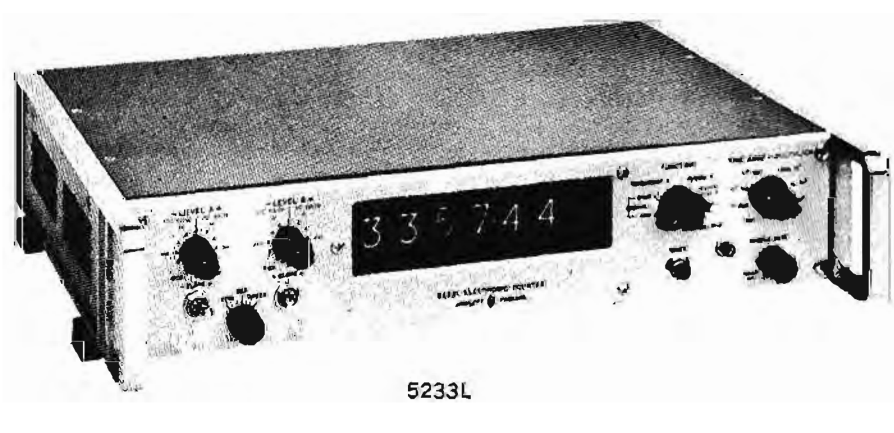
With the ac-coupled input, triggering responds to an average dc level. Therefore, the trigger point may change with wave shape and repetition rate. This situation is not significant in most frequency measurements since only the number of zero crossings are counted. However, if a pulse of large amplitude and duration is followed by a pulse of small amplitude and duration, the trigger may miss the small pulse, if circuit time constants are such that the average dc level does not have time to recover. This would be a serious limitation in nuclear work, where counted pulses are random in amplitude and width. Also the variability of trigger point with repetition rate and wave shape (produced with ac coupling) is an important source of error in time interval measurements —the actual trigger point is always in doubt. For instance, triggering may be at a point of low slope near the top of a pulse where noise can cause appreciable error.

Optimum trigger point definition

Both the 5223L and 5233L feature two identical input channels. Either separate or the same signals may be used to start and stop the count; the time interval measured may be selected between any desired points on either signal. Input channel controls allow selection of the slope, amplitude and polarity of the trigger voltage for all other measurement functions, as well as time interval.

Any input amplifier drift or noise will add to the trigger ambiguity. The effect of this internal noise becomes increasingly apparent as the input signal-to-noise ratio decreases. Consequently, to improve precise measurements, each input channel of the 5223L and 5233L has been designed to minimize amplifier drift and noise. In these instruments the amplifier noise referred to the input is typically less than 100 microvolts.

The input amplifiers also possess a wide dynamic range such that the input signal peaks can exceed 10 times the highest level control adjustment without changing the dc level. For example, on the X1 attenuator position, peaks considerably beyond 10 Volts do not alter the zero crossover point.



5233L

	5223L Electronic Counter	5233L Electronic Counter
Input channels (A and B)	**Range:** dc coupled: 0 to more than 300 kHz; ac coupled: 10 Hz to more than 300 kHz. **Impedance:** approx. 1 megohm, 80 pF shunt. **Sensitivity:** 0.1 V rms sine wave; 1 V pulse, 1 μs min. width. **Trigger level:** −100 to +100 V, adjustable, either positive or negative slope; independent controls on each channel. **Channel inputs:** Common, Separate, Check. **Marker output:** available at rear panel for oscilloscope intensity modulation to mark trigger points on input waveform; >1 μs duration and −15 V peak.	**Range:** dc coupled: 0 to more than 2 MHz; ac coupled: 10 Hz to more than 2 MHz. **Impedance:** approx. 1 megohm, 80 pF shunt. **Sensitivity:** 0.1 V rms sine wave; 1 V pulse, 0.2 μs min. width. **Trigger level:** −100 to +100 V, adjustable either positive or negative slope; independent controls on each channel. **Channel inputs:** Common, Separate, Check. **Marker output:** available at rear panel for oscilloscope intensity modulation to mark trigger points on input waveforms; 1 μs duration and −15 V peak.
Time interval	**Range:** 10 μs to 10^6 s. **Input:** Channels A and B. **Accuracy:** ±1 count ± time base accuracy ± trigger error.* **Reads in:** ms or s with positioned decimal. **Measurement:** time from A to B. **Self check:** period self check below applies, when levels and slopes of both channels are identical.	**Range:** 10 μs to 10^7 s. **Input:** Channels A and B. **Standard frequency counted:** 1 MHz to 0.1 Hz in decade steps or external frequency 100 Hz to 1 MHz. **Accuracy:** ±1 count ± time base accuracy ± trigger error.* **Reads in:** ms or s with positioned decimal. **Measurement:** time from A to B.
Frequency	**Range:** 0 to >300 kHz. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy. **Reads in:** kHz or MHz with positioned decimal. **Gate time:** 10 μs to 10 s in decades. **Self check:** counts 100 kHz for the gate time chosen by time base selector.	**Range:** 0 to >2 MHz. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy. **Reads in:** kHz or MHz with positioned decimal. **Gate time:** 1 μs to 10 s in decades. **Self check:** counts 1 MHz for the gate time chosen by time base selector.
Period	**Range:** 0 to 100 kHz. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μs or ms with positioned decimal. **Frequency counted:** 100 kHz to 0.1 Hz in decade steps. **Self check:** gate time is 1 s, frequency counted is 0.1 Hz to 100 kHz as selected by time base switch.	**Range:** 0 to 100 kHz. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** ms or s with positioned decimal **Frequency counted:** 1 MHz to 0.1 Hz in decade steps. **Self check:** gate time is 1 s; frequency counted is 0.1 Hz to 1 MHz as selected by time base switch.
Period average	**Range:** 0 to 300 kHz. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μs or ms with positioned decimal. **Frequency counted:** 100 kHz. **Periods averaged:** 10 to 10^6 in decade steps. **Self check:** gate time is 10 μs to 10 s (1 to 10^6 periods of 100 kHz); counts 100 kHz.	**Range:** 0 to 2 MHz (multiple period), 0 to 1 MHz (X10), 0 to 100 kHz (X1). **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μs or ns with positioned decimal. **Periods averaged:** 10 to 10^7 in decade steps. **Frequency counted:** 1 MHz **Self check:** gate time is 10 μs to 10 s (10 to 10^7 periods of 1 MHz); counts 1 MHz.
Ratio	**Range:** Channel A (F_A): 0 to above 300 kHz; Channel B (F_B): 0 to 300 kHz (X10 to X10 ^{6}), 0 to 100 kHz (X1). **Input:** Channels A and B. **Measures:** $\frac{F_A \text{ (multiplier)}}{F_B}$ **Reads:** $\frac{F_A}{F_B}$ or $\frac{1000F_A}{F_B}$, depending on multiplier setting. **Accuracy:** ±1 count of $F_A \pm \frac{\text{trigger error of } F_B}{\text{multiplier setting}}$ **Multiplier:** 1 to 10^6 in decade steps. **Self check:** counts 100 kHz for 10 μs to 10 s depending on multiplier setting.	**Range:** Channel A (F_A): 0 to more than 2 MHz; Channel B (F_B): 0 to 2 MHz (multiple period), 0 to 1 MHz (X10), 0 to 100 kHz (X1). **Input:** Channels A and B. **Measures:** $\frac{F_A \text{ (multiplier)}}{F_B}$ **Reads:** $\frac{F_A}{F_B}$ or $\frac{1000F_A}{F_B}$, depending on multiplier setting. **Accuracy:** ±1 count of $F_A \pm \frac{\text{trigger error of } F_B}{\text{multiplier setting}}$ **Multiplier:** 1 to 10^7 in decade steps. **Self check:** counts 1 MHz for 10 μs to 10 s, depending on multiplier setting.
Manual	**Input:** Channel A. **Multiplier:** prescales input of Channel A in decades, 1 to 10^6. **Totalize:** periodic events at rates to more than 3×10^5/s; random events with pulse spacing of 3.3 μs or more.	**Input:** Channel A. **Multiplier:** prescales input of Channel A in decades, 1 to 10^7. **Totalize:** periodic events at rates to more than 2×10^6/s; random events with pulse spacing to 0.5 μs or less.
Time base	**Frequency (internal):** 100 kHz. **Stability:** aging rate: <±2 parts in 10^8/week; as a function of line voltage: <1 part in 10^6 for 10% changes in line; as a function of ambient temperature: <±20 parts in 10^6 (+15°C to +35°C), <100 parts in 10^6 (−20°C to +65°C). **External input:** sensitivity: 1 V rms, sine wave into 1 K ohm; range: 100 Hz to 300 kHz, sine wave. **Outputs, rear panel** **Oscillator:** 100 kHz, 1 V peak to peak, open circuit; time base (separate BNC connector): 0.1 Hz to 100 kHz in decade steps, 5 V peak open circuit, 1 μs width; 1000-ohm source; available in Period, Time Interval, and Manual without reset interruptions.	**Frequency:** (internal): 1 MHz. **Stability:** aging rate: <±2 parts in 10^7 per month; as a function of line voltage <±1 part in 10^7 for changes of ±10%; as a function of ambient temperature: <±2 parts in 10^6 (+10° to +50°C), ±20 parts in 10^6 (0° to +65°C). **External input:** range: 100 Hz to 1 MHz, sine wave; sensitivity: 1 V rms above 1 kHz; 2 V rms, 100 Hz to 1 kHz. **Outputs, rear panel** **Oscillator:** 1 MHz, 3 V p-p; time base (separate BNC connector): 0.1 Hz to 1 MHz in decade steps, 5 V p-p, 600-ohm source; available in Period, Time Interval, and Manual without reset interruptions.
Scaling	**Range:** 0 to 300 kHz. **Function setting:** Manual. **Input:** Channel A. **Factor:** by decades up to 10^6. **Output:** rear panel in place of time base output frequencies.	**Range:** 0 to >2 MHz. **Function setting:** Manual. **Input:** Channel A. **Factor:** by decades up to 10^7. **Output:** rear panel in place of time base output frequencies 5 V p-p from 600 ohms.
General	**Printer output** **Output:** 4-line 4-2-2-1 BCD, 100 k each line; "0" state level: approx. −28 V; "1" state level: −2 V. **Reference levels:** approx. −2.4 V, 350-ohm source impedance, and −26.9 V, 1000-ohm source. **Print command:** +28 V step from 2700-ohm source in series with 1000 pF. **Hold-off requirements:** chassis ground to +12 V maximum. **Registration:** 5 long-life rectangular digital tubes with display storage. **Sample rate:** time following a gate closing during which the gate may not be reopened is continuously variable from less than 0.2 s to 5 s, independent of gate time; display can be held indefinitely. **Self check:** in all function and multiplier positions. **Operating temperature range:** −20°C to +65°C. **Power:** 115 or 230 V ±10%, 50 to 60 Hz***; 40 watts. **Dimensions:** 16¾" wide, 3-15/32" high, 11¼" deep (425 x 86 x 285 mm). **Weight:** net 16 lbs (7.2 kg); shipping 22 lbs (10 kg). **Price:** Model 5223L, $1325.00. **Option 02.:** 1-2-4-8 BCD output ("1" state positive), in lieu of 1-2-2-4 BCD output, add $10.†	**Printer output** **Output:** 4-line 4-2-2-1 BCD, 100 k each line; "0" state level: approx. −8 V; "1" state level: approx. +18 V. **Reference levels:** approx. +13 V, 900-ohm source impedance, and approx. −5 V, 1200-ohm source impedance. **Print command:** +28 V step, 2700-ohm source impedance; 1000 pF in series. **Hold-off requirements:** from +2 V to −20 V. **Registration:** 6 long-life rectangular digital tubes with display storage. **Measurements unit:** unit readout for frequency, period, period average, and time interval with positioned decimal point. **Sample rate:** time following a gate closing during which the gate may not be reopened is continuously variable from less than 0.2 s to 5 s; independent of gate time; display can be held indefinitely. **Self check:** in all function and multiplier positions. **Operating temperature range:** 0°C. to +65°C. **Power:** 115 or 230 V ±10%, 50 to 60 Hz,***; 50 watts. **Dimensions:** 16¾" wide, 3-15/32" high, 11¼" deep (425 x 86 x 285 mm). **Weight:** net 19 lbs (8.5 kg); shipping 24 lbs (11 kg). **Price:** Model 5233L, $1675.00. **Option 02.:** 1-2-4-8 BCD output in lieu of 1-2-2-4 BCD, add $10.†

* For any wave shape, trigger error is less than $\pm \frac{0.0025}{\text{signal slope } (V/\mu s)}$ μs; below 0.1 Hz maximum error may increase up to 10-fold, depending on line voltage and environmental conditions.

**With trigger level set at zero, either slope, trigger error for sine wave input is less than $\pm \frac{0.3\% \text{ of one period}}{\text{periods averaged}}$ at rated sensitivity for signals with 40 dB signal-to-noise ratio.

*** Line frequency limit imposed by cooling fan.

† Option 03.—same as 02, except "1" state negative, add $10.

ELECTRONIC COUNTERS

Low cost, IC, modular 10 MHz counters

Models 5221A/B, 5321A/B, H01-5321A, K01-5221A — K04-5221A

Advantages:

- High count rate at low price
- Compact, rugged, lightweight
- Blanking of insignificant zeros
- Crystal controlled gate in some models
- BCD output is standard in some models

These four HP counters make extensive use of integrated circuits resulting in instruments which are lightweight, compact, reliable in service, and low cost. They feature a greater frequency range and more measurement versatility than were formerly available in low-cost counters. All four counters have a sinusoidal frequency measurement range of 5 Hz to 10 MHz. Minimum input sensitivity over this range is 100 mV with an input impedance of 1 MΩ shunted by 30 pF. Pulses can be counted at repetition rates over this range and at any lesser rate. Longlife neon digital display tubes provide a bright and very legible readout.

Use of integrated circuits in these counters made possible the incorporation of sophisticated display and storage features not usually found in such low cost instruments. Readout storage provides a continuous display of the most recent measurement which is held even while the instrument is gating for a new count. The display changes only if the new count differs from the old. A unique blanking feature suppresses the display of all unwanted zeros to the left of the count total. Blanking and display storage can be disabled with a rear panel switch. Models 5221B and 5321B have, in addition, BCD output in the 8-4-2-1 code.

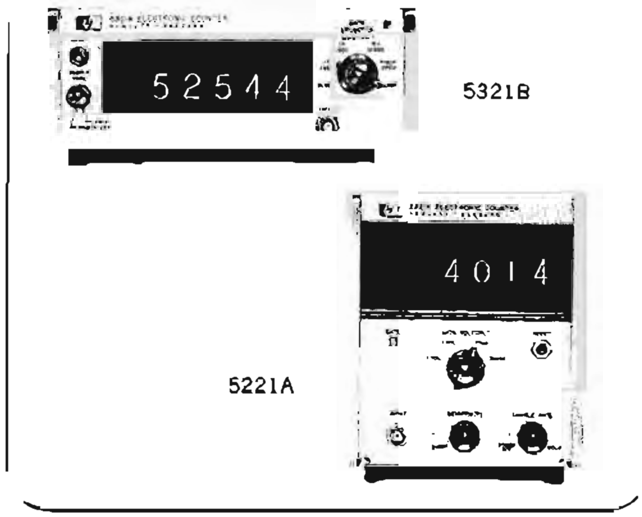
A sample rate control sets the length of time between counts. It is adjustable from approximately 50 ms to 5 s, and is independent of gate time. A hold position allows the display to be held indefinitely. All four counters include a check function where the counter counts its own time base for time interval measurements and for reassurance of proper operation of the instrument.

In electrical design Models 5221A and 5321A are identical; and Model 5221B is electrically the same as Model 5321B. For each of these versions there are available two types of cabinets. Models 5221A and 5221B are housed in HP's standard 1/3 width module enclosures, while Models 5321A and 5321B are housed in HP's standard 1/2 width module enclosures. Thus, they may be mounted in a variety of combinations using the HP 5060 Series of adapter frames, filler panels, and accessory drawers (refer to Modular Enclosure Systems in this catalog) Up to four units may be installed in a single adapter frame.

The lower cost 5221A/5321A Counters make frequency and time interval measurements using the power line frequency as a time base. A crystal time base is optional. For frequency, gate times of .1 s and 1 s are available, and with the gate open, input pulses are totalized. Time interval is measured by controlling gate time externally at a rear panel connector.

Models 5221A and 5321A include a 4-digit display as a standard feature. When the count is higher than can be totally displayed, the readout is the 4 least significant figures. Optional displays of 5 and 6 digits are offered. With the .1 s time base for 4, 5, and 6 digits respectively the maximum frequencies for full display are 99.99 kHz, 999.99 kHz, and 9.99999 MHz.

Models 5221B and 5321B Counters include a high quality room temperature quartz crystal time base with an aging rate of less than 1 part in 10^6 per month. Also featured are a calibrated 3-decade sensitivity switch and selectable gate times from .01 s to 10 s for frequency measurements. Also the gate



may be opened and closed manually for totalizing input pulses. Time interval is measured by controlling gate time externally at a rear panel connector. The ratio of two frequencies may be measured: a switch replaces the internal time base with the external signal source for gate control, inserted at the rear panel. The gate selector divides this external time base signal in decade steps of 10^4, 10^5, 10^6, and 10^7.

Models 5221B and 5321B include a 5-digit display as standard with the option of a 6-digit display. With .01 s gate time and the standard 5-digits the instruments will display the count fully up to 10 MHz with a 100 Hz resolution. A 6-digit display and .1 s gate time will give the full count up to 10 MHz at a 10 Hz resolution

H01-5321A

Measures high frequencies at minimum cost; e.g. monitors frequency of HP 8601A, a 0.1 to 110 MHz generator/sweeper with a divided by 10 auxiliary output. It is similar to the 5321A with Option 02 and Option 03 with the following exceptions: guaranteed to count to 11 MHz; gate times of .01 s and .1 s, and rear panel BNC paralleled with input connector. Price: $705.

K01-5221A to K04-5221A

These are counter boards for built-in use. Models K01-5221A, K02-5221A, and K03-5221A are identical to the main board used in the 5221A/5321A Counter with 4, 5, and 6 digit displays, respectively. The same features are offered except for off-board controlling switches, controls, and input amplifier. Required inputs to the single printed board connector are: input signal to be counted between +3 V and +5 V amplitude, 40 ns minimum pulse width, less than 10 ns rise and fall times; 5.1 V dc at 750 mA, 170 V dc at 1.5 mA for display tubes; 9 V rms at 60 Hz for the time base.

Model K04-5221A input amplifier board gives the same input characteristics as the 5221A Counter for the above counter boards. It eliminates the need for preshaping input signals and provides a 1 MΩ, 30 pF input impedance.

Prices:		
	K01-5221A	$300
	K02-5221A	$350
	K03-5221A	$400
	K04-5221A	$ 30

Specifications

Models 5221A, 5321A

Frequency measurement

Range: 5 Hz to 10 MHz.*
Input: .1 V rms max. sensitivity; 1 MΩ/30 pF.
Gate time: 1 s and 0.1 s derived from 60 Hz line frequency.
Accuracy: ±1 count ± power line frequency accuracy. (Line frequency accuracy is typically better than 0.1% for commercial power in the U.S.)

Time interval measurement

Range: 1 to 9999 counts at 1/60 s each (1 μs with Opt. 03).
Input: with GATE SELECTOR switch in OPEN, grounding EXTERNAL GATE BNC connector closes gate.
Frequency counted: 60 Hz (1 MHz with Opt. 03).
Accuracy: ±1 count ± time base accuracy ± accuracy of external gate control signal.
Readout: multiply reading by 16.7 for ms interval.
Reset: press front panel RESET switch to reset counter to zero after each reading.
Time base: 60 Hz power line frequency.

General

Display: 4 digits (5 and 6 available) with display storage, and automatic blanking of leading zeros. Rear panel switch disables blanking and display storage.
Sample rate: 50 ms to at least 5 s. Automatic or manual reset.
Signal input
Sensitivity: .1 V rms sine wave maximum sensitivity from 5 Hz to 10 MHz.
Pulses: 300 mV peak voltage (internal control adjusts for positive or negative pulses); 50 ns minimum pulse width.
Impedance: approximately 1 MΩ shunted by 30 pF.
Attenuation: continuous attenuator on front panel for counting from 100 mV to 250 V rms (approx.).
Overload: at maximum sensitivity, input should not exceed 3.5 V rms to retain rated input impedance. Damage level is 15 V rms maximum sensitivity and 250 V rms at minimum sensitivity.
Self check: counts power line frequency (crystal frequency with Option 03).
Operating temperature range: 0°C to 50°C.
Power requirements: 115 or 230 V ±10%, 60 Hz, 12 W max.
Weight: net 5¼ lbs (2,4 kg); shipping 7¾ lbs (3,5 kg).
Accessories supplied: 7½ feet (231 cm) power cord. HP 10503A, 4 feet (122 cm), 50 Ω BNC to BNC cable.
Price: HP Model 5221A, $425; 5321A, $425.
Dimensions:
5221A: 5⅛″ (130 mm) wide, 6³/₃₂″ (155 mm) high, 8″ (203 mm) deep.
5321A: 7¾″ (197 mm) wide, 3″ (76 mm) high, 11″ (279 mm) deep.

Options

01: 5-digit display, add $75.
02: 6-digit display, add $125.
03: 1 MHz crystal time base (same as 5221B/5321B), add $100.00.
10: 50 Hz operation, add $25.

5221B, 5321B

Frequency measurement

Range: 5 Hz to 10 MHz.*
Input: .1 V rms sensitivity; 1 MΩ/30 pF.
Gate time: rotary switch; .01, .1, 1, 10 seconds.
Accuracy: ±1 count ± time base accuracy.
Readout: 5 digits; 6 digits (Option 01).

*Sinusoidal signal range for rated sensitivity. Pulses can be counted over this range and at any lesser repetition rate.

Ratio measurement

Displays: M x f_a/f_b; M can be 10^4, 10^5, 10^6, 10^7.
Range: f_a: 5 Hz to 10 MHz; f_b: 1 kHz to 1 MHz.
Sensitivity: f_a: 0.1 V rms/1 MΩ; f_b: 1 V rms/1 kΩ.
Accuracy: ±1 count of f_a ± trigger error of f_b.
f_b applied to EXT. TIME input on rear panel.
f_a is applied to INPUT on front panel.

Time interval measurement

Range: 5 μs to 99,999 μs (5 digits), 5 to 999,999 μs (6 digits).
Input: with GATE SELECTOR switch in OPEN, grounding EXTERNAL GATE BNC connector closes gate.
Frequency counted: 1 MHz.
Accuracy: ±1 count ± time base accuracy ± accuracy of external gate control signal.
Readout: time interval in μs.
Reset: press front panel RESET switch to reset counter to zero after each reading.

Time base

Crystal frequency: 1 MHz.
Stability: aging rate: <|1| part in 10^8/month; Temperature ±3 parts in 10^5 (0°C to 50°C) ±5 parts in 10^6 (10°C to 40°C); Line Voltage: <±1 part in 10^6 for ±10% variation in line voltage.
Output frequencies: 1 MHz, 3 V p-p open circuit, 100 Ω.
External input: sensitivity: 1 V rms into 1 kΩ (10 V rms max).
Range: 1 kHz to 1 MHz.

General

Display: 5 digits (6 optional). Display storage and blanking are standard. Rear panel switch disables both.
Sample rate: 50 ms to at least 5 s, automatic or manual reset.
Signal input: sensitivity: 0.1 V rms sine wave from 5 Hz to 10 MHz. Stepped attenuator on front panel (.1, 1, 10 V rms) permits counting from 0.1 V to 300 V rms (approx.); Pulses: .3 V p-p voltage; internal adjustment for + or — pulses; 50 ns min. pulse width. Impedance: 1 MΩ shunted by 30 pF.
Overload level: input not to exceed 100 times attenuator setting to retain input impedance. Damage level: 15/300/300 V at attenuator settings of 0.1/1/10 V.
Self-check: counts 1 MHz for selected gate time.
Digital output: code: 8-4-2-1 "1" level positive; "0" Level: 0 V open circuit, 5.1 kΩ; "1" Level: 5 V open circuit, 7.6 kΩ; Reference Levels: Ground, +5 V. Print Command: Step from 5 V to 0 V, dc coupled; 5 kΩ at 5 V. Hold-off Requirements: >2 V dc inhibits gate opening; 56 kΩ.
Chassis connectors: special HP-manufactured 36-pin connector consisting of: 1 each HP part Nos. 1251-0334 and 1251-1115; 2 each 10513-4001.
Operating temperature range: 0°C to 50°C.
Power requirements: 115 or 230 V ±10%, 50 — 400 Hz, 17 W max.
Weight: net 5.5 lb (2,5 kg); shipping, 8 lb (3,6 kg).
Accessories furnished: power cord 7½ feet (231 cm) long. HP 10503A, 4 feet (122 cm), 50 Ω BNC to BNC cable.
Price: Models 5221B and 5321B, $775.
Dimensions:
5221B: 5⅛″ (130 mm) wide, 6³/₃₂″ (155 mm) high, 8″ (203 mm) deep.
5321B: 7¾″ (197 mm) wide, 3″ (76 mm) high, 11″ (279 mm) deep.
Option 01: 6 digit display, add $75.00.
Accessories available: HP cable 10513A to connect to 562A/AR and 5050A Digital Recorders. Price: $65.00.

FREQUENCY

ELECTRONIC COUNTER
Versatile, IC, 12.5 MHz counter
Model 5216A

5216A

Advantages:

Precision measurements: frequency, period, multiple period average, ratio, multiple ratio, time interval
Crystal time base
10 mV sensitivity
Blanking of insignificant zeros
BCD output (standard)

Model 5216A is a general purpose counter capable of a variety of measurements. It is designed extensively with integrated circuits providing the advantages of smaller size, less weight, and higher reliability.

The 5216A has a maximum counting rate of 12.5 MHz. Minimum input sensitivity is 10 mV rms which may be raised in decade steps to 10 V rms with a front panel control. Gate times offered for frequency measurements are in decade steps from .01 s to 10 s, which are derived from a high stability quartz crystal oscillator. This counter will also measure single periods and average up to 10^5 periods.

Internal storage, which may be disabled if desired, results in a continuous display of the most recent measurement on the 7-digit readout. At the same time the information is available in 4-line BCD code at the rear panel.

The 5216A is housed in a standard ½ module cabinet, which is convenient for bench use and easily rack mounted using the HP 5060-0797 adapter frame.

Specifications

Frequency measurement

Range: 3 Hz to 12.5 MHz.
Input: 10 mV rms sensitivity; 1 MΩ/50 pF.
Gate times: 10, 1, 0.1, 0.01 s.
Accuracy: ±1 count ± time base accuracy.
Readout: MHz and kHz with positioned decimal point.

Time interval measurement

Range: 10 μs to 10 s.
Input: contact closure or saturated NPN transistor to ground. Signal duration ≥1 μs. Current ≥2 mA. START signal must end before STOP signal begins. Time from STOP to next START: ≥30 ms for external reset or ≥30 ms + sample time for internal reset. Rear panel BNC inputs.
Frequency counted: 1 MHz internal, or external standard.

Period measurement

Range: 3 Hz to 1 MHz single period; to 2 MHz in multiple periods averaged.
Periods averaged: 1, 10, 10^2, 10^3, 10^4, 10^5.
Input: 10 mV rms max. sensitivity; 100 mV rms <1 kHz.
Frequency counted: 1 MHz internal, or external standard.
Accuracy: ±1 count ± time base accuracy ± trigger error.

Ratio measurement

Displays: (f_1/f_2) x multiplier; multiplier: 1-10^5.
Range, sensitivity: f_1: 1 kHz to 10 MHz into external time base BNC connector, 1 V rms minimum into 1 KΩ. f_2: 3 Hz to 1 MHz single period; to 2 MHz in multiple period; 10 mV rms sensitivity except 100 mV rms below 1 kHz.
Accuracy: ±1 count of f_1 ± trigger error of f_2.

Time base

Crystal frequency: 10 MHz.
Stability
Aging rate: <±|1| x 10^{-6}/month.
Temperature: < ±5 x 10^{-6} from +10°C to +40°C; <±3 x 10^{-5} from 0°C to +50°C.
Line voltage: <1 x 10^{-6} for ±10% change.
Output frequency: 1 MHz, 3 V p-p minimum open circuit; source impedance is 2 kΩ max.
External standard input: 1 kHz to 2 MHz sinewave, 1 V rms into 1 kΩ (10 V rms maximum).

General

Display: 7 digits, long-life Nixie® tubes.
Display storage, blanking: yes.
Reset: automatic or manual by pushbutton or remote.
Sample time: 50 ms to 5 s or hold until reset.
Signal input
Sensitivity: 10 mV rms max.; 30 mV peak pulse, min. width 40 ns.
Impedance: approx. 1 MΩ shunted by 50 pF.
Attenuation: step attenuator, .01, 0.1, 1, 10 V rms.
Trigger level adjustment: continuously variable within stepped attenuator ranges.
Overload: input voltage should be <60 dB above attenuator setting 300 V rms may cause damage.
Self-check: works on all functions.
Digital output
Code: 8-4-2-1, "1" state positive; "0" level: 0 V nominal; "1" level: +5 V open circuit, nominal; source impedance: 7.5 kΩ maximum, each line.
Reference levels: ground; +5 V, low impedance.
Print command: step from 0 V to +5 V, dc coupled.
Hold-off requirements: voltage from −10 V to −15 V.
Chassis connector: accepts HP Cable 10513A with one special connector for the 5216A and one 50 pin Amphenol or Cinch type 57-30500-375, HP part number 1251-0086, male connector, for HP 5050B or 562A Digital Recorder.
Operating temperature range: 0°C to +50°C.
Power requirements: 115/230 V ±10%, 50 - 400 Hz, 20 W maximum.
Weight: net 7 lbs (3,1 kg); shipping 8½ lbs (3,9 kg).
Accessories furnished: HP 10503A 4 feet, 50Ω cable, BNC connectors. Detachable power cord 7½ feet (231 cm) long, NEMA plug.
Dimensions: 7-25/32" (190 mm) wide, 6-3/32" (155) high, 11" (279) deep.
Price: HP Model 5216A, $985.

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ELECTRONIC COUNTERS

Versatile, low cost, 1.2 MHz and 300 kHz counters

Models 5211A,B, 5212A, 5512A, 5232A, 5532A

Advantages:

- Reliable, rugged
- High input impedance, high sensitivity
- Low power consumption with solid-state components
- Display storage
- Accurate measurement of frequency, ratio, period, multiple period
- Higher sampling rates; sampling time independent of gate time

These six Hewlett-Packard electronic counters offer the advantages of solid-state construction, broad measurement capabilities, rugged and compact packaging and a wide selection of performance characteristics.

Maximum counting rate ranges from 300 kHz to 1.2 MHz. A variety of visual readouts contain from 4 to 6 digits, with both in-line digital tube and neon columnar displays. Features offered in common by all six counters include modular cabinets only 3½" high, low heat dissipation and power consumption with solid-state components, 0.1 V sensitivity, display storage for non-blinking readout, four-line BCD output for systems and recorders (optional for 5211A), flexible operation and reduced operator errors. When a counter is in the frequency mode, the time between counts is adjustable from less than 0.2 second to more than 5 seconds and is independent of gate time. Because time between counts is not dependent upon gate time, faster sampling rates are often possible.

The instruments are compact and reliable, have low power consumption and can operate with specified accuracy over a wide temperature range. Plug-in module construction increases instrument versatility and simplifies maintenance. Conservative design features such as the use of decade dividers in the gate generating circuits, provide operational stability and eliminate calibration problems. Input sensitivity is 0.1 V rms, input impedance, 1 megohm, 50 pF.

5211A,B Counters

Models 5211A and 5211B have a maximum counting rate of 300 kHz and make direct frequency and ratio measurements. They also measure speed in rpm and rps, when used with transducers, and count events occurring within a selected period of time. They offer four-digit resolution and neon columnar display. They are identical except for gate times and recorder output. The 5211A has gate times of 0.1 and 1 second; the 5211B has a third gate time of 10 seconds.

Both offer manual control of the gate by a front-panel function switch, by external contact closure or by 3 volt peak positive pulses at least 10 μs wide at half-amplitude points. Time base is derived from the power line, and since power line frequency is usually held to better than 0.1%, the counters have an accuracy fully adequate for most industrial measurements. A special modification of the 5211B, the H22-5211B, offers an in-line readout.

5212A, 5512A, 5232A, 5532A Counters

With this group of solid-state instruments, two basic counters give maximum counting rates of 300 kHz and 1.2 MHz, with a choice of column or in-line readout. Each makes direct frequency, period, multiple period average and ratio measurements. Models 5212A and 5512A have a maximum counting rate of 300 kHz, 5-digit resolution and respective displays of neon columns and long-life digital display tubes. Models 5232A and 5532A have maximum counting rates of 1.2 MHz and 6-digit resolution with the same readout choice.

The front panel of each counter has input attenuation control, display control, reset button and function switch. In the rear are the storage-disable switch, external standard input jack (permits use of an external oscillator as the counter time base) and digital recorder output connector. Self-check is provided for both frequency and period measurement modes.

General specifications

Operating temperature range: −20°C to 50°C for 5211A, B; −20°C to +65°C for 5212A and 5512A; 0°C to +65°C for 5232A and 5532A*.

Power: 115 or 230 V ±10%, 50 to 60 Hz**, less than 40 W.

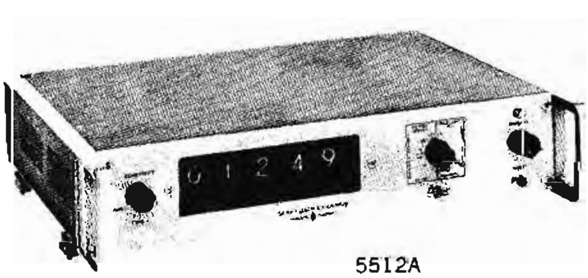
Weight: all models, net less than 15 lbs (6,8 kg), shipping less than 21 lbs (9,5 kg).

Accessories furnished: 10503A Cable, 4 feet long, BNC connectors; detachable power cord; circuit board extender.

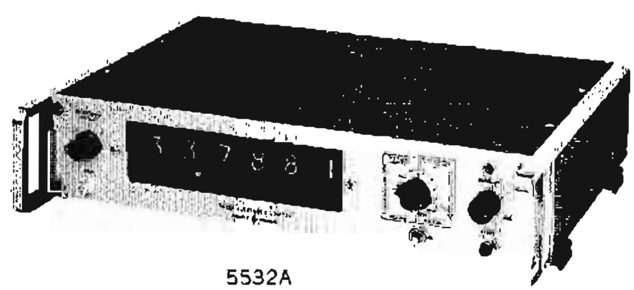
Dimensions: 16¾" wide, 3½" high, 11¼" deep (425 x 89 x 286 mm); hardware furnished for converting to 19" wide by 3½" high rack mount.

*The 5232A and 5532A will operate from −20°C to +65°C on special order or with an external time base.

**HP 5211A,B require 50 or 60 Hz operation (specify Option 01, for 50 Hz operation); 5212A, 5512A, 5232A and 5532A operate between 50 and 60 Hz line frequency with limit imposed by fan.

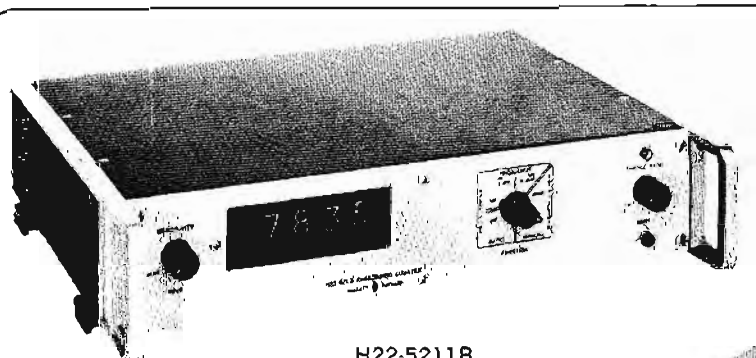


5512A

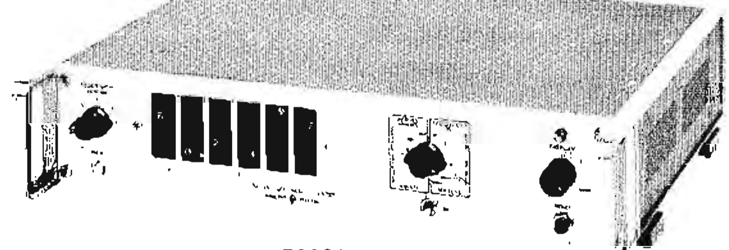


5532A

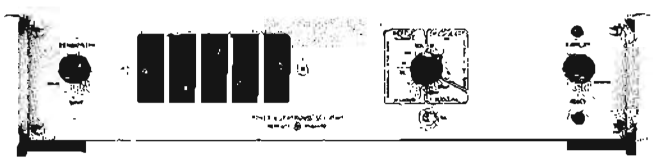
HP Counter		5211A,B	5212A	5512A	5232A	5532A
Max. counting rate		300 kHz	300 kHz	300 kHz	1.2 MHz	1.2 MHz
Registration		4 digits columnar	5 digits columnar	5 digital display indicators	6 digits columnar	6 digital display indicators
Time base		power line; accuracy typically $\pm$0.1% or better	100 kHz crystal oscillator; aging rate, $\pm 2 \times 10^{-6}$/week		1 MHz crystal oscillator; aging rate, $\pm 2 \times 10^{-7}$/month	
Input		sensitivity, 0.1 V rms sine wave; input impedance approx. 1 meg/50 pf				
Period and multiple period average measurement	Range	—	2 Hz to 300 kHz		2 Hz to 1.2 MHz	
	Periods averaged	—	1, 10, 10^2, 10^3, 10^4, 10^5			
	Accuracy	—	$\pm$ one count, $\pm$ time base accuracy, $\pm$ trigger error			
	Readout	—	msec or μsec with positioned decimal			
Frequency measurement	Range	2 Hz to 300 kHz			2 Hz to 1.2 MHz	
	Gate time	1, 0.01 sec; 5211B, additional 10 sec	10, 1, 0.1, 0.01 sec			
	Accuracy	$\pm$ 1 count, $\pm$ time base accuracy				
	Readout	KHz, Hz with positioned decimal	KHz with positioned decimal			
Ratio measurement	Display	f_1/f_2	f_1/f_2 x multiplier: multiplier: 1-10^5			
	Range, Sensitivity	f_1: 2Hz to 300 kHz (0.1 V rms); f_2: 100 Hz to 300 kHz (1 V rms into 1000 ohms)	f_1: 100 Hz to 300 kHz (1 V rms into 1000 ohms); f_2: 2 Hz to 300 kHz		f_1: 100 Hz to 1.2 MHz (1 V rms into 500 ohms above 1 kHz, 2 V rms into 500 ohms 100 Hz to 1 kHz); f_2: 2 Hz to 300 kHz	
	Accuracy	+1 count of f_1, $\pm$ trigger error of f_2				
Recorder output (optional at added cost in 5211A; standard in all other models)		4-line BCD (4-2-2-1); 4-line BCD (8-4-2-1) available as Option 02				
	Impedance	100 K each line				
	"0" state level	approximately − 28 volts				
	"1" state level	−2 volts				
	Reference levels print command	approximately −2.4 volts, 350-ohm source impedance; and approximately −26.9 volts, 1000-ohm source impedance				
		+28 V step, from 2700-ohm source in series with 1000 pF				
	Hold-off requirements	chassis ground to +12 volts maximum				
Price	H22-5211B, $850	HP 5211A, $650 HP 5211B, $750	HP 5212A, $950	HP 5512A, $1050	HP 5232A, $1350	HP 5532A, $1450



H22-5211B



5232A



5212A

PRESET CONTROLLERS/COUNTERS
Versatile, accurate, fast
Models 5331A/B, 5332A/B

These preset controllers/counters count electrical events and issue output signals when preset count values are reached; the 5332A and 5332B also measure and limit-detect input rates or frequencies. They provide practically all the features required in digital control and measurement applications: local and remote control, three versatile operating modes, wide frequency and voltage counting range, very fast recycling, high input impedance and sensitivity, lighted overflow indicator, and BCD output for recording or further digital processing. Applications include batching and precise control of weight, liquid level, length, rate, frequency, etc. The counters can also generate precise time intervals (or delays) and pulse trains. Use of integrated circuits provides compactness and maximum versatility coupled with economy, low power consumption and low heat dissipation.

Four models

To suit a wide range of instrument needs at least cost, there are four models to choose from. Major differences are:

The "B" versions (5331B and 5332B) are dual preset controller/counters and have two sets of preset limits, while the "A" versions have but one set of preset limits.

The 5332A and 5332B have crystal time bases to permit measuring and limit-detecting frequencies (or rates) of random and limit-detecting frequencies (or rates) of random or periodic events from 0 to over 10 million pps at precise gate times of 0.01, 0.1, 1.0, and 10 seconds. They also measure and limit-detect single and multiple frequency ratios as well as time intervals from 10 μs to 1.0 second. The 5331A/B are strictly preset controllers and do not have these additional capabilities. Consequently, the 5331A/B front panels do not have the FREQUENCY, FUNCTION nor the SAMPLE RATE controls. The latter is replaced by an ON/OFF power switch.

Operating modes

The three operating modes provided facilitate use in a wide variety of control applications.

In the MANUAL position of the FUNCTION switch, the control line outputs change state when the count reaches the numbers set on the limit switches, and then counting continues. See Figure 1.

In HOLD, outputs are generated as in MANUAL, but counting stops when the greater preset limit number is reached. See Figure 1.

The RECYCLE mode is the same as MANUAL except that when the greater limit is reached and the output lines have changed state, the counter automatically resets to zero and repeats the cycle. See Figure 2.

The 5331A and 5332A are single preset controllers and have one limit switch each, but otherwise the operation remains the same as for the 5331B and 5332B, which are dual preset counters and have two limit switches, L1 and L2.

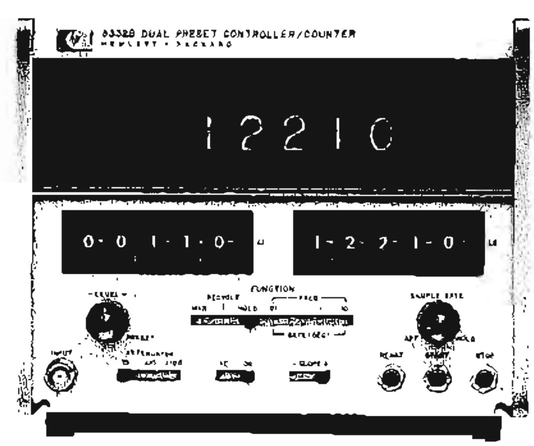
Control outputs

When the count reaches the preset limits, dc level changes occur on various output lines. There are two output lines, Lo and Hi, in the single limit 5331A and 5332A, and three lines, Lo, In, and Hi in the dual limit 5331B and 5332B. This choice of several types of electrical outputs can simplify external circuit design. The outputs are shown in Figures 1 and 2 and described under "Control Line Outputs" in the specifications.

In the FREQUENCY mode, and with the STORAGE switch on, the control outputs become latching and change only when the preset limits are reached. That is, under these conditions the outputs are unaffected by operations such as resetting the counter. Latching operation is desirable in automatic control system applications to eliminate the unwanted transient that occurs when the counter resets to zero before a new measurement. For non-latching operation, turn the STORAGE switch off; then, when the counter resets, the control line voltages return to their "pre-lower limit" values.

In some applications, latching operation is desired but the control lines are to remain in their "out of tolerance" condition until an external command is given, instead of automatically changing when the out of tolerance condition is corrected. For this purpose, there's a special reset line on the remote control connector and, after an internal jumper is removed, control

5331A



5332B

lines can be reset by external contact closure or DTL or TTL circuits (saturated NPN transistor to ground).

Use as a delay generator

The 5332A/B can generate time intervals or time delays with great accuracy and adjustability. In this operation, the counter counts an internal 100 kHz signal, and the change in voltage states that occur on the control line outputs when the count preset on the limit switch (or switches) is reached define the desired time interval or delay (see Figure 1, for waveshapes). For example, with the lower limit switch set to 1000 a control line level change occurs after 1000 cycles of the 100 kHz signal have occurred; i.e. in 0.01 s. Thus, the limit switch number represents the generated time interval in tens of microseconds. The time interval begins when the START button is pressed (or equivalent remote start signal is given) and ends when the preset limit (or limits) is reached. The counter HOLD mode is used.

In the 5332A/B the 100 kHz signal is derived from the time base precision quartz crystal oscillator, and is connected to the counter input when a rear panel switch is placed in its CHECK position. An internal 1 kHz or 10 kHz signal can be substituted by a simple wiring change. Or, 1 MHz can be obtained by connecting the rear panel FREQUENCY STANDARD BNC to the INPUT BNC and placing the rear panel switch at OPERATE (then, the limit switch settings express time intervals directly in microseconds). For longer time intervals use a suitable external signal lower than 1 kHz. Since the 5331A/B have no internal time base, an external frequency must be connected to the counter input for use as a time interval or delay generator.

Note that on the 5331B/5332B "IN" control line two intervals are generated: from RESET to LOWER LIMIT REACHED and from LOWER LIMIT REACHED to UPPER LIMIT REACHED.

Use as a pulse generator

In this use, the counters generate precision pulse trains. Principle of operation is similar to when used as a time interval or delay generator except that the counter RECYCLE mode is used: the counter counts a fixed frequency and voltages on the control lines change when the preset limit (or limits) are reached. Waveshapes are shown in Figure 2. The counted signal is a precise 100 kHz signal from the quartz crystal time base oscillator in the 5332A/B when a rear panel switch is in its CHECK position (1 or 10 kHz available by minor wiring change); in the 5331A/B an external frequency must be connected. When the counted frequency is 100 kHz, the limit switch settings represent pulse repetition rate in tens of microseconds.

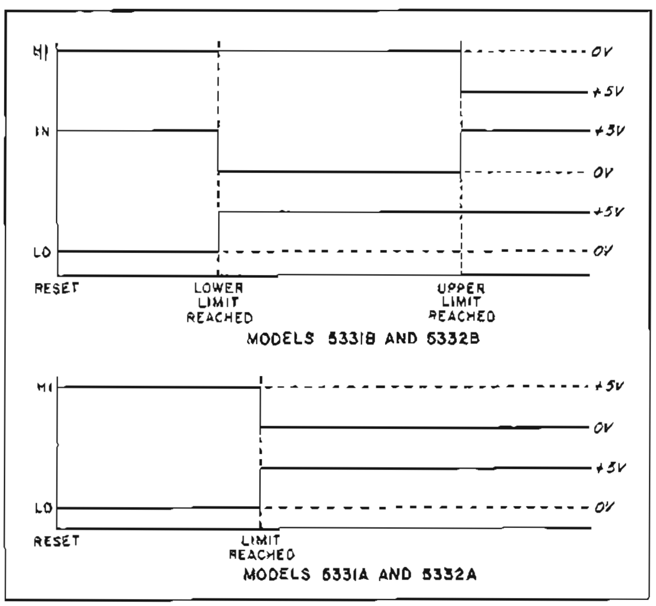


Figure 1. Control line outputs in MANUAL and HOLD modes.

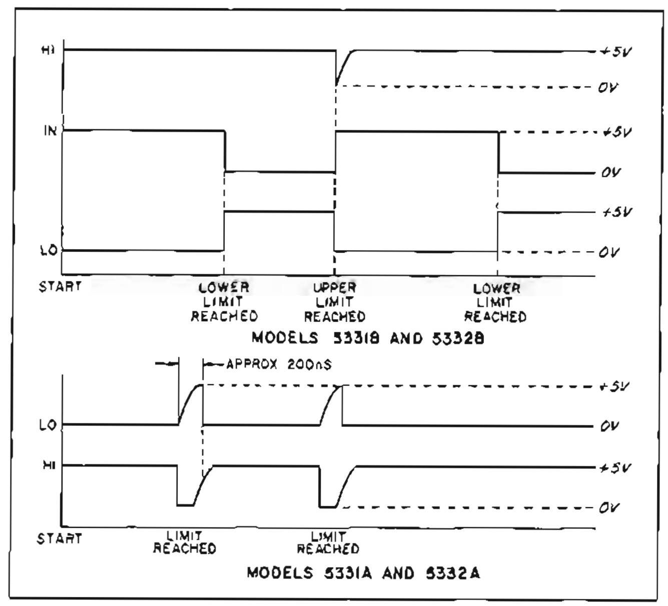


Figure 2. Control line outputs in RECYCLE mode.

Specifications

5332A and 5332B only

Frequency measurements

Range: 0 to 10 MHz for measuring; 0 to 2 MHz for limit detecting.

Gate times: 0.01, 0.1, 1, 10 seconds.

Accuracy: ±1 count ± time base accuracy.

Storage: holds readings between samples.

Time interval measurements (MANUAL mode)

Range: 10 μs to 1.0 second.

Input:

Start: START pushbutton or remote.

Stop: STOP pushbutton or remote.

Frequency counted: 100 kHz with rear panel OPERATE-CHECK switch at CHECK (1 and 10 kHz available by minor wiring change; or 1 MHz is available at FREQ. STD. connector with rear panel switch at OPERATE).

Accuracy: ±1 count ± time base accuracy ± any error in external trigger circuit.

Readout: time interval in microseconds (counting 100 kHz).

Ratio measurements (FREQUENCY mode)

Display: f1/f2 x multiplier M. M can be 10^4, 10^5, 10^6, 10^7.

Range and sensitivity:

f1: 0 to 10 MHz for measuring; 0 to 2 MHz for limit detecting.

0.1 V rms into 1 MΩ/30 pF.

f2: 1 kHz to 1 MHz.
1 V rms into 1 kΩ.
Accuracy: ±1 count ± trigger error of f2.*
Input:
f1: INPUT BNC.
f2: EXT. FREQ. STD. BNC.

Time base
Frequency: 1 MHz crystal oscillator.
Stability:
Aging rate: <|0.5| parts in 10^6/month.
Temperature: <±3 parts in 10^5 (0° to 65°C). <±5 parts in 10^6 (10° to 40°C).
Line voltage: <±1 part in 10^8 for ±10% line voltage variation.
Output: (for external use)
Frequency: 1 MHz.
Voltage: 3 V p-p open circuit.
Impedance: 100Ω source.
External Input: (to substitute external frequency for internal time base.
Sensitivity: 1 V rms into 1 kΩ (10 V rms maximum).
Range: 1 kHz to 1 MHz.

All models

Display: 5 digits (4 and 6 optional).
Overflow: indicator glows when register capacity of 99999 has been exceeded.
Sample rate (5332A and 5332B only): 1 ms to 5 seconds or HOLD.
Reset: RESET pushbutton or remote.
Signal Input:
Frequency range for rated sensitivity:

Mode	Freq.	Manual	Hold	Recycle
dc coupled, 0 Hz to:	2 MHz	2 MHz	1 MHz	500 kHz
ac coupled, 10 Hz to:	2 MHz	2 MHz	1 MHz	500 kHz

Impedance: 1 MΩ shunted by 30 pF.
Sensitivity: 0.1/1/10 V rms sine wave.
0.3 V p-p pulse, 50 ns minimum pulse width.
Maximum Input: 120 V rms X1 range
250 V rms X10 range
500 V rms X100 range
Overload protection: 1.5 V rms X ATTENUATOR settings.
Trigger level: PRESET to trigger at 0 V or adjustable:
± 1 V on X1 range
± 10 V on X10 range
±100 V on X100 range
Slope: independent selection of positive or negative slope.

Operating modes (selected at front panel or remotely):
Manual: control outputs are generated when the count reaches the number set on the limit switch or switches, but counting continues until reset manually.
Hold: control outputs are generated when the count reaches any preset limit; counting stops when the limit number is reached in 5331A, 5332A or when the greater limit number is reached in 5331B, 5332B.
Recycle: control outputs are generated when the count equals any preset limit; controller automatically resets to zero when the limit number is reached in 5331A, 5332A or when the greater limit is reached in 5331B, 5332B. The counting cycle then repeats.
Frequency: see Frequency Measurements.

Control line outputs
Nominal levels: +5 V and 0 V per Figure 1. Source impedance 2.5 kΩ for +5 V; can sink 10 mA at 0 V.
Cycling: per Figure 1 and 2:
When counter is reset, voltages return to the "pre-lower limit" values. Exception: when in FREQUENCY mode and with STORAGE switch on, the control line voltages "latch"; that is, they are stored and will change only if some future measurement falls into a different limit condition than the previous measurement (in FREQUENCY mode and with STORAGE off, control lines return to "pre-lower limit" values when counter is reset).
In RECYCLE mode, counter automatically resets when count exceeds the larger limit (the only limit in 5331A, 5332A); simultaneously, the Hi output line drops to 0 V momentarily.

Self check (5332A and 5332B only): connects internal 100 kHz to input (1 and 10 kHz available after minor wiring change).
Digital output (corresponds to readout display):
Code: 1-2-4-8 BCD, "1" state positive.
"0" level: 0 V, 5.1 kΩ maximum source impedance.
"1" level: 5 V, 7.5 kΩ maximum source impedance.
(Lower source impedance available on special order.)
Print command: step from +5 V to 0 V, dc coupled; impedance, 5 kΩ at +5 V.
Reference levels: ground and +5 V; negligible impedance.
Hold-off requirements: >2 V dc; 56 kΩ input impedance.
Chassis connector: special Hewlett-Packard-manufactured connector assembly.
Connectors: all are BNC's except for REMOTE FUNCTION which is HP #1251-0292 (Cinch or female Amphenol 57-40240) and DIGITAL OUTPUT. Mate for REMOTE FUNCTION connector is HP #1251-0293 (male Amphenol 57-30240).
Operating temperature: 0° to 50° C.
Remote operation: separate line for RESET, START, STOP and FUNCTION (switch set to MANUAL) operated by DTL or TTL circuits (saturated NPN transistor to ground) or contact closure to ground. See Options for remote control of limit switches.
Also, START and STOP lines can be connected together and driven as a single line with pulses <500 ns wide; first pulse starts counting, second pulse stops it.
5331A/B also have an additional control line; counting occurs as long as this line is held "low."
Power requirements: 115 or 230 V ±10%, 50 to 400 Hz, 22 W max.
Weight: net, 8 lb (3,6 kg); shipping, 10 lb (4,5 kg).
Accessories furnished: HP 10503A, 50Ω BNC to BNC cable, 4 ft (120 cm); detachable power cord, 7½ ft (230 cm).
Dimensions: 7-25/32" W x 6-3/32" H x 8.0" D (190 x 155 x 203 mm).
Prices: 5331A, $950; 5331B, $1,050; 5332A, $1,100; 5332B, $1,200.
Accessories available: HP 10513A Cable to connect HP 5050B Digital Recorder. Price: $65.
Option 01: add 1 digit of readout and limit switches (6 total), add $100.
Option 02: delete 1 digit of readout and limit switches (4 total), $75 less.
Option 03: remote control of 1 limit setting (4-line BCD), 5331A, 5332A, add $35.
Option 04: remote control of 2 limit settings (4-line BCD), 5331B, 5332B, add $50.
Other variations (contact closure limit outputs, etc.) on special order.

*Trigger error is caused by input signal noise and finite rise time, and it decreases as signal noise and rise time decrease or as signal amplitude increases. For a 100 mV rms sine wave input signal of <1 mV rms noise content (i.e., >40 dB signal-to-noise ratio) trigger error is <=0.3% (÷ M multiplier for ratio measurements) when level control is set to trigger on sinusoidal input signal zero crossing. Trigger error is extremely low for inputs that are clean pulses of short rise time.

PRESET COUNTER

Normalizes data; controls, counts and times

Model 5214L

Uses:

- Measures normalized rate
- Measures ratio
- Measures normalized ratio
- Measures time for N events to occur
- Counts N events, giving an output pulse at the start and the end of the count
- Allows N to be remotely preset (N may be set to any integer from 1 to 100,000)

Model 5214L Preset Counter not only measures frequency and period and totalizes, as do most universal electronic counters, but it also performs the additional measurement functions enumerated under "Uses". Such versatility is achieved by using two sets of decades; one set registers the signal being counted, the other, which may be preset to any integer from 1 to 100,000, controls the gate. Provision has been made so that the number N can be remotely programmed. Separate output signals also are available to operate external equipment whenever the gate opens or closes. Solid state circuits are used throughout.

Rate measurement

In rate measurements, which correspond to the frequency measurements of ordinary counters, gate time is controlled by the preset decades (N), the time base (100 kHz), and the multiplier (M). The gate is held open for N periods (N = 1 to N = 100,000) of the frequency furnished by the time base. If the internal 100 kHz time base is connected directly to the preset decades (M at X1), the gate time is set in 10 μs steps. Setting the Multiplier to X10 or X100 divides the time base frequency by 10 or 100 respectively, so that time may be set in 100 μs or 1 ms steps, as well. Setting gate time for 1 second permits frequency measurements directly in cycles per second.

Being able to select gate time allows you to normalize readings or to convert frequencies into practical units. For instance, if a tachometer generator, which produces 100 pulses per revolution, is connected to a rotating shaft, you can set the gate to 10.000 ms (0.01 s) and measure rps directly or you can set the gate for 600.00 ms (0.6 s) and measure rpm.

The long gate times that are available (up to 100 seconds) allow you to measure low frequencies or register the least significant digits of an input signal better to observe small variations of rate.

Ratio measurement

Model 5214L measures ratio over a wide range of frequencies and with a wide choice of normalizing factors. The signal connected to input B goes through the Multiplier switch and the preset decades, and controls the gate time; the signal connected to input A goes to the readout decades. Consequently, signal A is counted for a number of periods of signal B equal to the product of N and the Multiplier setting.

The number displayed by the readout decades is MNA/B, where A is the frequency of the signal connected to input A, and B is the frequency of the signal connected to input B. Gate length from 1 to 10^7 periods of signal B can be chosen in steps of 1, 10, or 100. Input B also can be used for extending gate time or for applications requiring an external time base.

Time measurement

In the Time function, which corresponds to period measurements in conventional counters, the hp 5214L measures the time in milliseconds for N events to occur. The measurement may be made in increments of 0.01, 0.1 or 1 ms by setting the Multiplier to X1, X10, or X100, respectively.

Period and multiple period measurements are also easily made with the function switch in the Time position, and period average is determined by dividing the time reading by N. The ability to choose the number of input cycles measured and to choose time increments of 0.01 ms, 0.1 ms, or 1 ms allows the operator to achieve the greatest accuracy possible, or to obtain a required accuracy in the shortest measurement time.

Preset counting

When the Function switch is set to Preset at N, the 5214L counts N events and provides an output pulse at the beginning and end of the preset count. This feature is useful in batching, as the gate signal can be used to control external equipment. Separate electrical output signals are available at the beginning and end of the count.

Display storage

All HP solid-state electronic counters have display storage which holds the most recent measurement even while the instrument is gated for a new count. If the new count differs from the stored count, the display will shift to the new reading directly. Where desirable, the storage feature may be disabled by a rear-panel switch.

Electrical readout

These counters provide a four-line BCD code output with assigned weights of 4-2-2-1 ("1" state positive with respect to "0" state). This output is suitable for systems use or for output devices such as HP 562A Digital Recorder, or the 580A, 581A Digital-to-Analog Converters. 8-4-2-1 BCD code output is also available at extra cost.

Specifications

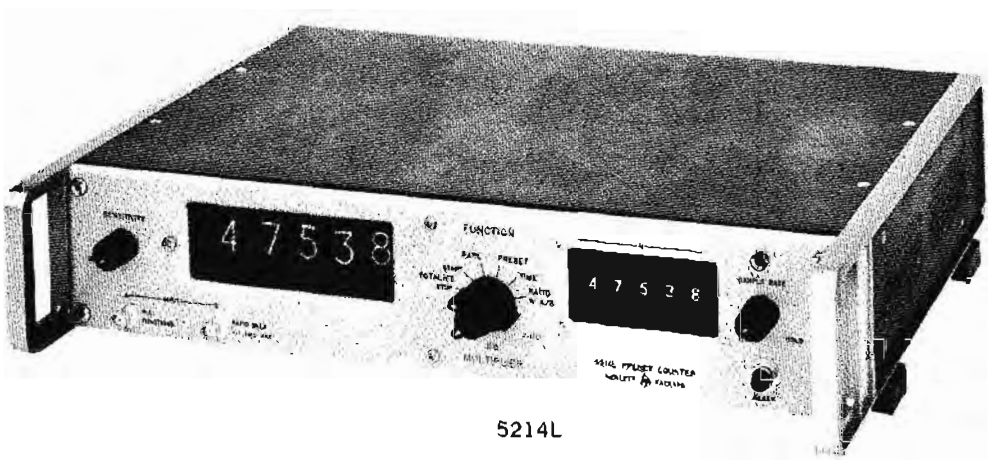
Functions

Totalize (input A)

Range: 2 Hz to 300 kHz.
Sensitivity: *0.1 volt rms sine wave.
Gate time: manual control.
Input impedance: 1 megohm, 50 pF shunt.
Capacity: 99,999 counts in units, tens or hundreds.

Rate (input A)

Range: 2 Hz to 300 kHz.
Sensitivity: *0.1 volt rms sine wave.
Gate time: 10 μs to 1 s in 10 μs steps; 100 μs to 10 s in 100 μs steps; 1 ms to 100 s in 1 ms steps.
Accuracy: ±1 count ± time base accuracy.
Input impedance: 1 megohm, 50 pF shunt.



5214L

Preset (Input A)

Input frequency range: 2 Hz to 100 kHz.

Sensitivity*: 0.1 V rms sine wave.

Reads: time for N events in ms.

Time units: 10 μs, 0.1 ms or 1 ms.

Input impedance: 1 megohm, 50 pf shunt.

Accuracy: ±1 count ± time base accuracy ± trigger error.†

Ratio

Display: N x A/B x Multiplier; Multiplier x N 1 to 10^7.

Input A: frequency range 2 Hz to 300 kHz; sensitivity, *0.1 V rms sine wave; input impedance, 1 megohm, 50 pf shunt.

Input B: frequency range, 2 Hz to 100 kHz on X1 (2 Hz to 300 kHz on X10 and X100); sensitivity, 0.1 V to 10 V rms; input impedance, 1 megohm, 50 pf shunt.

Accuracy: ±1 count.

Internal time base stability

Aging rate: <±2 parts in 10^6/ week.

Temperature: <±20 parts in 10^6 +15°C to +35°C; <±100 parts in 10^6 −20°C to +65°C.

Line voltage: <1 part in 10^6 for ±10% line.

General

Display: 5 long-life rectangular digital display tubes with display storage.

Sample rate: sample rate control determines length of time after gate closure before gate can be reopened; adjustable from 0.2 s min. to at least 5 s max. with counter in Rate, it is independent of gate time, and display can be held indefinitely.

Input connectors: BNC, on front and rear panels, wired in parallel.

Digital output

Output: 4-line 4-2-2-1 BCD; 8-4-2-1 BCD optional.

Impedance: 100 K each line; "0" state level: approx. −28 V; "1" state level: −2 V.

Reference levels: approx. −2.4 V, 350-ohm source impedance and −26.9 V, 1000-ohm source.

Print command: step from −29 V to −1 V from 2700-ohm source in series with 1000 pf.

Hold-off requirements: chassis ground to +12 V max.

Remote operation: number "N" can be remotely preset by appropriate contact closures.

Operating temperature: −20 to +65°C.

Power: 115 or 230 V ±10%, 50 to 60 Hz, 35 W (line frequency limit imposed by fan motor).

Weight: net 15 lbs (6,75 kg); shipping 22 lbs (10 kg).

Accessories provided: two 10503A cables, 4 feet long, BNC connectors, circuit board extender, detachable power cord.

Outputs: positive pulse approx. 10 V high and 5 μsec wide at gate opening and closing.

Dimensions: 16¾" wide, 3-13/16" high, 13¼" deep (426 x 97 x 337 mm); quickly converts to rack mount: 19" wide, 3½" high, 11¼" deep behind mounting surface (483 x 89 x 286 mm).

Price: HP 5214L, $1300.

Options

02. 8-4-2-1 BCD ("1" state positive) in lieu of 4-2-2-1, add $10.

03. Same as Option 02. except "1" state negative, add $10.

* Internal control allows trigger adjustment for negative or positive periodic pulses.

† Trigger error (sine wave) $< \frac{0.3\% \text{ of one period}}{N}$ for $\geq$ 40 dB signal-to-noise ratio on input signal; trigger error decreases with increased signal amplitude and slope.

REVERSIBLE COUNTER

Counts up, down at 2 MHz rate; very versatile

Model 5280A

The 5280A/5285A Reversible Counter/Plug-In combination has two input channels ("A" and "B") with an individual range of dc to more than 2 MHz. The superior trigger level controls for each channel allow the use of a wide range of inputs in all modes of operation. Drift of the differential dc amplifiers, used in the input circuitry, is unusually low to provide more accurate definition and retention of set trigger points.

Three basic types of measurement provide exceptional versatility.

Algebraic A, B

A: The A input is totalized, dc to more than 2 MHz, for the length of time the main gate is open.

A − B: The input A minus the input B is totalized, dc to 1 MHz each channel, for the gate open period. In this mode the 1 MHz rate is retained while reversing direction of count, and while passing through zero.

A + B: The input A plus the input B is totalized, dc to 1 MHz each channel, for the gate open period.

B: The B input is totalized, dc to more than 2 MHz, for the length of time the main gate is open.

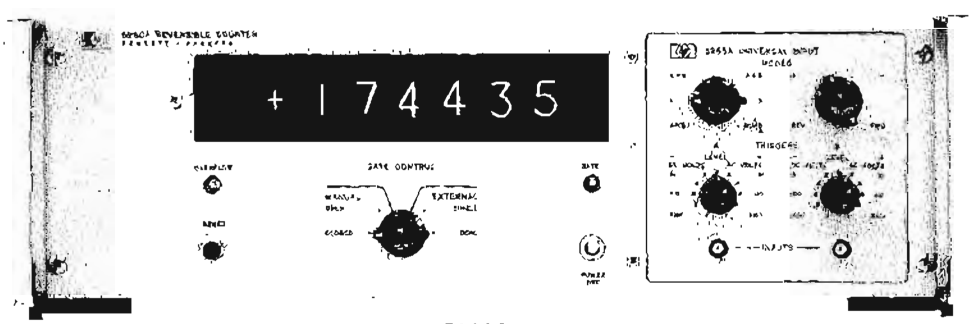
A directional MODE switch can be used to reverse the measurements in the above 4 modes, i.e., −A, −A+B, −A−B, and −B. In the A−B and A+B modes, an anti-coincidence circuit is used to prevent the loss of any counts that arrive at the inputs in time coincidence.

Af(B)

In this mode of operation, A is counted forward when the B input is more positive than its trigger level setting, and A is counted in reverse when B is more negative than its trigger level. (Inverse operation is possible). A unique count direction gating system is used to prevent the inherent propagation delay down the readout decades from limiting the input frequency capability of A. The maximum input to channel A in this mode is 2 MHz even when the 7th and 8th digits have been added to the readout. The count direction can be reversed without count error with a minimum of 250 ns between the reverse step function command and the next input pulse.

A Quad B

This mode of operation is designed to operate with transducers having two outputs separated 90° in phase (in quadrature). The A output is totalized, up or down, depending upon its phase relationship with the B input. When B leads A, A is totalized in a positive direction; when B lags A, A is totalized in a negative direction. (Inverse operation is possible.) The direction of count may be reversed at a 1 MHz rate, which is also the maximum frequency allowable on A and B.



5280A

Readout

Registration is by a 6-digit in-line display of rectangular Nixie tubes with a 7th and 8th digit of display available on request. Overflow of the displayed readout is indicated by a front panel neon light. A long-life Nixie® displays + or − corresponding to the algebraic sign of the readout.

Four-line, BCD-coded output including polarity and overflow is provided as a standard feature with the assigned weights of 1-2-4-8 ("1" state positive with respect to the "0" state). This output is suitable for systems use, or for output devices such as the Hewlett-Packard Model 562A Digital Recorder, the HO4-580A and HO4-581A Digital-to-Analog Converters.

Gating

Three gating modes are available, selected by a front panel switch. Manual "OPEN" and manual "CLOSED" operate the main gate for all functional modes of the plug-in operation. External "SINGLE" requires a dc voltage applied to a rear panel "START" input for the desired gate open period. In the external "DUAL" position separate inputs to two wires at the rear "START" "STOP" connectors are required to open and close the main gate. Reset may be accomplished by a front panel push button or by applying an input to a rear panel connector.

5285A Universal Input Plug-In

The 5285A Plug-In operates in conjunction with the 5280A Reversible Counter. Both units must be ordered; neither one will operate independently of the other.

Typical Applications

With laser interferometer for precision metrology.

With flow meters to measure and control liquid flow rates or volume in a tank.

With rotary optical encoders to measure and control position and velocity, for example, of rolls of paper.

For crystal frequency comparison in production testing.

With optical encoders or stepping motors to indicate position of numerically controlled machine tools.

With V to F converters to integrate dc voltages and thus obtain the average value of drift over a time period.

Request Application Note 85 for further discussion of applications.

Specifications

5280A Reversible Counter

General

Range: dc to 2 MHz Channel A or Channel B (see 5285A specifications for details concerning other input requirements).

Display: 6 long-life rectangular Nixie® tubes (7th and 8th digit of readout optional). + and − indication by long-life rectangular Nixie tube. Overflow indication by front panel neon light.

Reset: remote by contact closure or saturated NPN transistor to ground. Input via rear panel BNC. Manual by front panel pushbutton.

Reset time: less than 10 μs.

Inhibit: start channel is inhibited during reset time with the function switch in the DUAL position only. Inhibit released at end of reset time.

Gate light: gate light indicates main gate open.

Gate control

Manual: controlled by front panel function switch for OPEN and CLOSED positions.

External dual

Input: separate BNC's on rear panel for START and STOP inputs.

Sensitivity: sine wave 1 volt rms; pulse 2 V p-p.

Impedance: approximately 100 k ohms, 25 pF in shunt.

Trigger level: +10 volts to −10 volts, adjustable at the rear panel. Independent controls on each input.

Polarity: + or − rear panel switch selects triggering slope.

External single

Input: START BNC on rear panel.

Sensitivity: sine wave 1 volt rms; pulse 2 V p-p.

Impedance: approximately 100 k ohms, 25 pF in shunt.

Trigger level: +10 volts to −10 volts, adjustable at rear panel.

Polarity: + or − rear panel switch selects gate open polarity.

Gate: (+) opens when input is positive with respect to the trigger level. Closes when input is negative with respect to the trigger level. (−) inverse of (+). Manually switched dc voltage is a satisfactory gating input.

Printer output

Code: 4-line 1-2-4-8 BCD.

"0" state level: approximately −14 volts.

"1" state level: approximately +10 volts.

Impedance: 100 k ohms each line.

Reference levels: 0 volts for "0" and "1" states.

Print command: positive 15-volt step from −15 volts to 0 volts.

Hold-off requirements: externally applied level change from 0 volts or more negative than 0 volts to +10 volts (effective with function switch in DUAL position only).

Overflow: single line output, 100 k ohms impedance. "OFF" level approximately +17 volts, "ON" level approximately −13 volts.

± Nixie sign (indicates sign of count): single line output, 100k ohms, impedance, + level approximately −15 volts, − level approximately +13 volts.

Physical specifications

Rear panel connectors: BNC "START" and "STOP" gate inputs. BNC rear terminal in parallel (RTIP) inputs for "A" and "B" channels of the 5285A Universal Input plug-in. BNC input for external RESET. BNC MONITOR outputs for channel A and B triggers. 50 pin mating connector for BCD output, Amphenol #57-30500-375 (HP #1251-0086).

Rear panel controls: ± polarity switch for single and dual gate control input. Trigger level adjustments for "START" "STOP" inputs, ±10 volts.

Power: 115 or 230 volts ±10%, 50 to 60 Hz, 110 W (with 5285A plug-in).

®Burroughs Corp.

Operating temperature range (5280A/5285A): 0°C (32°F) to +65°C (+149°F).

Weight: Net, 29 lbs (13,2 kg). Shipping, 40 lbs (18,1 kg). (Weights include plug-in.)

Price: $1600.

Dimensions: 5¼" high, 16¾" wide, 16⅜" deep (132 x 425 x 416 mm).

Option 01: 4 line BCD 4-2-2-1 "1" state positive in lieu of 8-4-2-1 "1" state positive. $15 per decade.

H19-5280A: Addition of 100 kHz internal time base allows gate times of 0.1 s, 1 s, and 10 s. The time base is the same as in the 5223L counter. Add $545.

H20-5280A: "Readout on the Fly" enables the count to be saved in an internal buffer storage register on command (within 10 μs) without interrupting counting. Output in BCD code 8-4-2-1 "1" state negative, add $1200.

H21-5280A: Same as H20-5280A except output in BCD code 4-2-2-1 "1" state positive, add $1200.

5285A Universal Input Plug-In

(for operation in HP Model 5280A only)

Input channels (A and B)

Range: dc coupled: 0 to more than 2 MHz. ac coupled: 10 Hz to more than 2 MHz.

Impedance: approximately 1 megohm, 75 pF shunt.

Maximum input: ac coupled, ±600 volts peak; dc coupled, 25 volts rms (X1), 150 volts rms (X10), 350 volts rms (X100).

Sensitivity: 0.1 volt rms sine wave; 1 volt pulse, 0.2 μs minimum width.

Trigger level: −100 to +100 volts, adjustable, independent controls on each channel.

Modes of operation

A Quad B: totalizes A as a function of B phase. Maximum rate 1 MHz (same frequency in both channels).

Totalizes A positively if B leads A.

Totalizes A negatively if B lags A.

(Above for directional MODE switch in FWD position. Count direction reversed with switch in REV position.)

Af(B): totalizes A as a function of B from dc to more than 2 MHz. If B is positive, A is totalized positively. If B is negative, A is totalized negatively. Count direction reversed within 250 nsec of B step function command. (Direction of A counted as a function of B is reversed with directional MODE switch in REV position.)

Algebraic A, B: totalizes both A and B according to MODE selector setting.

A: A only to greater than 2 MHz.

A−B: input A minus input B; to 1 MHz per channel. Anti-coincidence circuit prevents count loss when pulses arrive in time coincidence.

A+B: input A plus input B; 1 MHz per channel. Anti-coincidence circuit prevents count loss when pulses arrive in time coincidence.

B: B only to >2 MHz.

Direction of counting is reversed with the directional MODE switch in − position, i.e., modes would be −A, −A+B, −A−B, −B.

Physical specifications

Weight: Net, 3 lbs (1,4 kg). Shipped in 5280A.

Dimensions: 4-25/64" high, 4-37/64" wide, 8½" deep (112 x 116 x 216 mm).

Price: $500.

COMPLEMENTARY EQUIPMENT

Increases versatility of basic instruments

The versatility of Hewlett-Packard counters is greatly enhanced by complementary Hewlett-Packard equipment.

The HP 2590B Microwave Frequency Converter extends frequency range of a 5245L/M, 5248L/M, 5247M or 5246L Counter, 5253B 500 MHz Frequency Converter Plug-In combination to 15 GHz. The HP 5260A Automatic Frequency Divider with a suitable Counter makes possible automatic frequency measurements up to 12.4 GHz.

The HP 2539A Digital Comparator and HP 2514A Digital Scanner increase the number of systems applications by providing data handling for making Go/No-Go decisions on counter measurements, and by scanning the BCD outputs of up to six counters.

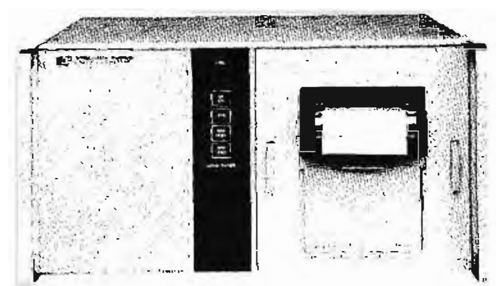
Various solid state output couplers increase the forms in which the BCD output of counters may be recorded and stored for additional data handling or processing by digital machines.

HP 562A and HP 5050B are solid state digital recorders that provide permanent printed records of counter measurements in digital form. X-Y and strip-chart recorders, in conjunction with HP 580A/581A Digital-to-Analog Converters, provide the user with a selection of equipment for analog recording of digital data.

The HP 2212A voltage-to-frequency converter transforms analog information (i.e., voltages) into signals suitable for feeding directly into electronic counters.

Figure 1 demonstrates the capability of the HP-2539A Digital Comparator to compare readings made with the HP 5246L Counter with a predetermined level (or predetermined upper and lower levels). The result of the comparison is available and may be printed by the HP 5050B or 562A Recorder or may be fed back to the system being monitored by the counter, thus completing a feedback control system. Front-panel indication of the comparison is also available. The data from the counter used by the digital comparator in the actual comparison is available from the comparator in BCD form. It may be printed with the Go/No-Go indication by the digital recorder or converted to analog form by the HP 580A, 581A Digital-to-Analog Converters and plotted on an HP 680 Strip-Chart Recorder, providing a permanent, visual record of the comparison.

The system in Figure 2 demonstrates the use of the HP 2547A Coupler to scan up to six HP counters. In the figure, 5248L 135 MHz Counters with 5253B Frequency Converter Plug-ins and the HP 2590A Microwave Frequency Converter or HP 5260A Automatic Frequency Divider, are used to measure microwave frequencies. Frequency measurements made by the counters are scanned by the 2547A, and the data is made directly available, in BCD form, to one of seven types of output equipment. The coupler can be linked with the HP 562A or 5050B Digital Recorders, magnetic tape and punched tape recorders, card punch, typewriter, Teleprinter, or Flexowriter.



5050B

The 5050B Digital Recorder can print up to 18 columns at 20 lines per second. Numbers and a limited set of symbols can be printed. The code base is easily changed by changing an inexpensive code disc. Mixed codes can be used. Price: 5050B, $1900 plus $70 per column board (one board needed for every two columns used), $50 or $65 per input cable.

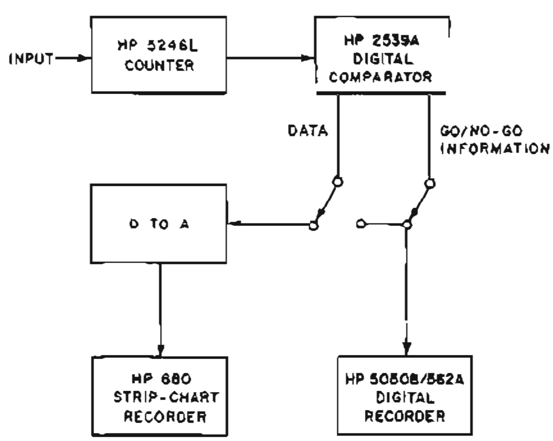


FIGURE I

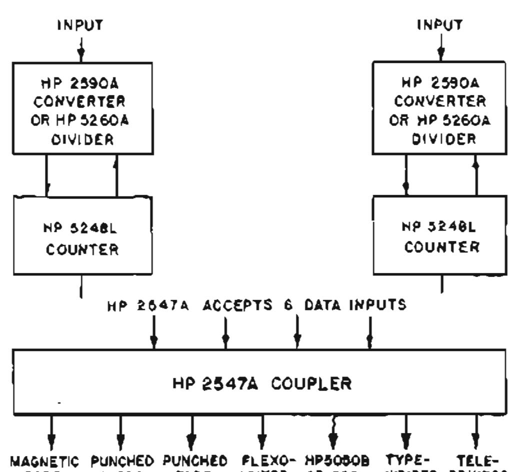
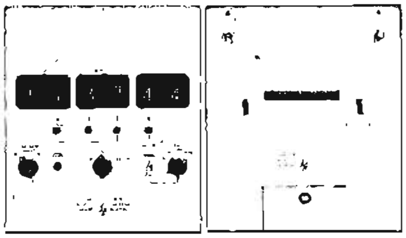
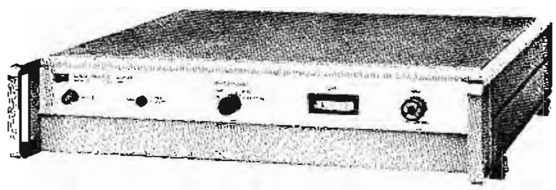


FIGURE 2



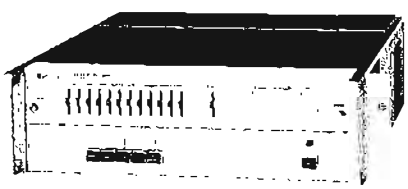
562A

The HP 562A Digital Recorder (shown with HP H03-571B Digital Clock) prints measurements made by counters or records other digital data in parallel entry BCD or 10-line decimal form. Maximum rate is 5 lines/s. BCD data is transferred in 2 ms. $2183 for 11 columns. See page 135.



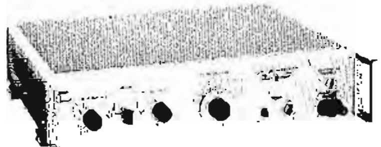
5260A

The HP 5260A Automatic Frequency Divider zero beats with input frequencies between 0.3 and 12.4 GHz automatically and without offset, and then provides an output frequency exactly equal to 1/100 or 1/1000 of the input frequency. Thus no tuning or harmonic computation are required, and the input frequency is displayed immediately and directly on an electronic counter. $3450; page 610.



2515A

The HP 2515A Digital Scanner transmits digital data from up to six counters to one digital recording instrument. The scanner is compatible with the BCD outputs from all HP solid-state counters, data acquisition systems. The 2515A can operate in either sequential or random scanning modes with continuous scan, single scan or manual steps. $4200 (3 sources, 12 digits per source); page 119.

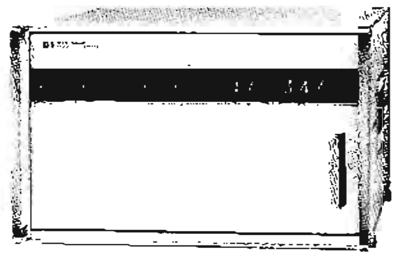


580A

The HP 580A Digital-to-Analog Converter accepts 4 line BCD output for all HP solid-state counters. It provides highly precise expanded scale plots on galvanometer or potentiometer recorders. $550; page 137.

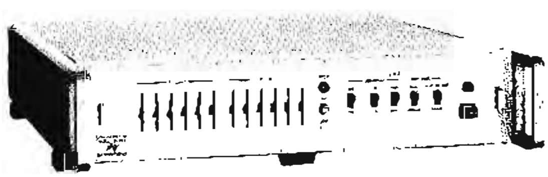
2590B

The HP 2590B Microwave Frequency Converter measures frequency to 15 GHz by phase-locking an internal transfer oscillator to the signal source. It enables observation of jitter, FM and AM even on drifting signals. Measurement accuracy is equal to that of the counter time base. A search oscillator is provided to simplify phase locking. $2150; page 612. See also HP 540B, $1150; page 613; HP 5257A, page 608.



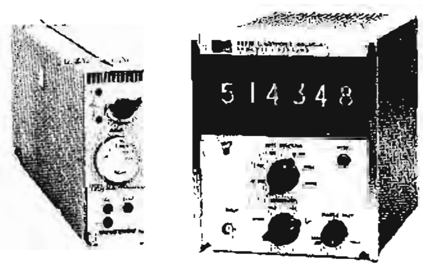
2547A

The HP 2547A Coupler scans data from up to six counters, records on one digital recording device. Compatible with HP counters, nuclear scalers, DVM's having BCD output. Up to 10 characters per instrument may be recorded. System operates completely automatically. Price determined by number of inputs and output recorder; page 122.



2539A

The HP 2539A Digital Comparator compares BCD information against single or dual preset limits providing Go/No-Go lamp indications and electrical output. Comparisons take less than 3 msec. The 2539A provides all possible comparison conditions—combinations of relative sign and magnitude—encountered in measurement situations with counters. $2650 for 6 digit and sign comparison; page 121.



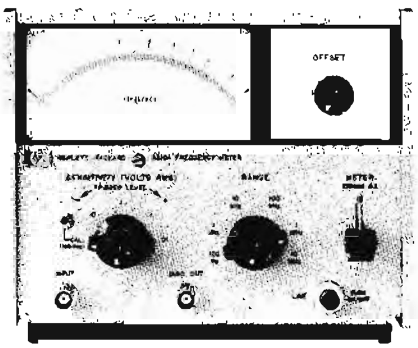
2212A

The HP 2212A Voltage-to-Frequency Converter transforms a dc input voltage to a proportional pulse rate output. The counter reads the average value of the signal over the sample period, thereby minimizing effects of noise and ripple. May be used to integrate analog signals over extended periods. $995 (without counter); page 247.

FREQUENCY METER

Wideband, highly linear FM Discriminator

Model 5210 A/B



5210A/B

The Model 5210A Frequency Meter/FM Discriminator directly measures frequency or repetition rate of signals from 3 Hz to 10 MHz, independent of input voltage waveform. A sensitivity control allows for measurement of noisy signals. The special log linear scale offers an accuracy of 1% of reading from 10% of full scale up. With calibrated offset (Option 01) the accuracy is up to 0.2% of full scale.

The 5210A is also a wideband highly linear FM Discriminator with a 3 dB output bandwidth of better than 1 MHz for precise measurements on FM and PM signals. With output filters (HP 10531A) frequency deviation, modulation index, frequency response, distortion, incidental FM, and FM noise can be determined as well as "flutter" and "wow" to better than 100 dB below carrier frequency. It is particularly well suited for tachometry work with calibration directly in rpm.

For more application details see HP Journal, March, 1967, and HP Application Note 87.

Specifications, 5210A

Frequency range: 3 Hz to 10 MHz in six decade ranges from 100 Hz full scale to 10 MHz full scale.

Expanded scale: with a continuously adjustable OFFSET control, meter and recorder output display any 10% of full scale expanded to full scale.

Sensitivity: maximum sensitivity of 10 mV rms from 20 Hz to 10 MHz increasing to 200 mV at 3 Hz with four attenuator ranges of 0.01, 0.1, 1.0 and 10 V.

Input impedance: 1 MΩ shunted by 30 pF; used with HP 10003A 10:1 divider probe 10 MΩ shunted by 10 pF.

Accuracy:

- **Discriminator output current:** 0.2% of reading below 1 MHz, 0.3% of reading on 10 MHz range.
- **Meter:** 1% of reading from 10% of full scale to full scale.
- **Expanded scale:** 0.1% of full scale for differential frequency readings.
- **Calibration:** crystal calibration oscillator at 100 kHz accurate to ±0.01%.
- **Line voltage and frequency:** changes in line voltage of ±10% and frequency of 50-1000 Hz cause less than 0.05% change in output.
- **Temperature:** frequency reading changes less than 0.02%/°C 100 Hz to 1 MHz ranges, 0.04%/°C 10 MHz range from 0 to +55°C.

Recorder output:

- **Level:** potentiometer outputs of 10 mV and 100 mV, adjustable from 9 mV to 11 mV and 90 mV to 110 mV for full scale; galvanometer output 1 mA into 2 kΩ max for full scale. Adjustable ±10% for 1 kΩ to 2 kΩ loads.
- **Linearity:** 0.025% of full scale 100 Hz to 100 kHz ranges; 0.05% of full scale 1 MHz range; 0.1% of full scale to 10 MHz range.
- **Accuracy:** same as discriminator output current above.
- **Time constant:** approximately 100 ms.

Discriminator output:

- **Level:** adjustable 0.8 to 1.2 V for full scale.
- **Linearity:** 0.025% of full scale 100 Hz to 100 kHz ranges. 0.05% of full scale 1 MHz range. 0.1% of full scale 10 MHz range.
- **Bandwidth:** 3 dB down at greater than 1 MHz.
- **Residual FM noise:** rms line frequency components below 300 Hz are 100 dB below the 1 V full scale output. At other frequencies the rms noise deviations are at least 120 dB below the carrier frequency when the noise is measured in a 6 Hz bandwidth.

Power requirements: 115 or 230 V ac ±10% 50-1000 Hz at less than 10 W.

Dimensions: 7-25/32" wide, 6-3/32" high and 11" deep; (190 x 155 x 279 mm).

Weight: net, 9 lbs (4 kg); shipping, 11 lbs (4,8 kg).

Price: HP 5210A $625.00; Option 01 add $125.

Option 01, Calibrated Offset

General: the calibrated offset provides for display of any of the 10 major divisions on a separate full meter scale (the EXPAND scale). This allows frequency measurements to be made with higher accuracy than is possible using the meter in the NORMAL mode.

Discriminator output: same as above except bandwidth is 3 dB down at greater than 750 kHz.

Accuracy: 0.2% of full scale (range switch setting) for 100 Hz to 1 MHz ranges; 0.3% of full scale (range switch setting) for the 10 MHz range.

Temperature: the accuracy specification is increased by 0.01%/°C of reading on the 100 Hz to 1 MHz ranges and 0.03%/°C of reading on the 10 MHz range from 0°C to 55°C for deviations from 25°C when zero and self-calibration adjustments are made at the ambient temperature.

Price: add $125 to price of 5210A/B.

HP 10531A, Filter Kit

General: the HP 10531A Accessory Filter Kit provides a series of three plug-in low pass filters which can be adjusted to cover frequencies from 100 Hz to 1 MHz. These filters provide rejection of carrier and carrier harmonics while passing modulation components. Thus it is possible to measure demodulated signal components up to 20% of the carrier frequency using the HP 302A or 310A Wave Analyzers or similar narrow band voltmeters on their most sensitive ranges. By lowering filter cut-off frequency or in case of wide deviation signals measurements may be made using less selective voltmeters or other instruments

Frequency range: the upper cut-off frequency can be adjusted from 100 Hz to 1 MHz. The lower cut-off frequency will vary up to 10 Hz, depending on load resistance used with the filter.

Carrier rejection: with the output filter the carrier and its harmonics are less than 30 mV rms total when the filter cut-off is less than 15% of the carrier frequency and drops to 1.0 mV maximum for filter cut-off frequencies less than 5% of the carrier frequency.

Output impedance: nominal 600Ω. However, matched loads are not required.

Output level: zero to full scale deviations give 1 V open-circuit at discriminator output.

Price: HP 10531A $175.

Specifications, 5210B

Model 5210B frequency meter is identical in construction and circuitry to 5210A but is calibrated in rpm for greater convenience in tachometry applications.

Speed range: 6000; 60,000; 600,000; 6,000,000 (CAL position) rpm.

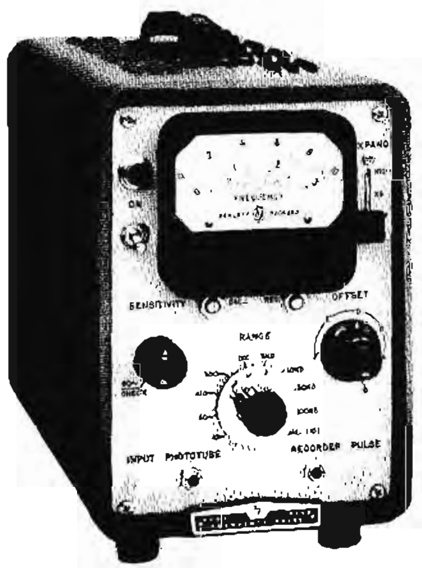
Maximum resolution: 6 rpm.

Price: HP 5210B, $625.00.

METERS; TRANSDUCERS

Measure frequency, 3 Hz to 100 kHz

Models 500B,C; 506A; 508A,B,C,D



500B

The HP Model 500B directly measures the frequency of an alternating voltage from 3 Hz to 100 kHz. Suitable for laboratory and production measurements of audio and ultrasonic frequencies, it also is useful for direct tachometry measurements with a transducer such as HP 506A or 508A,B,C,D.

Readings on the 500B and 500C are not affected by variations of input signal level or power line voltage. The meter will count sine waves, square waves or pulses and will indicate the average frequency of random events. Provision is made for checking the calibration against power line frequency and to operate a recorder for a continuous frequency record or x-y plot.

Specifications, 500B

Frequency range: 3 Hz to 100 kHz, 9 ranges in 10, 30, 100 sequence.
Expanded scale: allows any 10% or 30% portion of a selected range to be expanded to full meter scale (except 10 Hz range).
Input voltage: sensitivity: 0.2 V rms minimum for sine waves, +1 V peak minimum for pulses; maximum, 250 V peak; sensitivity control reduces threshold sensitivity.
Input impedance: approx. 1 MΩ shunted by 40 pF BNC connector for input.
Accuracy: better than ±2% of full scale (unexpanded); reading affected less than 0.5% by ±10% variation from nominal line voltage; expanded scale ±0.75% of range switch setting.
Output linearity: *(relation of input frequency to output current at the external meter jack)*: on 100 kHz range, within approx. ±0.25% of full-scale value; other ranges, ±0.1% of full-scale value.
Recorder output: 1 mA for full-scale deflection into 1400 ±100Ω.
Pulse output: to trigger stroboscope, etc., in synchronism with input signal; to measure FM.
Photocell input: phone jack on panel provides bias for Type 1P41 Phototube; allows direct connection of 506A Tachometer Head.
Power: 115 or 230 V ±10%, 50 to 1000 Hz, 110 W.
Dimensions: cabinet: 7½" wide, 11½" high, 14½" deep (191 x 292 x 368 mm); rack mount: 19" wide, 7" high, 13" deep (483 x 178 x 330 mm).
Weight: net 17 lbs (8 kg), shipping 19 lbs (9 kg) (cabinet); net 20 lbs (9 kg), shipping 30 lbs (14 kg) (rack mount).
Accessory furnished: 10501A Cable.
Accessories available: 506A Optical Tachometer, $195; 508A, B,C,D Tachometer Generators, $125 each; 500B-95A Accessory Meter for remote indication (operates from recorder jack), $55.
Price: Model 500B (cabinet), $425.00, Model 500BR (rack mount), $425.00.

Specifications, 500C

Model 500C Frequency Meter is identical in construction and circuitry to 500B but is calibrated in rpm for greater convenience in tachometry applications.

Speed range: 180 rpm (15 rpm with multiplying transducer) to 6,000,000 rpm, 9 ranges.
Accessory available: 500C-95A Accessory Meter, $55.
Price: Model 500C (cabinet), $435.00. Model 500CR (rack mount), $435.00.

506A Optical Tachometer

Model 506A is a light source and photocell for use as a transducer with instruments such as HP 521 Series Electronic Counters; HP 500B Electronic Frequency Meter and HP 500C Electronic Tachometer Indicator.

Specifications, 506A

Range for direct reading: 1 to 5000 rps with 521 Series; 3 to 5000 rps with 500B; 180 to 300,000 rpm with 500C; lower speed may be measured by using a multisegment reflector.
Output voltage: at least 1 V rms, 300 to 100,000 rpm (into 1 MΩ or more impedance) with reflecting and absorbing surfaces ¾" square.
Light source: 21 candlepower, 6 V automotive bulb.
Phototube: Type 1P41.
Phototube bias: +70 to +90 V dc (supplied by 500B,C 521).
Power: 115 or 230 V ±10%, 50 to 1000 Hz, 25 W.
Dimensions: 22" high, 11" wide maximum (559 x 279 mm).
Weight: net, 8½ lb (4 kg); shipping, 10½ lb (4,8 kg).
Accessories available: 56A-16B Adapter Cable (connects 506A to 522B Counter), $40.
Price: HP 506A, $195.

508 Tachometer Generators

Models 508A,B,C,D Tachometer Generators are rotational speed transducers for use with electronic counters or frequency meters in making fast, accurate rpm measurements, 15 to 40,000 rpm. They are specifically designed to operate with Hewlett-Packard electronic counters and frequency meters.

Specifications, 508 Series

Shaft speed range: 508A, 15 to 40,000 rpm; 508B, 30 to 30,000 rpm; 508C, 40 to 25,000 rpm; 508D, 50 to 5000 rpm.
Output: 508A, 60 cycles/rev.; 508B, 100 cycles/rev.; 508C, 120 cycles/rev.; 508D, 360 cycles/rev.
Output voltage: varies with speed and model; approx. 0.2-30 V.
Drive shaft: ¼" diameter, projects 19/32".
Running torque: approx. 0.15 in-oz; 0.5 in-oz at 1500 rpm.
Peak starting torque: approximately 4 in-oz.
Dimensions: 2-7/16" H, 3½" W, 3¾" D (62 x 89 x 95 mm).
Weight: net 2 lbs (1 kg); shipping 3 lbs (1 kg).
Price: HP 508A,B,C,D, $125 each.

TIME INTERVAL COUNTER

Measure intervals from 10 nanosec to 0.1 sec.

Model 5275A

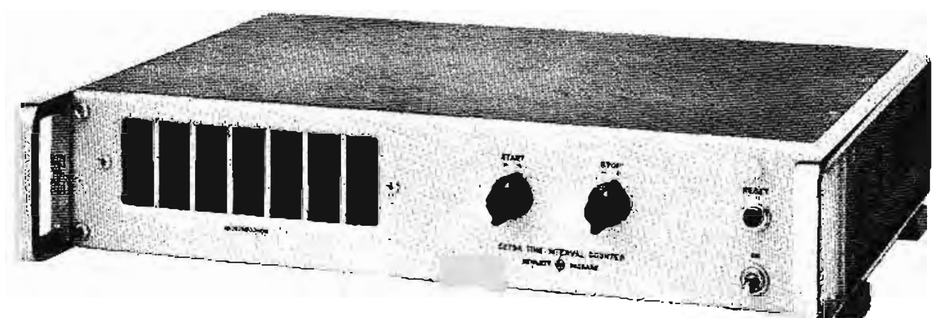
Model 5275A is ideally suited for precise digital measurements of short time intervals between events that can be represented by suitable electrical pulses. Resolution to 10 nanoseconds is achieved in automatic measurements over the full 10 nsec to 0.1 sec range of the instrument.

Counted frequency is 100 MHz, obtained from an external 1 MHz standard by a multiplier in the counter. Applications include measurement of explosive burning rates, speed and acceleration timing of vehicles in free-flight wind tunnels, and nuclear measurements.

Rugged, modular construction and solid-state components contribute to the quality and reliability of this instrument. Standard features of remote reset, rear-mounted trigger terminals and 4-line BCD output make the 5275A suitable for many applications that would otherwise require equipment of special design.

For system installation, the HP 101A 1 MHz Oscillator (see page 648) is capable of supplying the time base for as many as twenty 5275A Time Interval Counters. Using one frequency standard conserves valuable rack space and reduces system cost where several time interval counters are required.

For greater input impedance, higher sensitivity and more versatile trigger level control, consider the 5248L Counter with 5267A Time Interval Plug-In. This combination gives 10 ns resolution but shortest interval measured is 100 ns, compared to 5275A's 10 ns.



5275A

Specifications

Time interval measurement

Range: 10 nanoseconds to 0.1 seconds.

Resolution: 10 nanoseconds.

Input: start, stop trigger by separate channels.

Frequency counted: 100 MHz.

Accuracy: ±10 nanoseconds ± time base accuracy

Readout: in microseconds, with decimal point.

Time base input: (HP 101A Oscillator recommended)

Frequency: 1 MHz.

Stability: compatible with measurement needs.

Amplitude: 1 V rms into 1000Ω.

Signal to noise ratio: 60 dB.

Phase and amplitude modulation: less than 0.1%.

General

Display: 7 places, digital, in neon columns.

Reset: automatic, manual, or remote, using rear terminals (30 μs minimum connection to ground).

Input trigger pulse

Sensitivity: 3 V peak, 0.5 V/ns rise time, 5 ns width.

Impedance: 50Ω

Polarity: selectable, positive or negative.

Digital output

Code: 4-2-2-1; "0" level: −8 V, "1" level: 18 V, impedance: 100 kΩ, each line.

Reference level: + level 17.6 V; 350Ω; − level −6.9 V; 1000Ω.

Print command: step from −6 to 13 V, dc coupled, 2000Ω source.

Hold-off requirements: 0 V enables the reset; +13 V disables reset; 10 kΩ impedance.

Chassis connector: BNC connector; mates with Amphenol 57-30500.

Operating temperature range: −20°C to +65°C.

Power requirements: 115 or 230 V ±10%, 50 to 60 cps, 50 W.

Weight: net 15 lbs (7 kg); shipping 25 lbs (11,4 kg).

Accessories furnished: two 10503A cables, 4 ft. long, male BNC connectors.

Price: HP 5275A, $2450.

Dimensions: 16¾" wide, 3-15/32" high, 19" deep (425 x 88 x 483 mm).

Option 02: 4 line BCD output, 8-4-2-1, "1" level positive in lieu of 4-2-2-1 (identical in all other respects), add $10.

Option 03: same as Option 02, except "1" level negative, add $10.

FREQUENCY-TIME STANDARDS

Hewlett-Packard offers Frequency & Time Standards systems which provide accurate frequencies, time intervals and time-keeping capabilities. Further, Hewlett-Packard systems provide means for comparing these quantities against national standards such as the National Bureau of Standards (NBS). Units of frequency or time cannot be kept in vault for ready reference. They must be generated for each use, hence must be regularly compared against recognized primary standards.

Frequency and Time Standard systems manufactured by Hewlett-Packard are used for control and calibration at observatories, national centers for measurement standards, physical research laboratories, missile and satellite tracking stations, manufacturing plants and radio monitoring and transmitting stations. System applications include the following:

Distributed standard frequencies in factories or research facilities ("house standards"), controls of standard frequency, time standard broadcasts, synchronization of electronic systems for navigation, investigation of radio propagation phenomena, radio astronomy frequency synthesis, control, and adjustment of single sideband communication equipment.

Four performance characteristics are of vital interest to users of frequency and time measurement equipment and standards: accuracy, precision, stability and reliability. Hewlett-Packard systems offer these four in ample measure, plus operational simplicity. Hewlett-Packard has devoted the efforts of an entire division to the continual improvement and innovation necessary to keep in the forefront of frequency and time measurements and standards.

Types of frequency standards

At the present time, four types of frequency standards are in common use. These are:

1. The atomic hydrogen maser.
2. The cesium atomic beam controlled oscillator.
3. The rubidium gas cell controlled oscillator, and
4. The quartz crystal oscillator.

Of these four standards, the first two are referred to as primary frequency standards and the last two as secondary frequency standards. The distinction between a primary standard and a secondary standard is that the primary standard does not require any other reference for calibration; whereas the secondary standard requires calibrations both during manufacturing and during use as well as at certain intervals depending upon the stability desired. Hewlett-Packard is manufacturing all four types of frequency standards. The models are: for the hydrogen maser, the HP Model H-10 (not described in this catalog—data upon request); for the cesium beam frequency standard, the HP Model 5061A; for the rubidium standard, the HP Model 5065A; and for the quartz crystal oscillators, the HP Models 105A and B, 106A and B, and 107AR and BR. Table 1 gives a summary of the advantages and limitations for these four types of frequency standards and the following paragraphs give more detailed descriptions.

TABLE 1

Sources of Advantages and Limitations for Frequency Standards

Standard	Principal construction feature	Principal advantage	Principal limitation
Atomic Hydrogen Maser	Active maser with coated wall storage cell having longest atomic interaction time	Greatest intrinsic reproducibility, long and short-term stability. Primary standard capability	Size and weight
Cesium Atomic Beam Resonator Controlled Oscillator	Atomic beam interaction with fields—minimum disturbance of resonating atoms due to collisions and extraneous influences	High intrinsic reproducibility and long-term stability. Designated as primary standard for definition of time interval	Short-term stability
Rubidium Gas Cell Resonator Controlled Oscillator	Gas buffered resonance cell with optically pumped state selection	Compact and light weight. Very high degree of short-term stability	Requires calibration against primary standard
Quartz Crystal Oscillator	Piezoelectrically active quartz crystal with electronic stabilization	Very compact, light and rugged. Inexpensive	Long term stability. Requires calibration against primary standard

Atomic hydrogen maser

Figure 1 gives a schematic diagram of an atomic hydrogen maser. A beam of atomic hydrogen is directed through a highly inhomogeneous magnetic field which acts to selects atoms in states of higher energy from those in states of lower energy and allows them to proceed into the quartz bulb. The quartz bulb is enclosed in a tuned microwave cavity set to the transition frequency of the hydrogen atom between the $F=1$, $m_F=0$ and $F=0$, $m_F=0$ energy levels. The quartz bulb has teflon coated walls to reduce perturbation of the important energy states.

Inside the coated storage bulb, the hydrogen atom makes random transits, being reflected upon each encounter with the walls. During this interaction process within the bulb, the atoms tend to relax and give the energy up to the microwave field within the tuned cavity. This field also tends to stimulate more atoms to radiate, thus building in intensity until steady state maser operation is achieved. However, some atoms relax unproductively due to collisions with the wall; magnetic inhomogeneity or other hydrogen atoms. Some atoms also escape through the bulb opening. Although the atoms undergo many collisions while in the bulb, their effective interaction time has been lengthened to more than 1 second. Perfecting these techniques, the extremely sharp resonance frequency has led to a Q approaching 10^9. The low power level of approximately 10^{-12} watts requires that considerable amplification be used to obtain a useful standard frequency.

Figure 2 shows a block diagram of a complete hydrogen maser. It illustrates how a slave oscillator is phase locked to the maser. The Hewlett-Packard Model H-10 Hydrogen Maser does not supply this phase lock system. It only supplies the maser frequency of 1.420+ MHz at a very low output level, namely 5μV

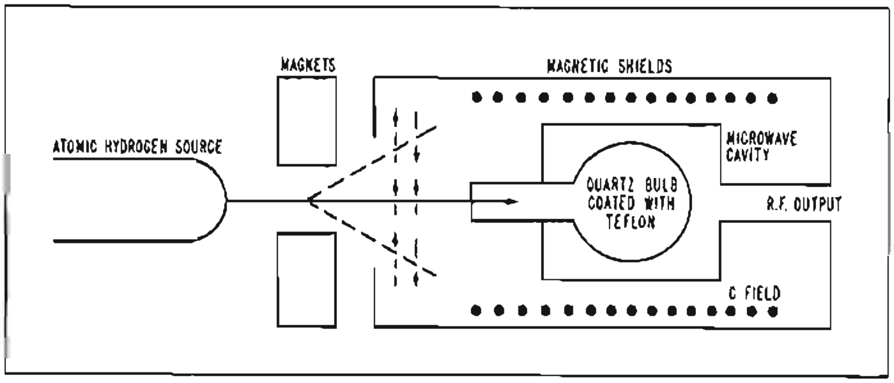


Figure 1. Atomic hydrogen maser diagram

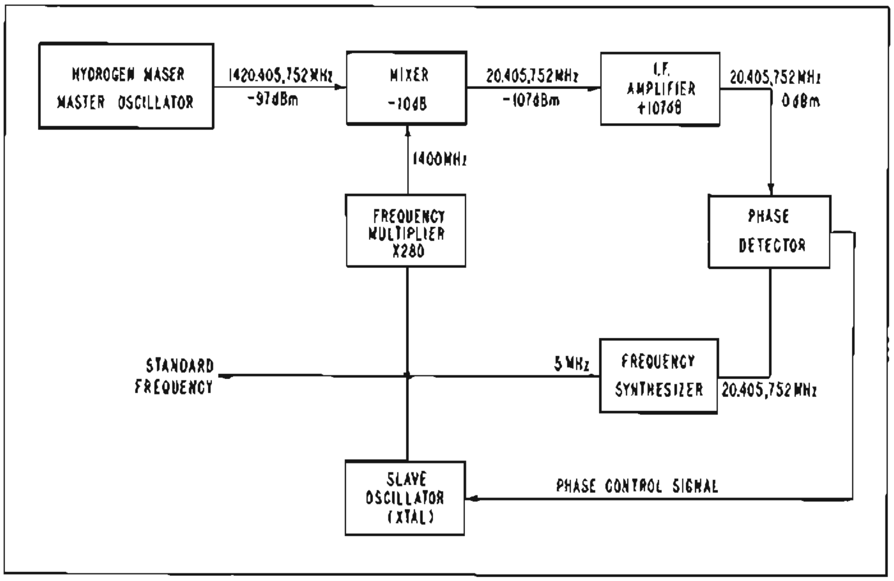


Figure 2. Hydrogen maser block diagram

across 50Ω. The receiver system to translate the 1,420+ MHz hydrogen frequency to 5 MHz is available as a separate unit. Maximum long term fractional frequency excursion including resettability of the Hewlett-Packard H-10 Hydrogen Maser is 2 x 10^{-12}. During observations of two hydrogen masers extending over a period of one year no long term drift of one with respect to the other has been detected. Measurement resolution during this period was better than 1 part in 10^{12}. The short term stabilities for averaging intervals of 10 seconds is better than 1 part in 10^{13} rms.

Cesium beam frequency standard

Cesium beam standards are in use wherever the goal is very high accuracy primary frequency standard. In fact, the NBS frequency standard itself is of the cesium beam type. The cesium beam standard is an atomic resonance device which provides access to one of nature's invariant frequencies in accordance with the relationship of quantum mechanics. The cesium standard is a true primary standard and requires no other reference for calibration.

Atomic frequency standards are based on the frequency, ν, corresponding to a transition between two atomic states separating the energy by ΔE:

$$\Delta E = h\nu,$$

where h is Planck's constant. Common to atomic standards are means for 1) selecting atoms in a certain energy state, 2) enabling long lifetimes in that state, 3) exposing these atoms to (microwave) energy, and 4) detecting the results.

For the cesium beam standard, the quantum effects of interest arise in the nuclear magnetic hyperfine splitting of the ground state of the atoms. The transition described as $(F=4, m_F=0) \longleftrightarrow (F=3, m_F=0)$ is observed.

The HP Model 5061A is a portable cesium beam standard proved capable of realizing the cesium transition frequency to the same levels of accuracy and long-term stability usually achieved by large-scale laboratory models.

The 5061A operates to keep an ultra stable quartz oscillator precisely "on frequency" via servo-control that refers, ultimately, to the center of the atomic resonance. The output signal is derived from the quartz oscillator, the cesium beam tube serves as its reference—and the two are linked by circuitry that includes means to adjust the frequency of the quartz oscillator to automatically compensate for its aging or drift.

A simplified sketch of the beam tube is shown in Figure 3.

It is possible to accelerate cesium atoms by a force dependent on the applied magnetic field gradient together with the atom's magnetic dipole moment. Thus cesium atoms can be sorted and focused by passing a beam of them through a magnetic field having a high gradient ("A" magnet). Atoms in the quantum state of interest are directed down the beam tube and others are deflected away. These selected atoms then drift through a space where the field ("C" field) is kept low (typically, about 50 milligauss) and uniform and are subjected to microwave radiation corresponding to just the frequency which separates the two energy levels. The atoms flop from one energy state to the other; and those which have made the transition in the desired direction are selected and directed by a second field ("B" magnet) onto a detector.

Now, the maximum signal means that the maximum number of transitions are

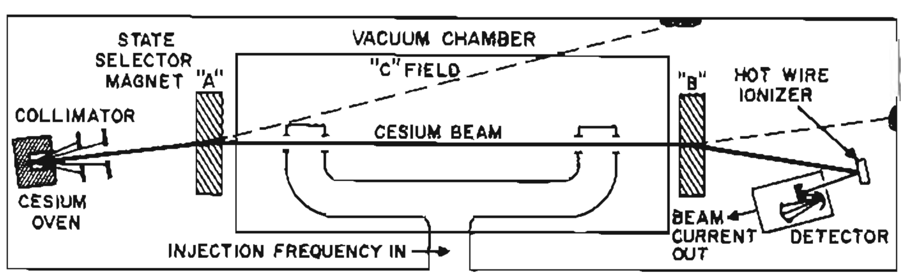


Figure 3. Schematic of cesium beam resonator

occurring, which indicates that the injected microwave energy is of precisely the transition frequency. The oscillator which is the source of this energy is therefore known to be operating at a frequency directly related to the transition frequency. A constant of the atom has been made the frequency reference.

Rubidium vapor standard

Rubidium vapor or rubidium gas cell frequency standards feature a high order of both short-term and long-term frequency stability. Both are important for progress in certain fields such as deep-space communications, satellite ranging, and doppler radar. Also, rubidium standards are noted for being of small size.

Rubiduim standards are similar to cesium beam standards in that an atomic resonant element prevents drift of a standard frequency quartz oscillator through a phase lock loop. Such a system is shown in Figure 4. Yet the rubidium type is a secondary standard. Since the atomic resonant frequency of a rubidium gas cell is dependent upon gas mixture and gas pressure in the cell, it must be calibrated and then it is subject to a small degree of drift. The drift is typically 100 times less than the best quartz crystal standard.

A rubidium standard may also be smaller and lighter than previously described primary standards. Therefore, this type of instrument is ideal for transporting time and frequency from one location to another. For instance, HP Model 5065A weighs only 37 pounds and offers a built-in standby power battery with a 10 minute minimum capacity to allow moving the unit about a plant. And the HP Model E21-5065A portable rubidium time standard is available for long haul transportation.

Criteria in choosing a rubidium standard should encompass the ease of calibration and time scale selection, and the method of clock pulse synchronization when a clock is included. Hewlett-Packard has mastered all of these in the 5065A design. Using a single quartz oscillator at a frequency of 5 MHz, a thumbwheel controlled frequency synthesizer translates the 5 MHz to a frequency, which when multiplied, matches the atomic cell transition frequency. Simply changing the four thumbwheels to a predetermined number (table in operating manual) shifts the synthesis ratio to give either UTC offsets or atomic A1 time. Thumbwheel steps are approximately 2 x 10^{-9} of frequency. Finer adjustments and calibration are performed by a front panel magnetic field control. This control is designed to give a linear frequency change with dial reading to make adjustments simple.

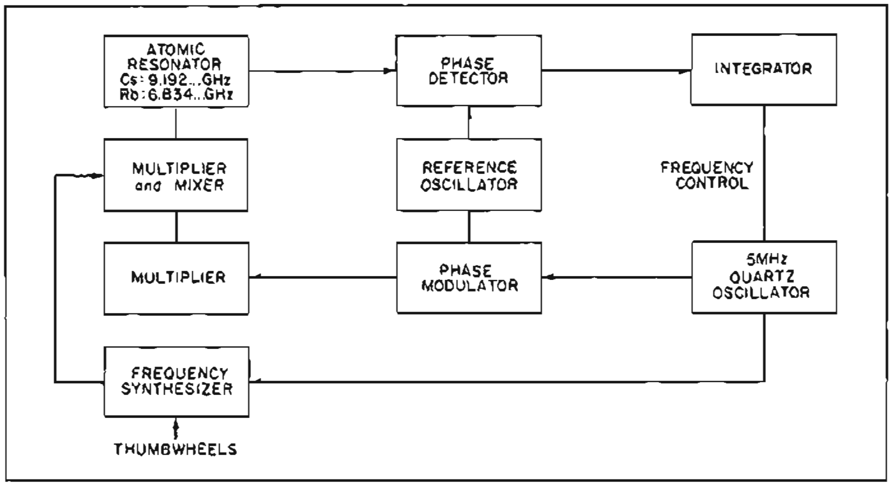


Figure 4. Typical atomic standard phase-lock loop system.

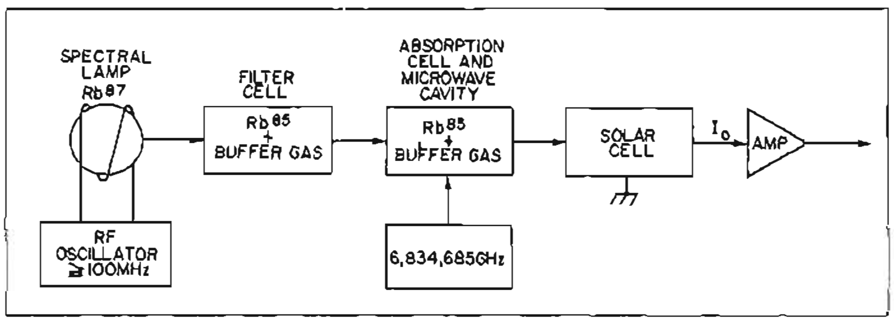


Figure 5. Schematic representation of rubidium-vapor cell resonator.

Model 5065A's Option 01 Time Standard furnishes an output pulse of 1 pps as well as a front panel 24 hour clock driven by a frequency standard signal. The time pulse may be delayed up to 1 second for phasing purposes using a sync pushbutton which synchronizes with an external pulse to 10 ± 1 μs and the thumbwheels are settable in 1 μs increments.

The high long term stability of the rubidium standard originates in the atomic resonator operating with a flywheel in the form of a very-high-quality quartz controlled oscillator. The closed-loop bandwidth of the control system is limited to about 2 Hz. Thus, the stability of frequency output for intervals (averaging times) of a fraction of a second is essentially that of the crystal oscillator. The short term stability of this oscillator is very high—equal to that of Hewlett-Packard's most stable crystal standard. As longer averaging times are considered, the control system constrains the crystal oscillator to the superior long term stability of the atomic resonator. The result is a combination of superior long and short term stability. The bandwidths of the control loop is a fixed value that yields the full short term stability of the crystal oscillator without degradation by atomic resonator noise.

The rubidium resonator is shown schematically in Figure 5. In operation, the rf oscillator produces in the spectral lamp a plasma in which the rubidium atoms are energized to an excited state. As the atoms then relax, they emit two closely spaced wavelengths. One of these is intercepted by the filter cell and the remaining enters the absorbtion cell.

Energy is absorbed in the cell as a pumping action takes place where Rb atoms are excited into the optical state. This depletes one of the ground state energy levels of the gas molecules until no more radiated energy can be absorbed. The cell, thus, becomes transparent and a solar cell detects the amount of incident radiation. Microwave excitation of the absorbtion cell at the correct transition frequency (6,834.685 MHz) causes a replenishment of the depleted ground state energy level such that further optical state pumping can take place.

The pumping absorbs some of the optical radiation such that less reaches the solar cell, and the presence of the correct frequency is thus detected. A small amount of low frequency fm is applied to the microwave carrier to allow accurate phase sensing and synchronous detection.

Any error in frequency will be summed in the integrator, preventing any accumulated time error, and a correction voltage will be applied to the quartz crystal oscillator. This, in turn, counteracts the original deviation in frequency.

Quartz crystal oscillators

The modern era of precision frequency control was initiated in the 1920's when the quartz crystal resonator was first applied in the construction of frequency oscillators. Its use in instruments for the generation and measurement of precision frequencies is now universal in national and industrial laboratories of the world. Today, the most exacting uses demand atomic resonance control. Nonetheless, quartz crystal oscillators remain the workhorses of virtually every frequency control application.

When used to control an oscillator, a quartz resonator is mounted between conducting electrodes, usually thin metallic (gold) coatings deposited directly on the crystal by evaporation. Mechanical support is provided at places on the crystal chosen to avoid any inhibition of the desired vibration and if possible such that unwanted vibration modes are suppressed. Advantage is taken of the piezoelectric effect that links mechanical vibrations and electrical effects in certain crystals. An alternating voltage at a selected natural frequency applied across a properly cut quartz crystal causes it to vibrate. This crystal resonator behaves as though it were an electrical network and can be made to impose its own frequency upon an oscillator circuit.

An inherent characteristic of crystal oscillators is that their resonant frequency changes slightly as they age. This "aging rate" or "drift" of a well-behaved oscillator is almost constant. After the initial aging period (a few days to a month) the rate can be taken to be constant with but slight error. Once the rate is measured, it is usually easy to correct data to remove its effect. Over a long period, the accumulated error drift could amount to a serious error. Thus, periodic frequency checks are needed to maintain a quartz crystal frequency standard. (The cesium beam standard, on the other hand, has no known drift.)

Hewlett-Packard offers the Models 105A/B Quartz Oscillators rated at 5 parts in 10^{10} per day long term stability, the HP Models 106A/B rated at 5 parts in 10^{11} per day long-term stability, and the ruggedized HP Models 107AR/BR, rated at 5 x 10^{10} per day. Such exceptional stability (and, substantially better performance is attained under normal operating conditions) results from careful attention to all controllable factors such as selection of the highest quality crystals, their operation in precision temperature controlled ovens, and their incorporation into inherently stable circuits designed for low power dissipation within the crystal.

Spectral purity

Spectral purity is the degree to which a signal is coherent or, expressed in another way, a single frequency with a minimum of side band noise power. It is greatly desirable to have high spectral purity in a standard signal from two standpoints. One, when used as a frequency and time reference the short term perturbations will be less for higher accuracy. And two, in applications where the standard frequency is multiplied to very high or microwave frequencies the frequency spectrum of the signal will be reasonably narrow.

The signal and its frequency spectrum are analogous to a frequency modulated wave where the total power is constant. If the frequency multiplying device is broadband, the ratio of the total sideband power to the signal power increases as the square of the multiplying factor. Consequently the increased sideband power must come from the carrier. With increasing multiplication factors the spectrum of the signal spreads since the increased sideband amplitude causes intermodulation between sidebands to become appreciable. For frequency multiplication the standard's signal-to-noise ratio will be degraded 6 dB per octave and 20 dB per decade.

Hewlett-Packard quartz oscillators are designed to give exceptional spectral purity. After high multiplication they give spectra which are only slightly degraded from the fundamental frequency. Figure 6 shows a noise spectrum plot for the HP 106A/B Quartz Oscillator (see Hewlett-Packard Application Note 52, "Frequency and Time Standards," page 5-3 for details of this noise measurement).

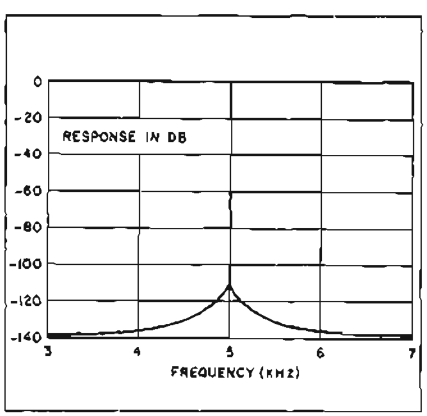


Figure 6. Spectrum of a 5 kHz beat note at 9.2 GHz: comparison of two HP 106A,B Oscillators.

Stability

Long term stability refers to slow changes in the average frequency with time due to secular changes in the resonator and is usually expressed in fractional parts per unit of time. Short term stability refers to changes in average frequency over a time sufficiently short so that change in frequency due to long term effects is negligible. To be meaningful, this specification should reflect variation in frequency caused by unwanted components of noise and spurious signals. It is Hewlett-Packard's practice to specify this instability in terms of RMS Fractional Frequency Deviation.

A short term stability specification should include a statement of averaging time to be meaningful. The longer the averaging time used, the more the deviation is obscured since the average must approach the mean or nominal output frequency in the long run. In comparing specifications for standards, one should keep these facts in mind. Also, there can be a considerable difference in actual performance if the specifications denote peak deviations over the time designated, averaged peak deviations over the given time, or simply a straight line approximation of the short term deviations. Hewlett-Packard's practice is to additionally include maximum RMS Phase Deviation as a statistical measure of peak deviation.

The mathematical relationship which relates frequency, time, and phase deviation is:

$$\frac{\Delta f}{f} \sim \frac{\Delta t}{t} \sim \frac{\Delta \phi}{\phi}$$

where Δf represents the frequency deviation from the mean or average value of f; Δt is the observed period deviation from t, the average or mean period of a single cycle of f; and $\Delta \phi$ represents the phase deviation in radians from ϕ, for the average or mean value of ϕ over the averaging time. RMS or standard deviation values are obtained by calculation from these deviation measurements. An RMS value means that 68.3% of all observed deviations are less than the RMS value, 95.1% will be less than two times the RMS value, and 99.7% will be less than three times the RMS value.

When the Δf_{rms} value is normalized by dividing it by F the RMS fractional frequency deviation is obtained. This gives values in parts in 10^X; for instance, 1 x 10^{-11} over an averaging time of 1 second for Model 105 Quartz Frequency Standard.

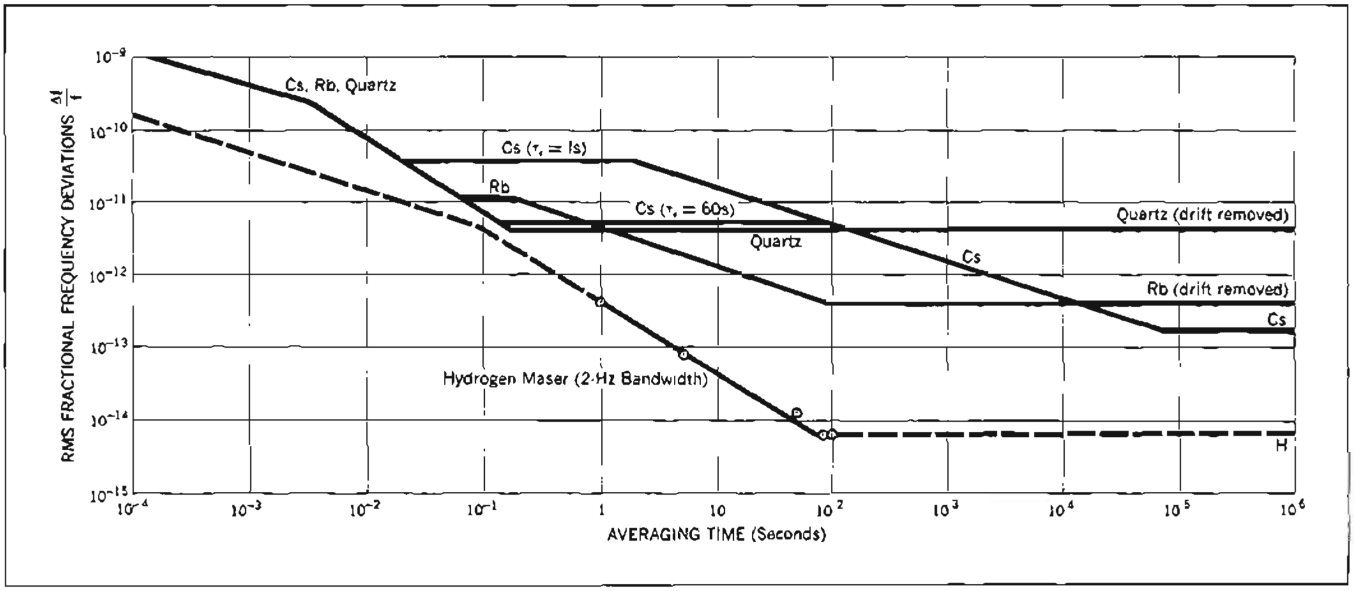


Figure 7. Typical short term stability of Hewlett-Packard frequency standards.

Short term stabilities of the various standards offered by Hewlett-Packard are compared in Figure 7. The long term drift was removed from the curves so that the short term variations could be more readily recognized.

Long term stability, or long-term instability in the alternate sense, refers to gradual drift in average frequency due to changes in the resonator or changes in other components of the oscillator. For quartz oscillators this is often termed "aging rate" and specified in "parts per day." Rubidium standards being more invariant are specified in "parts per month." On the other hand, Cesium Beam Standards and Hydrogen Maser Standards are primary units having no gradual change or drift. Therefore, these primary standards are given a specified accuracy to within which the frequency is guaranteed. They also have a reproducibility specification which means that through a sequence of comparisons (as of an instrument against a standard) the unit will yield a mean or standard deviation. Use of this term implies that the instrument was independently adjusted between comparisons, so the resettability of the instrument is a factor.

Aging or long term drift can be in either direction; i.e., either higher or lower in frequency. Thus the specifications are often given as ± parts in 10^X. If plus or minus is not stated, it is implied unless otherwise noted.

Frequency standards and clocks

Time standards and frequency standards have no fundamental differences—they are based upon dual aspects of the same phenomenon. The reciprocal of time interval is frequency. Frequency measurements are measurements of the number of cycles—counted one by one—per time interval (second). For precision oscillators, a complete statement of frequency must include the time scale in use, so that the exact length of the time interval is specified.

As a practical matter, to maintain a time standard places stringent additional requirements upon a frequency standard. A clock is a device for counting cycles. The time it keeps is a function of its driving frequency: in effect, a clock integrates frequency. Even a small frequency error can cause large time errors to accumulate, for a clock must measure off nearly 100,000 seconds in just one day.

The basis for a modern time standard clock is an ultra-stable oscillator, often a quartz crystal oscillator. The low frequency convenient for clock operation must be derived from the high quartz frequency (typically, 0.1 MHz to 5 MHz) in a way that does not degrade its accuracy. This is accomplished by fail-safe regenerative dividers. A local time standard, then, comprises 1) a stable, precision oscillator and 2) a frequency divider and clock.

A cesium beam standard is an excellent frequency standard to drive a clock because of its extremely good long-term stability. If a quartz oscillator or other secondary standard is used, it must be evaluated for rate of drift and be kept carefully corrected.

The Hewlett-Packard Model 5061A Cesium Beam Frequency Standard and Model 5065A Rubidium Frequency Standard offer an Option 01 Time Standard.

The Option 01 provides the units with a 1 pulse per second clock output available at both front and rear panel BNC connectors. The clock is driven by 1 MHz, internally connected. The clock pulse is adjustable with respect to a reference by 6 thumbwheel switches in decade steps from 1 μs to 1 s. An internal screwdriver adjustment allows fine continuous adjustment over any 1 μs range. The thumbwheel switches are located under the access door in the top cover.

The time standard option includes a Patek Philipe 24 hour clock movement indicating time in hours, minutes and seconds. Advance/Stop pushbuttons on clock module allow clock to be set to the nearest second. Pressing an internal sync button automatically synchronizes the 1 pps clock pulse to an external sync pulse.

Frequency comparison by VLF broadcast

One excellent way to keep a local system's frequency—hence, time interval—referenced against master time interval is by use of a low frequency standard broadcast such as the National Bureau of Standards WWVB, 60 kHz. Prime means for doing this with ease and convenience is the HP 117A Comparator. This unit is a complete system in itself. The strip chart produced by the 117A records minute by minute the results of a precision phase comparison (resolution, 1 μsec) of the local signal against the received signal to show frequency offset or error of the local standard.

Reliable, fail-safe operation

Hewlett-Packard frequency and time standards have many features that ensure ease of operation and maintenance. This allows house frequency standards and timekeeping systems to be operated at the highest possible accuracies. Hewlett-Packard standards have built-in dependability. For example, regenerative dividers of the non-self-starting type are used in the 115BR frequency divider and clock; the very presence of an output signal is a positive indication that divider output has not lost time relative to the driving signal. The dividers stop and remain stopped upon any interruption of signal or of supply power.

The HP 105A/B, 106A/B and 107AR/BR quartz oscillators have a digital indicator, calibrated in parts in 10^{11} (10^{10} for 105A/B, 107AR/BR), which greatly facilitates making fine corrections to bring the oscillator back to reference frequency, as determined by offset measurements made against NBS via the 117A Comparator.

Standby power supplies

Minimum down-time, important for any system, is vital to a time standard. Its worth depends directly on continuity of operation. Non-interrupted operation is also important to ultra-precise quartz oscillators. If a crystal is allowed to cool from its operating temperature, upon renewed operation it may assume a frequency offset and even an altered aging rate for a short period of time.

Hewlett-Packard standby power supplies ensure continued operation despite line interruptions, and operate over a range of ac line voltage to supply regulated dc to operate frequency standards and frequency dividers and clocks. The batteries in the supplies assume the full load immediately when ac power fails.

Alarm systems include local indication of operating conditions and provisions for remote alarms.

Variable frequency source

There are applications in many areas such as microwave spectroscopy and production testing of frequency sensitive devices for an instrument having the basic stability and spectral purity of a precision quartz oscillator, yet offering not just a few but many thousands of discrete frequencies. This capability is offered by the line of frequency synthesizers produced by Hewlett-Packard. The Model 5100B/5110B covers the frequency range of 0.01 Hz to 50 MHz in 0.01 Hz steps. The Model 5105A/5110B covers the frequency range of .1 MHz to 500 MHz in .1 Hz steps. Other models cover various other ranges.

Atomic and universal time scales

The time interval of the atomic time scale is the International Second, defined in October 1967 by the Thirteenth General Conference of Weights and Measures:

The Universal Time Scale, UT2 is related to the earth's rotation and has been proceeding at a rate slightly slower than that of the atomic scale. Its time interval—second—is slightly longer.

U. S. Standard Time, kept by the U. S. Naval Observatory's master clock, differs from nominal UT2 by an integral number of hours. The time interval broadcast by NBS stations WWV, WWVH and WWVL is that of a stepped approximation to UT2. WWVB (60 kHz) broadcasts the atomic second, without offset.

A time scale which approximates UT2 can be produced by oscillations offset from the atomic frequency in an amount proportional to the difference in the intervals employed. By international agreement, the amount of this frequency offset is fixed each year by the Bureau International de l'Heure, in Paris: for 1968 it is -300×10^{-10}.

Operational complications which arise owing to the need for changed offsets from year to year are eased considerably by design provisions Hewlett-Packard makes. The HP 5061A and HP 5065A can be easily referenced to either of the two time scales, Atomic, A.1, or UTC. The UTC time scale is the stepped approximation of the UT2 time scale. These changes are accomplished by simply changing the setting on a set of 4 thumbwheel switches located inside the unit under to top cover. The HP 117A Comparator is adjustable simply by a gear ratio change in the translator kit.

Hewlett-Packard systems anticipate future needs as well, and can easily be set up to new offset UTC offset scales as required.

Timekeeping to microsecond accuracy

Studies and systems requiring synchronized measurements at points widely separated in distance increasingly demand time standards capable of microsecond accuracy. Examples are studies of the propagation of electromagnetic waves, advanced systems for navigation, and aircraft collision avoidance.

In the 1967 Flying Clock Experiment* Hewlett-Packard demonstrated a system of three cesium beam time standards, one stationary and two transported by commercial airlines and automobiles on a 100,000 kilometer journey, that maintained time over 41 days to a mutual agreement within two microseconds.

Older methods relying on high frequency radio signals cannot correlate widely separated clocks to much better than a millisecond. The use of a portable time standard that travels among all the clocks of a system to correlate them with a master clock has proved to be ideal means of establishing time to microsecond accuracies.

Hewlett-Packard offers a portable time standard, the E21-5061A, which has proved itself capable of microsecond accuracy and which is easily transported by commercial airlines and automobiles.

Hewlett-Packard time and frequency standard

The HP House Standard has as its basic reference the HP 5060A Cesium Beam Standard. The output is continually compared in phase with the U.S. National Bureau of Standards (NBS-A) at Boulder, Colorado by reception of NBS standards stations WWVB and WWVL via HP 117A Comparators. The standard is also compared to two of the U. S. Navy's VLF stations. Time is correlated on each occasion when the HP Flying Clocks visit U. S national timekeeping centers. Frequency is maintained in agreement with NBS-A with an accuracy of parts in 10^{12}. Studies have shown this standard to rank among the world's most accurate.

Time is maintained relative to the Naval Observatory's master clock to an accuracy of better than ± 2.5 microseconds. This accuracy is verified with Flying Clock trips from the Naval Observatory to both Hewlett-Packard Palo Alto and Hewlett-Packard Geneva. Both locations have been designated U.S. Naval Observatory Time Reference stations.

A precision time comparison is made by the use of the HP 5325A Electronic Counter.

The measurement is one of totalizing pulses during the interval separating the one-second ticks generated by the flying clock and those generated by the reference clock.

Hewlett-Packard Application Note 52, "Frequency and Time Standards", discusses practical aspects of equipment, operation, and time scales (100 pages).

* Hewlett-Packard Journal December 1967

CESIUM BEAM TUBE

±1 x 10^{-11} long term stability

Model 5082A

Applications

Ultra Precise Frequency Standards for the calibration of lesser standards and the study of oscillator performance.

Time Keeping during long continuous intervals in which the highest degree of uniformity and reliability is required.

Communications for the fine resolution of frequencies up through the microwave spectrum.

Spectroscopy for the resolution of the finest details of physical spectra.

The HP Model 5082A Cesium Beam Tube (formerly BLR-2) is an ultra stable resonator or frequency reference component based upon the quantum mechanical properties of Cs^{133}. A unique motion within the cesium atom is coupled to an electromagnetic circuit to provide a resonance signal for the accurate control of frequency in electronic oscillators.

Through the use of the Cesium Beam Tube, it is possible to construct electronic oscillators with an extremely high degree of reproducibility and stability. Long term drifts and aging effects which are unavoidable in the best quartz crystal oscillators are absent in cesium beam stabilized oscillators. The Cesium Beam Tube is applied as the reference component in a feedback control system. All radio frequencies may be derived from the cesium controlled frequency without loss of precision by the use of well established synthesizing techniques.

Features

High Intrinsic Reproducibility—The HP Cesium Beam Tube characteristics are reproducible from unit to unit with no requirement for calibration against a primary standard during manufacture or during use.

Unifom Magnetic Field—To realize the highest degree of intrinsic reproducibility, the tube has been designed with special attention to the uniformity of the magnetic field in the atomic interaction space. Particular care has been exercised with respect to shielding factors and with respect to end effects.

High Q Resonance—Resonance Q of 3.5 x 10^7 permits high accuracy from associated oscillator circuits.

Reliability, Long Life—The 5082A provides the highest degree of reliability and long trouble-free operation. Tube life exceeds commonly accepted standards for microwave tubes.

Mass Spectrometer Detector—The high performance potential of the cesium beam technique is fully realized by the use of an efficient mass spectrometer detector which eliminates spurious impurity signals. Reliability and stability would otherwise be compromised by impurity signal pulses occurring, for example, as infrequently as once per week.

Construction—The tube is designed to ensure maximum accuracy in the alignment of the beam deflecting components. Every advantage is taken of the most advanced microwave tube technology to attain reliable, rugged construction. The vacuum envelope protects all critical parts from environmental effects. There are no external adjustments.

5082A

Specifications

Electrical

Frequency: 9,192,631, 770.0 ±0.2 Hz.

Long term stability: ±1 part in 10^{11}.

Reproducibility: ±1 part in 10^{11}. (Reproducibility refers to the degree to which resonance frequency is the same from one unit to any other.)

Output voltage: (signal/noise) 750 min. for 1 second time constant.

Output signal: 5 x 10^{-8} A at resonance peak.

Operating life: 10,000 hour warranty (35°C max. storage temp.). For details request 5082A Data Sheet.

Orientation: Frequency change is less than 5 x 10^{-12} for any position in the earth's field.

Mechanical

Dimensions: 25¼" long; diameter approximately 5⅝".

Weight: 23 lbs (11,5 kg) net; 34 lbs (15 kg) shipping.

Power requirements

R-F power: 30 μW maximum.

C-Field supply: nominal +20 mA dc regulated into 1Ω.

Hot wire ionizer: 1.5 V, 3.0 A ac or dc.

Mass spectrometer: nominal +14 V dc regulated to 0.5%.

Cesium oven: steady state, nominal 5 V at 0.8 A ac or dc. Thermistor included for proportional control.

Electron multiplier: −1800 to −2500 V dc ±0.1% at 50 μA maximum.

Ion pump (internal): initial, 1 mA dc at +3500 V. Steady state, nominal 1 μA dc at +3500 volts ±15%.

Price: Model 5082A, $5500.

CESIUM BEAM FREQUENCY STANDARD

Compact primary standard, $\pm 1 \times 10^{-11}$ accuracy

Models 5061A, E21-5061A

Advantages:

- Accuracy of ± 1 part in 10^{11}
- Circuit-check meters and lights monitor operation
- Clock and Digital Divider built-in (optional)
- Standby battery supply built-in (optional)
- All solid-state circuits, low power consumption
- Compact—8¾ inches high, 60 pounds

The Hewlett-Packard Model 5061A is a compact, self-contained primary standard of the atomic beam type, utilizing Cesium 133. A cesium beam tube resonator stabilizes the output frequency of a high quality quartz oscillator. Solid-state modular design is used throughout, and the closed-loop, self-checking control circuit yields exceptional accuracy of $\pm 1 \times 10^{-11}$. The 5061A has provision for an optional internal clock and digital divider and for battery with 1 hour (typical) standby power capacity.

The cesium beam tubes exhibit frequency perturbations so small that independently constructed tubes compare within a few parts in 10^{12}. Outstandingly reliable, these tubes have a 2.5 year typical life (guaranteed 10,000 hours). The 5061A can easily be referred to either of the two time scales in widespread scientific use: UTC or Atomic. The change is accomplished by changing a set of 4 thumbwheel switches and a slide switch, located under the top cover.

The quartz crystal oscillator used in the 5061A has superior characteristics even without control by the atomic resonator. The quartz oscillator portion of this cesium beam standard is identical to the HP 105A.

The 5061A is compact and portable, no complex permanent installation is required.

Operation

In the atomic resonator a beam of state selected Cesium 133 atoms passes through a microwave cavity. When the frequency of the microwave magnetic field is near the hyperfine transition frequency of Cesium 133, it induces transitions from one energy level to another. Those atoms which have undergone such a transition are then detected by a hot wire ionizer and electron multiplier. The microwave field, derived

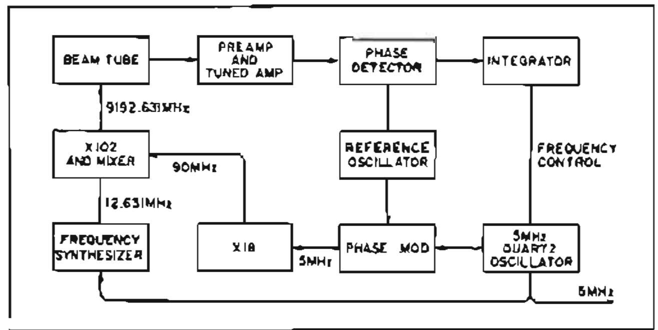


Figure 1

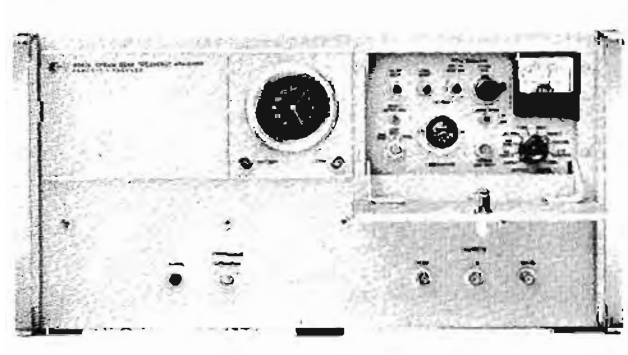
from a precision quartz oscillator by frequency multiplication and synthesis, is phase modulated at a low audio rate. When the microwave frequency deviates from the center of the atomic resonance, the current from the electron multiplier contains a component alternating at the modulation rate and proportional to the frequency deviation. This component is then filtered, amplified, and synchronously detected to provide a dc voltage proportional to the frequency deviation. The integral of this dc voltage is then used to automatically tune the quartz oscillator to zero frequency error.

The control circuit provides continuous monitoring of the output signal. Automatic logic circuitry is arranged to present an indication of correct operation. Figure 1 shows a simplified block diagram of the 5061A operation.

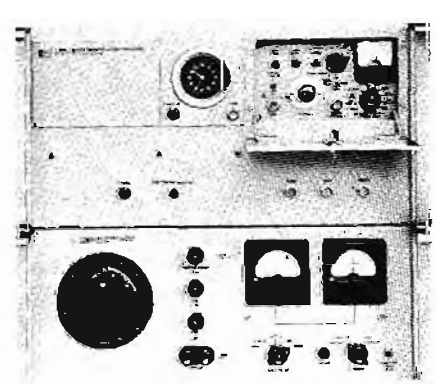
E21-5061A

The E21-5061A consists of a 5061A Cesium Beam Standard and a K02-5060A Power Supply joined together with a bracket to make one portable unit. The power supply, which can be operated from 6 or 12 V dc, 24 to 30 V dc, or 115/230 V ±10%, 50-400 Hz, will provide approximately 8 hours standby power (from batteries) for the 5061A. Thus the E21-5061A is a truly portable, primary frequency standard, and with option 01 on the 5061A, a complete flying clock of considerably smaller dimensions than the E20-5060A.*

*See Hewlett-Packard Journal, August 1966 and December 1967.



5061A

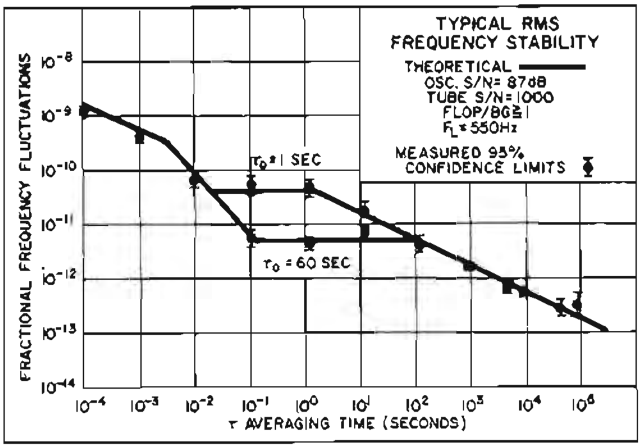


E21-5061A

Specifications

5061A Cesium Beam Standard

Accuracy:* $\pm 1 \times 10^{-11}$.
Reproducibility:* $\pm 5 \times 10^{-12}$.
Long term stability:* $\pm 1 \times 10^{-11}$ (for life of tube).
Short term stability: rear panel switch selects 1 s or 60 s loop time constant (see figure below).



Warm-up time: ¾ hour to fully operational from 25°C ambient temperature.
Harmonic distortion: (5 MHz, 1 MHz, and 100 kHz) down more than 40 dB from rated output.
Non-harmonically related output: (5 MHz, 1 MHz, and 100 kHz) down more than 80 dB from rated output.
Output frequencies: 5 MHz, 1 MHz, 100 kHz sinusoidal, 100 kHz clock drive.
Output voltages: 1 V rms into 50Ω; clock drive suitable for Hewlett-Packard Frequency Divider and Clocks.
Output terminals: 5 MHz, 1 MHz, 100 kHz, front and rear BNC connector, 100 kHz clock drive, rear BNC connector.
Time scale: adjustable with 4 thumbwheel switches and a slide switch from 0 to -700×10^{-10}. 12.63 . . . MHz test frequency available on rear panel.

Cesium Beam Tube

Tube life: typically 2 to 3 years. 10,000 operating hours guaranteed within 2 years of receipt of tube.
Length: 16 ± 1/16 in.
Diameter: approximately 5⅝ in.
Weight: 16 lbs.
Line width: 550 Hz (±20%).
S/N Ratio (Voltage): typical, 1000 (¼ Hz noise bandwidth).
RF power (9192 + MHz): 30 μW.
Power Input, 25°C, typical: 6.5 W.

Quartz Oscillator

Aging rate: <5 parts in 10^{10} per 24 hours.
Signal-to-noise ratio: for 1 and 5 MHz, > 87 dB at rated output (in a 30 kHz noise bandwidth, 5 MHz output filter bandwidth is approx. 100 Hz).
Frequency adjustments:
Fine adjustment: 5 parts in 10^{9} range, with dial reading parts in 10^{10}.
Coarse adjustment: 1 part in 10^{6}, screwdriver adjustment at front panel.
Stability: as a Function of Ambient Temperature: $< 2.5 \times 10^{-9}$ total frequency change from 0° to +50°C.
As a Function of Load: $< \pm 2 \times 10^{-11}$ change for open circuit to short, and 50Ω R,L,C load change.
As a Function of Supply Voltage: $< \pm 5 \times 10^{-11}$ change for 22 to 30 V dc, or for 115/230 V ac, ±10%.

General

Environmental: typical temperature stability is better than $\pm 5 \times 10^{-12}$, 0 to 50°C. Humidity, 0 to 95%. Typical magnetic stability is better than $\pm 5 \times 10^{-12}$, 2 gauss field, any orientation. Production 5061A's have passed the vibration per MIL-STD-167, electromagnetic compatibility specification, MIL-I-6181D (EMC, also known as RFI) and shock Mil-A-21200 class 1.
Power: 115 or 230 V ac ±10%, 50 to 400 Hz or 22 or 30 V dc. 39 W operating from dc with options. Approximately 75 W operating from ac with options.
Dimensions: 16¾" wide x 16⅜" deep x 8¾" high (425 x 416 x 221 mm).
Weight: net, 60 lbs, no options. Option 01 add 2 lbs. Option 02 add 5 lbs.
Accessories furnished: Rack Mounting Kit 5060-0777; 22 pin plug-in extender board 5060-7202; detachable 6 ft. ac power cord, connectors 1251-0038 (Cannon MS 3106A10SL-3SC) and 1251-0037 (A.P.M. Corp.) UP1 131M (NUP 121M).
Accessories available: 103A-16A dc Cable (connects 5061A to 5085A dc output), $21.50.
Price: HP Model 5061A, $14,800.00.

Option 01 Time Standard

Clock pulse:
Rate: 1 pulse per second.
Amplitude: +10 V ±10% peak.
Width: 20 μs min.
Raise time: < 50 ns.
Fall time: <1 μs.
Jitter: < 20 ns.
All specs are with 50Ω load.
Synchronization: 10 μs (±1 μs) delayed from reference input pulse (rear BNC). Reference pulse must be > + 5 V, with a rise time > 50 ns.
Price: Option 01, add $1,500.00.

Option 02 Standby Power Supply

Capacity: 30 minutes minimum (1 hour typical at 25°C) at full charge.
Charge control: automatic when ac power is connected.
Indicator: a front panel light flashes when ac power is interrupted and battery is being used.
Price: Option 02, add $600.00.

Option 03

(combines Options 01 and 02)
Price: Option 03, add $2100.

*Definition of Terms
Accuracy: The degree to which oscillator frequency is the same as that of an accepted primary standard (for example, the NBS-A Frequency Standard), or the degree to which oscillator frequency corresponds to the accepted definition, presently that of the 13th General Conference of Weights and Measures.
Reproducibility: The degree to which an oscillator will produce the same frequency from unit to unit and from one occasion of operation to another. Included within this definition is the degree to which the frequency of an oscillator can be set by a calibration procedure.
Intrinsic Reproducibility: The degree to which an oscillator will reproduce a given frequency without the need for calibrating adjustments either during manufacture or afterwards. This quality is a characteristic of an apparatus design, not of a resonance.
Long Term Stability: Total fractional frequency drift for the life of the cesium beam tube.

RUBIDIUM FREQUENCY STANDARD

Compact, lightweight atomic standard

Models 5065A, E21-5065A

Advantages:

- Low price atomic standard.
- Long term drift rate of $<2 \times 10^{-11}$/mo.
- Short term stability of $<7 \times 10^{-13}$ for 100 s average.
- Frequency synthesizer time scale changer.
- Calibrated dial fine frequency adjustment.
- Battery standby power guards against power failure (optional).
- Clock with precision 1 pps (optional).

Uses:

- Precise frequency source for sytsems operating in the radio spectrum.
- Coherent signal sources of all types.
- Precision timekeeping.
- House standards and calibration laboratories.

The HP Model 5065A is an atomic-type secondary frequency standard which uses a rubidium vapor resonance cell as the stabilizing element. As a result, its long term stability exceeds typical quartz oscillator frequency standards by 10 to 100 times. Furthermore, it has excellent short term stability. These features contribute to its desirability as a coherent signal source, as a master oscillator for radio and radar systems where special requirements for stability and/or narrow bandwidth must be met, as a precision timekeeper where the better performance of a cesium beam primary standard is not required, and as a house frequency standard for improved accuracy with fewer NBS calibrations compared to that required with quartz standards.

A thumbwheel settable frequency synthesizer is a standard feature of this frequency standard. The user can, himself, easily set his 5065A Standard to either Atomic or UTC time, or other offsets to suit a particular requirement, with 4 thumbwheels and a slide switch.

Front panel controls and circuit check meter of the 5065A are protected by a drop-down panel door. The magnetic field control provides fine frequency adjustment with which the frequency can be set to a precision of less than 2×10^{-12} without reference to a chart. Oscillator frequency adjustments are to correct for aging of the 5 MHz low noise quartz oscillator which is phase locked to the atomic frequency and provides the standard 5 MHz, 1 MHz, and 100 kHz outputs. The circuit check meter with selector switch monitors key voltages and currents for routine maintenance readings, calibration procedures, and fault finding.

The 5065A is designed for assured operation—to give the user confidence that the standard output signals are correct and locked to the atomic frequency. Logic within the unit maintains power to a "continuous operation" light on the front panel at all times—if operation is interrupted, even momentarily, for any reason the light goes out and stays out until manually reset. The logic reset button on the control panel is for this purpose. An integrator limit light warns if the atomic to quartz resonator phase-lock error voltage is high and should be adjusted.

A standby power option provides 10 minutes, minimum, of off power-line operation. For longer periods use the 5085A standby power supply or the K02-5060A. Switch over to battery is automatic. A front panel light warns when ac power has been lost. The time standard option generates 1 pulse per second, available at a front panel BNC connector. The clock pulse phase is adjustable with respect to a reference in precise increments from 1 μs to 0.1 s. A variable control allows adjustment from 0 to 1 μs. A clock movement indicates hours, minutes, and seconds.

The HP Model 5065A is contained in a small sized package and is lightweight in comparison to a cesium beam standards. Additionally, the rubidium resonance cell is much more frequency stable than quartz oscillators while subjected to shock and vibration. Its environmental specifications include temperature, shock, vibration, EMC, humidity, and magnetic field effects.

E21-5065A
Portable time standard

E21-5065A portable time standard is a complete system for precision timekeeping and for transporting time from one location to another. Its main components are the 5065A Rubidium Standard with digital clock and divider (option 01) and the K02-5060A power supply with 6 or more hours standby. Its batteries recharge from a wide variety of power sources including 115 or 220 V, 50 - 400 Hz, ac and 6 or 12 V dc. Thus, it may be powered from commercial aircraft, auto electrical systems, storage batteries, commercial power lines, or its own internal batteries. The component units are held together by two side bars.

Weight: 110 lb (50 kg).

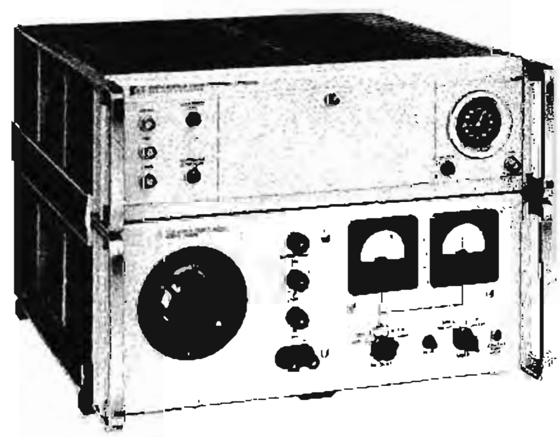
Dimensions: 16¾" (425 mm) wide, 14" (355 mm) high, 18⅜" (467 mm) deep.

Price: $12,300.00.

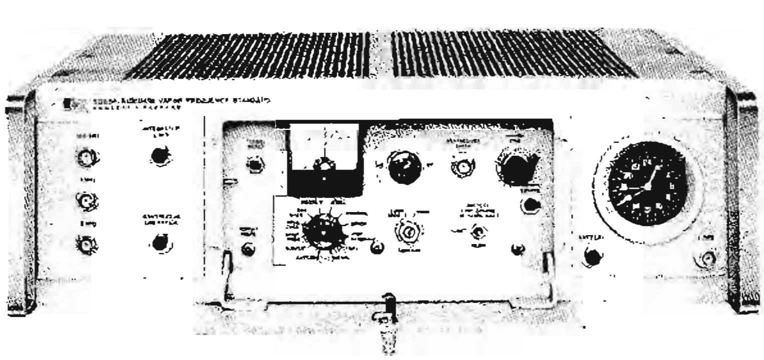
E20-5065A
Portable time standard

Electrically identical to the E21-5065A described above, the E20-5065A differs in that the component instruments are enclosed in a single aluminum cabinet.

Price: available on request.



E21-5065A



HP 5065A shown with Option 03 consisting of clock and standby battery

Specifications, 5065A

Frequency stability:

Long term: 2×10^{-11} per month (maximum limit of drift rate).

Short term: $\frac{\Delta f}{f}$ (Std. Dev.)

$\frac{\Delta f}{f}$ (Std. Dev.)	Avg. Time
$<7 \times 10^{-12}$	1 sec.
$<2.2 \times 10^{-12}$	10 sec.
$<7 \times 10^{-13}$	100 sec.

Calibration accuracy: set at factory to $< \pm 1 \times 10^{-11}$ of specified time scale.

Time scale: set at factory to UTC unless specified differently.

Tunability:

Coarse frequency synthesizer adjustment:

Range: 1000×10^{-10}

Resolution: $<2 \times 10^{-9}$, thumbwheel adjustable.

Fine frequency magnetic field adjustment:

Range: 2×10^{-9}.

Resolution: 2×10^{-12}.

Warm-up: within 1×10^{-10} in one hour and 5×10^{-11} in 4 hours after 24 hours "off" time.

Outputs:

Frequencies: 5 MHz, 1 MHz, 100 kHz and isolated 100 kHz clock drive for external clocks.

Voltage levels: 1 V rms into 50 ohms at 5 MHz, 1 MHz, 100 kHz; 0.5 V rms into 1000 ohms at 100 kHz, clock drive.

Connectors: BNC front and rear for 5 MHz, 1 MHz, 100 kHz; BNC rear for 100 kHz clock drive.

Harmonic distortion: (5 MHz, 1 MHz, 100 kHz) >40 dB down from rated output.

Non-harmonic distortion: (5 MHz, 1 MHz, 100 kHz) >80 dB down from rated output.

Signal-to-noise ratio: for 1 and 5 MHz, >87 dB at rated output (in a 30 kHz noise bw, 5 MHz output filter bw is approx. 100 Hz).

Environmental:

Temperature, operating: 0° –50°C. Frequency change is $<1 \times 10^{-10}$ over this range.

Temperature, non-operating: –40° to +75°C. (With options, to 50°C.)

Production units have passed type tests as follows:

Humidity: 0 to 95% relative humidity.

Magnetic field: $<1 \times 10^{-11}$ frequency change for 1 Gauss change (earth's field is typically 0.5 Gauss).

Vibration: MIL-Std-167.

Shock: MIL-T-21200, Class 1 (30 G's).

Electromagnetic compatibility (EMC): MIL-I-6181D.

Mating connectors:

EXT DC input: 1251-0126 (5-contact), Cannon MS 3106E-14S-5S (Series ME) furnished.

Clock output: 1251-0127 (4 contact), Cannon MS 3106E-14S-2P (Series ME).

AC line: 1251-0038, Cannon MS 3106A-10SL-35 (C).

Power: 115 or 230 V ac ±10%, 50 to 400 Hz: or 23 to 30 V dc. Approx. power required:

	24 V dc	115 V ac
Without options:	35 W	49 W
Option 01	Add 8 W	9 W
Option 02	0 W	6 W
Option 03	Add 8 W	15 W

Accessories furnished: power cord, 6 ft (180 cm) detachable. Rack Mounting Kit, HP 5060-0775. Accessory Kit, HP 05065-6066, includes Micon connector adapter male-male, mating connector 1251-0126 for EXT DC input, 3 circuit board extenders, test cable, and a special coil tuning screwdriver.

Dimensions: 16¾" (425 mm) wide, 5-7/32" (132.6 mm) high, 18⅜" (467 mm) deep.

Weight: net, 37 lb (16,8 kg). Option 01 add 2 lb (,9 kg): Option 02 add 3.5 lb (1,6 kg).

Accessories available: EXT DC cable: connect 5065A to 5085A standby supply, 103A-16A, $21.50.

Price: $7,500.00.

Option 01 time standard

Clock pulse:

Rate: 1 pulse per second.

Amplitude: +10 V ±10%.

Width: 20 μs min.

Rise time: <50 ns.

Fall time: <1 μs.

Jitter: <20 ns.

All specs are with 50 Ω load.

Synchronization: 10 μs (±1 μs) delayed from reference input pulse (rear BNC). Reference pulse must be >+5 V, with a rise time <50 ns and width >0.5 μs.

Clock movement: 24 hrs., Patek Philippe.

Price: Option 01, add $1,500.00.

Option 02 standby power supply

Capacity: 10-minute minimum at 25°C after full charge (incl. Option 01).

Charge control: front panel Fast-Float-Reset charge switch.

Indicator: a front panel light flashes when ac power is interrupted and battery is being used.

Price: Option 02, add $300.

Option 03
(Combines Options 01 and 02)

Price: Option 03, add $1,800.00.

Performance of quartz oscillator only
(Rubidium control loop open)

Aging rate: $<5 \times 10^{-10}$ per 24 hours.

Frequency adjustments:

Fine adjustment: 5×10^{8} range, with dial reading parts in 10^{10}.

Coarse adjustment: 1 part in 10^{6}. screwdriver adjustment at front panel.

Stability:

As a function of ambient temperature: $<2.5 \times 10^{-9}$ total, 0° to +50°C.

As a function of load: $< \pm 2 \times 10^{-11}$ for open circuit to short, and 50 Ω R, L, C load change.

As a function of supply voltage: $< \pm 5 \times 10^{-11}$ for 22 to 30 V dc, or for 115/230 V ac, ±10%.

QUARTZ OSCILLATORS

State-of-the-art frequency stability

Models 105A,B; 106A,B; 107AR,BR; 101A

Advantages:

- High spectral purity
- Well-buffered outputs
- Solid-state reliability

Uses:

- In-house frequency and time standards
- Microwave spectroscopy
- Comparisons with atomic standards
- Advanced navigation, communication systems

Models 105A,B, 106A,B and 107AR,BR Quartz Oscillators provide state-of-the-art application in precision frequency and time standard systems because of their excellent long and short term stability characteristics, spectrally pure outputs, unexcelled reliability, and ability to operate under a wide range of environmental conditions.

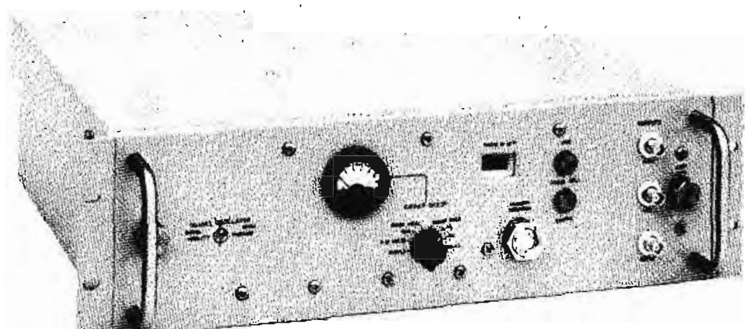
The Models 107AR and 107BR are rugged, hermetically sealed, precision quartz oscillators for frequency and time standards. Model 107AR operates from 26 ± 4 V dc; Model 107BR operates from the ac line and includes a 2-hour standby battery mounted within the oscillator. Both instruments provide sinusoidal signals of 5 MHz, 1 MHz, and 100 kHz with excellent short term stability and long term drift rate. They operate over a wide range of environmental conditions.

Models 107AR and 107BR have been prototype tested to conform to the shock and vibration requirements of MIL-E-16400E. MIL-E-16400E subjects the instrument to vibration at 5 to 33 Hz rates with excursions from 0.03 to 0.01 inch in each of three mutually perpendicular planes. Under the shock test the instrument receives nine blows from a 400-pound hammer. Blows are from one foot, three and five feet in each of three planes.

Particular care was taken to provide a spectrally pure 5 MHz output which, when multiplied high into the microwave region, provides signals with spectra only a few cycles wide. Spectra less than 1 Hz wide can be obtained in X-band (8.2 to 12.4 GHz). The stability and purity of the 5 MHz output make it suitable for doppler measurements, microwave spectroscopy, and similar applications where the reference frequency must be multiplied by a large factor.

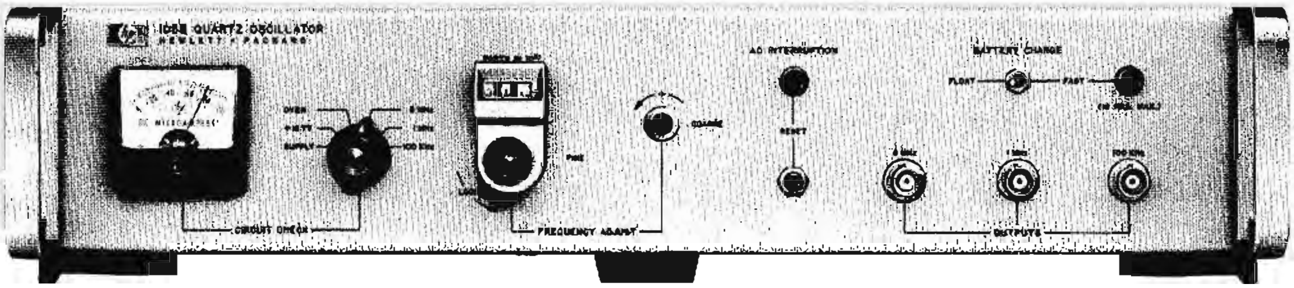
Provision also has been made in the 107AR and 107BR Quartz Oscillators so that they can be voltage controlled; therefore these oscillators can be used in phase locked systems. The sensitivity of this automatic frequency control is such that a change from $+5$ to -5 volts will change the output by approximately 2 parts in 10^8.

The models 106A,B have the highest long term stability



107AR

106B



105B

of the HP quartz oscillators. In addition to high stability these oscillators have very high spectral purity and Hewlett-Packard's unexcelled reliability.

The heart of these oscillators is an extremely stable 2.5 MHz quartz crystal mounted with other critical components in a proportionally controlled double oven. The crystal and this type of control results in an oscillator with extremely good long term stability—better than 5 parts in 10^{11} per day. Short term stability is also excellent, being 1.5 parts in 10^{11} rms for sample periods as short as 0.1 second.

The 5 MHz output provided by these oscillators has the stability and high spectral purity of the 2.5 MHz crystal. Spectra only a few cycles wide may be obtained in the GHz region by multiplication of the 5 MHz output.

Models 106A and B are identical in every respect except for their power requirements. The 106B operates from 115 or 230 volts ac line or from an external dc power supply (HP 5085A recommended) and contains an emergency standby power supply capable of sustaining operation for 8 hours. The 106A requires an external supply voltage of 22 to 30 V dc, such as the HP 5085A.

The models 105A,B are the latest addition to the HP quartz oscillator line. They fill a need for a smaller and more economical and yet highly stable precision quartz oscillator for frequency and time standards. Both models can be operated from the ac line; the 105B has a built-in 8-hour standby battery supply for uninterrupted operation should line power fail. Both models have 5 MHz, 1 MHz, and 100 kHz sinusoidal outputs with excellent short term stability (1 part in 10^{11} rms for 1 s averaging time) and aging rate (<5 parts in 10^{10} per day). In addition, the 105A/B features rapid warm-up. Typically, the oscillator will be within 5 parts in 10^9 of the previous frequency in one hour after an "off" period of approximately 24 hours under lab conditions.

The basis of these oscillators is an extremely stable 5 MHz, 5th overtone quartz crystal developed by Hewlett-Packard. New technologies in the crystal mounting and packaging have resulted in a cleaner crystal which in turn has a lower aging time. The crystal, oscillator and AGC circuit are all enclosed in a proportional oven which reduces the temperature effects on these components and circuits.

Each frequency output of the 105A/B is buffered to provide an output stable to within ± 2 parts in 10^{11} regardless of load changes occurring in any other output. Buffering between the outputs, in addition to the excellent stability of the 5 MHz crystal, makes the 105A and 105B ideal for application in frequency standard systems requiring use of multiple outputs. The 105A and 105B may be used in complex systems with complete assurance that loading changes, such as accidental shorts or disconnections in other outputs, will not affect frequency of the output of primary concern.

Provision has been made in Models 105A/B to control the output frequency, using an externally applied voltage for uses such as phase lock systems. A 10 V change in applied voltage will change the 5 MHz output frequency by approximately 5 parts in 10^8.

101A

Hewlett-Packard Model 101A 1 MHz Oscillator is a high-stability crystal controlled oscillator suitable for many field and laboratory applications. Although designed specifically to be the time base for Model 5275A Electronic Time Interval Counter, the high precision capabilities and low cost of Model 101A make it an ideal instrument for many other applications as well.

Long term stability of 5 parts in 10^8 per week is achieved by careful oscillator design and by housing the high quality crystal and associated critical components in a well-regulated oven. This unit will operate over the wide ambient temperature range of $-5°C$ to $55°C$.

Stability, including all effects of line, load, and ambient temperature variation over specified ranges, is better than 3 parts in 10^8. A front panel adjustment permits frequency adjustment over a range of approximately ± 1 part in 10^6.

Specifications, Model 101A

Stability

Short term: 3 parts in 10^8.

Long term: 5 parts in 10^8 per week.

Output frequencies: 1 MHz and 100 kHz (sinusoidal), rear BNC connectors.

Output voltage: 1 V rms min into 50-ohm load.

Distortion: less than 4% into rated load.

Oven temperature indicator: front panel dial thermometer.

Frequency adjustment: front panel screwdriver adjust with range of approximately ± 1 part in 10^6 for calibration from primary standard.

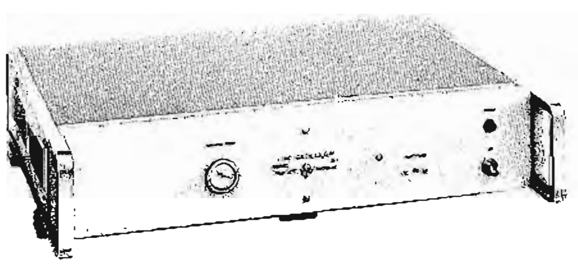
Power: 115 or 230 V $\pm 10\%$, 50 to 400 Hz, 2 to 15 W depending on oven cycle.

Dimensions: 16¾″ wide, 3½″ high, 11½″ deep (426 x 89 x 292 mm).

Weight: net approximately 10 lbs (4,5 kg); shipping 13 lbs (5,9 kg).

Accessories furnished: 10503A, 4-foot (122 cm) cable assembly, each end terminated by BNC male connector.

Price: model 101A, $700.



101A

Specifications

Models	107AR,BR
Output frequencies	5 MHz, 1 MHz, 100 kHz sinusoidal; 100 kHz clock drive
Output voltages	5 MHz, 1 MHz, and 100 kHz, 1 V rms into 50 ohms; 100 kHz for driving HP frequency divider and clocks, 0.5 V rms into 1000 ohms
Stability (long term)	$< \|5\| \times 10^{-10}$ per 24 hours
As a function of ambient temperature	$< \pm 1 \times 10^{-10}$ from 0° to +50°C
As a function of humidity	none (instruments are hermetically sealed)
As a function of load	$< \pm 2 \times 10^{-11}$ for any resistive load change
As a function of supply voltage	(107AR) $< \pm 5 \times 10^{-11}$ for 22 to 30 V dc
As a function of line voltage	(107BR) $< \pm 1 \times 10^{-11}$ for 10% change from 115 or 230 V ac
RMS deviation of 5 MHz (short-term stability)	averaging time / max. rms fractional-frequency deviation (Δf/f) / max. rms phase deviation (milliradians): 1 ms: 8×10^{-10}; 0.03 10 ms: 1.5×10^{-10}; 0.04 0.1 s: 1.5×10^{-11}; 0.04 1 s: 1.5×10^{-11}; 0.4 10 s: 1.5×10^{-11}; 4
Noise-to-signal ratio (5 MHz)	at least 87 dB below rated 5 MHz output; output filter bandwidth is approximately 125 Hz
Harmonic distortion (5 MHz, 1 MHz, and 100 kHz)	down more than 40 dB from rated output
Non-harmonically related output (5 MHz, 1 MHz, and 100 kHz)	down more than 80 dB from rated output
Output terminals	5 MHz, 1 MHz, 100 kHz, front and rear BNC connectors; 100 kHz clock drive, rear BNC connector
Frequency adjustments	
Fine adjustment	5 parts in 10^8 total; 1 part in 10^9 per rev; 1 part in 10^{10} per division at 10 divisions per revolution
Coarse adjustment	1 part in 10^6 ($\pm 0.5 \times 10^{-6}$)
Environmental	
Storage temperature	−65°C to +85°C (mfr. specifies −40°C to +50°C limit for 107BR battery storage)
Operating temperature	0°C to +50°C
Humidity	instrument is hermetically sealed, will operate under water without degradation of performance
Vibration and shock	completely passes vibration and shock requirements of MIL-E-16400E
Weight	107AR: net 20 lbs (9 kg), shipping 38 lbs (17 kg); 107BR; net 35 lbs (16 kg), shipping 53 lbs (24 kg)
Dimensions	
Height	5-7/32″ (133 mm)
Width	19″ (483 mm)
Depth	16⅜″ (416 mm)
Power	107AR: 22 to 30 V dc, approx. 12 W operating, 15 W during warm-up; 107BR: 115 or 230 V ac ±10%, 50 to 1000 Hz, approx. 25 W operating with battery on trickle charge (30 W on fast charge), 33 W during warm-up (38 W on fast charge)
Price	Model 107AR, $2600 Model 107BR, $2950

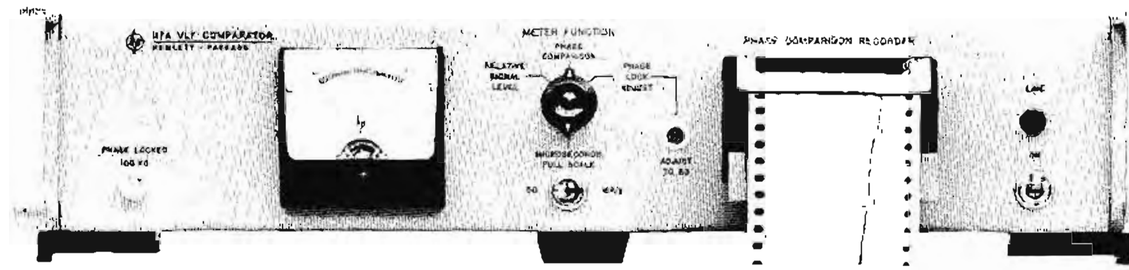
Specifications

Models	106A,B	105A,B
Output frequencies	5 MHz, 1 MHz, 100 kHz sinusoidal; 100 kHz clock drive	5 MHz, 1 MHz, 100 kHz sinusoidal; 1 MHz or 100 kHz clock drive
Output voltages	5 MHz, 1 MHz, and 100 kHz, 1 V rms into 50 ohms; 100 kHz for driving HP frequency divider and clocks, 0.5 V rms into 1000 ohms	
Stability (long term)	$< \|5\| \times 10^{-11}$ per 24 hrs	$< \|5\| \times 10^{-10}$ per 24 hours
As a function of ambient temperature	$<= 1 \times 10^{-10}$ from 0° to +40°C	2.5×10^{-9} total from 0°C to +50°C
As a function of humidity	none (basic oscillator is sealed)	none
As a function of load	$<= \pm 2 \times 10^{-11}$ for any resistive load change	$<= \pm 2 \times 10^{-11}$ for open, short, 50Ω resistive, inductive and capacitive
As a function of supply voltage	(106A) $<= \pm 3 \times 10^{-11}$ for 22 to 30 V dc	$<= \pm 5 \times 10^{-11}$ for 22-30 V dc
As a function of line voltage	(106B) $<= \pm 1 \times 10^{-11}$ for ±10% change from 115 or 130 V ac	$<= \pm 5 \times 10^{-11}$ for 115/230 V ac ±10%
RMS deviation of 5 MHz (short-term stability)	averaging time / max. rms fractional-frequency deviation (Δf/f) / max. rms phase deviation (milliradians) 1 ms / 8×10^{-10} / 0.03 10 ms / 1.5×10^{-10} / 0.04 0.1 s / 1.5×10^{-11} / 0.04 1 s / 1.5×10^{-11} / 0.4 10 s / 1.5×10^{-11} / 4	averaging time / max. rms fractional-frequency deviation (Δf/f) / max. rms phase deviation (milliradians) 1 ms / 5×10^{-10} / 0.016 10 ms / 1×10^{-10} / 0.031 0.1 s / 1×10^{-11} / 0.031 1 s / 1×10^{-11} / 0.31 10 s / 1×10^{-11} / 3.1
Noise-to-signal ratio (5 MHz)	at least 87 dB below rated 5 MHz output; output filter bandwidth is approximately 125 Hz	>90 dB below rated output; output filter bandwidth (3 dB) is 100 Hz
Harmonic distortion (5 MHz, 1 MHz, and 100 kHz)	down more than 40 dB from rated output	
Non-harmonically related output (5 MHz) 1 MHz, and 100 kHz)	down more than 80 dB from rated output	
Output terminals	5 MHz, 1 MHz, 100 kHz, front and rear BNC connectors; 100 kHz clock drive, and electrical frequency control rear BNC connector	5 MHz, 1 MHz, 100 kHz, front and rear BNC connectors; clock drive and electrical frequency control, rear BNC connectors
Frequency adjustments Fine adjustment Coarse adjustment	 2 parts in 10^8 total; 1 part in 10^{10} per rev; 1 part in 10^{11} per division at 10 divisions per revolution 5 parts in 10^7 ($\pm 2.5 \times 10^{-7}$)	 5×10^{-8} total, with digital dial reading parts in 10^{10} 1×10^{-6} (screwdriver adjustment)
Environmental Storage temperature Operating temperature Humidity Vibration and shock	 −40°C to +75°C (mfr. specifies −40°C to +50°C limit for 106B battery storage) 0°C to +40°C basic oscillator is sealed 	 −40°C to 75°C (mfr. specifies −40°C to +50°C limit for 105B battery storage) 0°C to +50°C 0 – 95% Mil-STD – 167 30 G's
Weight	106A: net 25 lbs (11,3 kg), shipping 33 lbs (15 kg); 106B: net 39 lbs (17,6 kg), shipping 47 lbs (21,3 kg)	105A: net 16 lbs (7,3 kg), shipping 23 lbs (10,4 kg). 105B: net 24 lbs. (10,9 kg), shipping, 31 lbs (14,1 kg)
Dimensions Height Width Depth	 6-31/32" (177 mm) 16¾" (425 mm) 16⅜" (416 mm)	 3-15/32" (88 mm) 16¾" (425 mm) 11¼" (286 mm)
Power	106A: 22 to 30 V dc, negative ground, approx. 8W operating, 13W during warm-up; 106B: 115 or 230 V ac ±10%, 50 to 1000 Hz, negative ground approx. 17 W operating with battery on trickle charge (27 W on fast charge), 33 W during warm-up (43 W on fast charge)	105A: 115/230 V ±10%, 50-400 Hz, at 17 W (21 W warm-up) 105B: 115/230 V ±10%, 50-400 Hz, at 18 W (24 W warm-up), at float charge. Add 12 W for fast charge Both: 22-30 V dc at 6.4 W (10.3 W warm-up)
Price	Model 106A, $3650 Model HP 106B, $3750	Model 105A, $1500 Model 105B, $1800

VLF COMPARATOR

Compares frequency against NBS standard

Model 117A



117A

Advantages:

- Plots minute-by-minute phase record
- Provides all equipment needed for frequency comparison
- Offers one microsecond resolution
- Makes available 100 kHz phase-locked output

Uses:

- Offset and drift determinations for crystal oscillators
- Quick and easy checks of counter time-base accuracy
- Monitors atomic standards against N.B.S.

The HP 117A VLF Comparator measures the frequency offset of a local standard frequency source against a radio signal based on the N.B.S. Frequency Standard to an accuracy that can reach a few parts in 10^{11} in a 24-hour period. The HP 117A thus provides a link between house frequency standards and the Boulder, Colorado, laboratories of the National Bureau of Standards (NBS) via station WWVB, which broadcasts at 60 kHz on a continuous basis.

The strip chart produced by the HP 117A records, minute by minute, the results of a precision phase comparison of the local signal against the received signal to show frequency offset or error of the local standard, and over a few hours to a day or more, its drift rate.

Local precision frequency sources, such as quartz crystal oscillators that drive clocks or synthesizers or that serve as counter time bases, can be quickly compared in frequency for purposes of calibration or can be monitored over as long a time as desired to determine their behavior and to measure long-term drift rate.

Method of Operation

The VLF Comparator is a complete system (exclusive of local standard) which consists in one package of a receiver, an electronic servo-controlled oscillator which functions as a narrow band tracking filter, a linear phase comparator, and a strip chart recorder. The servo loop and phase-locked oscillator provide a continuous output signal despite noise and interfering signals. A front panel meter can be switched to show relative signal level, phase lock with WWVB, or phase comparison. Output terminals on the rear provide for the connection of external galvanometer and potentiometer recordings if desired. A loop antenna with built-in preamplifier and 30 meters of lead-in cable is included.

The recorded trace is easily evaluated directly in terms of frequency offset with a transparent template supplied with the instrument. Chart speed is 1 inch per hour and full-scale chart width may be set for either 50 μsec or 16-2/3 μsec by operation of a front panel switch. The readability of the trace and the overall stability of the comparator easily provide a resolution of better than 1 μsec under normally encountered laboratory conditions.

NBS Standard Broadcast WWVB

The WWVB 60 kHz signal reaches a primary service area that includes the entire continental United States. NBS controls the broadcast frequency to within $\pm 2 \times 10^{-11}$ of its intended value. NBS publishes monthly, in *Proceedings of the IEEE*, frequency correction data relative to WWVB and also to the other standard broadcasts, which are WWV and WWHV (high frequency) and WWVL.

WWVB is referenced to the National Bureau of Standards Frequency Standard and its frequency is *not* offset. WWVB seconds pulses are those of the time scale NBS-A, for which time interval is the international (atomic) second. (Frequency of the other NBS services is offset by an amount coordinated through the Bureau International de l'Heure: for 1968, offset is -300×10^{-10}. Purpose of the offset is to make the second of time interval correspond closely to that of UT-2, the time scale in ordinary use.)

Accuracy of the HP 117A approaches that of the broadcast signal itself. The HP 117A takes advantage of the phase-stable nature of the lower frequencies to make possible quick comparisons to accuracies far exceeding those achieved by use of the older high frequency services. In the continental U.S., frequency standard comparisons to an accuracy of a part in 10^{10} can be approached in an 8-hr. period. A 24-hr. period may give 2 parts in 10^{11}, and a 30-day period may give accuracies of parts in 10^{12}. The local standard being calibrated must, of course, be of a quality commensurate with the realization of such high accuracies.

Template

A transparent template, overlayed on the HP 117A's strip chart recording, enables the operator to read at a glance the frequency offset of his local standard. The template curve most nearly matching the chart's trace is selected, then offset is read directly, together with its sign. The sign indicates whether local frequency lies above or below reference frequency.

Atomic and UT-2 Time Scales

Many users prefer to maintain their local frequency standard referenced to the interval of UT-2, the time scale in ordinary use, rather than to NBS-A. (These two scales are explained at the beginning of the "Frequency and Time Standards" section.) Use of a translator kit adapts the 117A for UT-2 service. Hewlett-Parkard offers two translators:

The 00117-91027 Translator Kit installs in the 117A. A power-line-driven synchronous motor and gear train rotate a phase shifter to continuously retard the phase of the WWVB signal, thereby decreasing the frequency. Power-line frequency changes of 0.1% cause translation errors of only about 1.5×10^{-11}. Most lines average much less than 0.1% frequency deviation over extended periods.

The K10-117A Translator is a separate instrument for use external to the 117A. It also uses a motor-driven phase shifter. It shifts the frequency of, and derives its time base from, the external 100 kHz (1 MHz, optional) source being compared with WWVB, and is unaffected by line frequency. The direction of translation can be changed.

In both translators, the correct gear ratio is supplied for coordinated frequency offset in effect at time of purchase. Different gear ratios will be available at a nominal charge to change the translation ratio when the offset is changed. The 117A is available with the 00117-91027 translator installed (see Specifications).

Antenna

The loop antenna supplied with the 117A contains a preamplifier which allows at least 300 meters of cable (30.5 meters supplied) between antenna and receiver. The cable's center conductor carries power to the preamplifier.

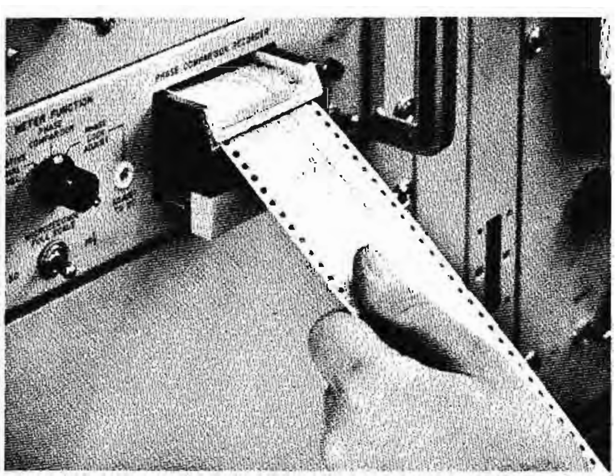
Antenna location and orientation are important. For best signal pick-up it should be mounted on the roof (it is sealed against the weather) and oriented with the plane of the loop aligned with signal direction.

Additional Information

A complete discussion of the use of lower frequency broadcasts in frequency standardization is included in Hewlett-Packard Application Note 52, "Frequency and Time Standards."

Phase Comparison Record

The slope of the trace plotted by the 117A's strip chart recorder is, at a given instant, frequency offset between the local standard and the received signal. This slope may be read at a glance with the transparent template supplied with the instrument. Two offset readings separated by a span of time usually chosen to be one day give all data needed to allow a determination of the drift rate of the local standard (drift rate is given by the difference in offset over a specified elapsed time).



Greatest accuracy results when the user selects the times he makes observations to fall in a period when propagation conditions are stable, as revealed by the nature of the trace. VLF signals are normally highly stable when the entire propagation path is in sunlight. Near sunrise and sunset, the diurnal shift makes an apparent change in the offset.

Any VLF Comparator is but one element of the system which the user must consider: (1) transmitted signal, (2) transmission path, (3) VLF comparator, and (4) local standard. Since the first two elements are not under the user's control, he must make his observations in accordance with reception conditions. While VLF signals are noted for their stability, variations in propagation conditions do exist and must be taken into account.

European service

A modified 117A may be used to receive the 75 kHz frequency and time broadcast of HBG, Prangins, Switzerland. This station is one of the most accurate services in Europe.

It broadcasts the atomic standard frequency to a published accuracy of 2×10^{-11}.

The standard 117A may be used to receive MSF, Rugby, England, which broadcasts the atomic standard frequency on 60 kHz with an accuracy of 1×10^{-10}.

Specifications, 117A

Received standard frequency: 60 kHz. NBS station WWVB.

Sensitivity: 1 μV into 50Ω.

Local standard input: 100 kHz, 1 V rms into 1000Ω (divider to accept 1 MHz at extra cost).

100 kHz phase-locked output: 5 V rectangular positive pulses into 5000Ω.

60 kHz test output: self-checks the 117A.

Recorder outputs: phase comparison and relative signal strength: 0-1 mA dc into 1400 Ω and 0,100 mV dc from 2000Ω.

Overall phase stability: ±1 μs 0-50°C.

Chart speed: 1 in/hr (6 or 12 in/hr available).

Chart width: 50 μs or 16⅔ μs (selected by front panel switch).

Meter readings: three switch positions: (1) relative signal level; (2) phase comparison calibrated scale 0-50 μs 0-16⅔ μs full scale; (3) phase-lock range indicated insures negligible phase error.

Adjustments: a front panel control adjusts free-running frequency of voltage-controlled oscillator; three rear panel adjustments provide calibration of phase comparison, full-scale adjustment for internal recorder, internal meter, and external galvanometer recorder.

Storage temperature: −50° to +75°C.

Operating temperature: 0° to 50°C.

Dimensions: 16¾" wide, 3-15/32" high, 13¼" deep (425 x 88 x 337 mm).

Weight: 117A: net 20 lbs (9,1 kg), shipping 22 lbs (10 kg); antenna: net 12.5 lbs (5,7 kg), shipping 21 lbs (9,5 kg).

Power: 115 or 230 V ±10%, 60 cycles, 40 watts.

Accessories (included):

10509A loop antenna: antenna has electrical height of 1.6 mm, is 43 in (109 cm) in diameter and mounts on 1-in. pipe thread. Operating temperature: −60° to +80°C. Also available separately (for use only with HP 117A). $280.

10512A coaxial lead-in cable: 50Ω BNC-BNC connectors 100 feet (30,5 m) long. Also available separately, $30.

Accessories (not included with 117A):

Time Scale Translators:

00117-91027 translator kit, $350.

K10-117A translator. $1,100.

9281-0081 recorder chart paper: box of six 30-ft rolls, $12.50.

Prices: 117A including 10509A antenna/pre-amp and 10512A lead-in cable, $1400.

H21-117A: is model 117A with 0117-91027 translator installed, $1775.

STANDBY POWER SUPPLIES

For Frequency and Time Standards

Models 5085A, K02-5060A

Advantages:

2 amperes at 24 volts
Up to 18 ampere-hours of standby
Solid state, modular

Uses:

Continued operation
of primary standards when
ac line power is interrupted

The HP Model 5085A 24 volt 2 ampere power supply keeps primary frequency or time standard systems in operation when ac line power is interrupted. Specifically designed to deliver standby power to the HP Cesium Beam Standards, Rubidium Vapor Standard, and peripheral equipment, the 5085A will also serve HP Quartz Oscillator Frequency Standards and the 115BR Frequency Divider and Clock. The only requirement is that the total current drawn from the supply not exceed 2 A for any extended period of time.

The frequency and time standard system is not affected during changeover since no switching is used in transferring power from line to battery operation and back again.

Vented nickel-cadmium batteries with an 18 ampere-hour guaranteed capacity (derated from 25) are used in the 5085A. They provide about 8 hours of standby power for the 5061A Cesium Standard or 5065A Rubidium Standard (at average ambient temperature of 25°C).

Front panel lights indicate mode of operation, report fuse failure, ac interrupt.

Specifications, 5085A

Output voltage: 24 ±2 V dc at rated current.

Maximum rated current (total external load): 2 amperes.*

Standby capacity: (At 25°C**) 18 ampere hours after 48 hours with manually operated CHARGE switch set to CHARGE.

Alarm indicators: Panel lamps indicate: (1) FUSE FAILURE, (2) AC POWER, (3) AC INTERRUPT, (4) CHARGE.

Remote alarm provisions: SPDT relay contacts provided at rear terminals for operating remote alarm from separate power system. Contacts rated at 3 A (resistive) 115 V ac or 28 V dc.

Panel meters: Voltmeter and ammeter indicate battery voltage and battery charge/discharge current.

Power requirements: 115 or 230 ±10% Vac; 50 to 400 Hz (2.0 A max. at 115 V line).

Output connectors: MS type female connectors at rear mate with 106AR, 107AR, 5061A, 5065A power cables (Cannon Part No. MS3102R14S-5P, HP No. 1251-0129).

Battery (supplied) Vented nickel-cadmium 25 ampere-hour capacity derated to 18 ampere-hours. Periodic maintenance required.

Additional (external) battery provision: MS3102R14S-2S female connector, with cap, at rear.

Dimensions: 16¾" wide, 6-31/32" high, 16⅜" deep (425 x 177 x 467 mm).

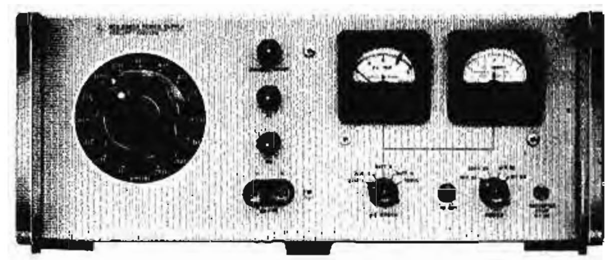
Weight: net, 75 lbs (34,1 kg); shipping, 101 lbs (45,9 kg) including battery. Option 01 (no batteries) is 50 lbs (22,8 kg) less.

Accessories furnished:
AC Power Line Power Cable, 6 feet long
Instrument Extension Slides (for std. 24" deep rack).

Price: Model 5085A (complete with batteries), $1700.

Options: Specify Option 01 if batteries are to be excluded. Model 5085A with Option 01 is $950.

* 2.5 A for 30 minutes.
** Derate capacity to 75% at high temperature (50°C) and low temperature (0°C).



K02-5060A

The K02-5060A was specifically made as a portable standby power supply for the 5061A and 5065A "Flying Clocks" and incorporates a number of features not found in the 5085A. The K02-5060A has a special inverter which will allow it to operate from 6 or 12 V dc or 24 to 30 V dc besides 115/230 V. The nickel-cadmium batteries are of the sealed type and thus spill-proof.

Tentative Specifications, K02-5060A

Output voltages: 115/230 V ac, (nominal), 50 to 400 Hz, 26 ±4 volts dc.

Output current:
ac, 0.5 A
dc, 2 A.

Standby capacity: 12 ampere-hours at 25°C, 7 hours standby when used in E21-5061A, 6 hours in E21-5065A.

Recharging: 1.6 hours recharging time required for each ampere hour of discharge.

Alarm indicator: external power failure.

Panel meters: Voltmeter, Ammeter indicating voltage and current of 4 internal batteries and load.

Power requirements: 6 or 12 V dc −10% +20%; or 24 to 30 V dc; or 115/230 ±10% V ac, 50 to 400 Hz. Can be connected simultaneously with ac or other dc power inputs for extra standby reserve.

Output connectors:
ac: CA-3102R-10SL-5S.
dc: MS-3102R-14S-5S.

Input connectors on instrument:
6 and 12 V dc: MS-3102R-16-11P.
24 to 30 V dc: GR type.
ac: MS-3102R-10SL-3P.

Battery: four paralleled, 20 series Ni-Cd cell, 3.5 ampere-hour, rechargeable batteries that can be individually removed from the circuit without interfering with power supply operation.

Dimensions: 16¾" wide, 6-31/32" high, 16⅜" deep (425 x 177 x 416 mm).

Weight: net, 67 lbs.

Accessories furnished: ac Power line cable, 6 feet long.

Price: $2850.

FREQUENCY DIVIDER, CLOCKS

Time comparison capability to ±1 μs

Models 115BR, H20-115BR

Advantages:

Generates precise time signals
In-line digital readout
Compatible with atomic or quartz frequency standards
Suitable for mobile applications

Uses:

Frequency and time standard systems
Time comparisons against broadcast time signals

The HP 115BR and the H20-115BR Frequency Divider and Clocks generate precise time signals, offers the convenience of digital readout, and provide features which make possible highly accurate comparisons against national time standards. Detailed records of oscillator drift rates and of time and frequency differences can be obtained. The H20-115BR is modified for ±1 μs capability versus the ±10 μs of the 115BR.

Time readout is an in-line digital display of hours, minutes and seconds. An additional drum allows an operator to resolve time visually to 0.1 s or by stroboscopic methods to 0.01 s.

Overall time comparison accuracy is ±1 μs (H20-115BR) and the divided outputs have very little jitter. The time reference control is a precision resolver and the unique optical gate system cannot contribute jitter.

Hewlett-Packard Application Note 52 explains in detail how a time comparison system, set up to use precise time signals from WWV or another standard broadcast, can yield timekeeping accuracy to within a millisecond and enable studies of oscillator frequency drift rate and error. For microsecond accuracy a portable master clock is an ideal means for establishing this reference.

Success of time comparisons, typically made over periods of weeks or months, depends upon continuous operation. Premium electrical and mechanical components used in the 115BR insure maximum reliability. The non-self-starting regenerative dividers avoid noise and spurious signal problems.

Driving standard

The 115BR input frequency is 100 kHz. Recommended driving standards include the HP 105A/B, 106A/B, 107AR/BR Quartz Oscillators, HP 5065A Rubidium Standard, and HP 5061A Cesium Beam Standard. The HP 5061A and 5065A option 01 is a self-contained Frequency Divider and Clock which has considerably better rise and fall times and less jitter than the 115BR.

Specifications, 115BR, H20-115BR

Input frequency: 100 kHz for ordinary time, input bandwidth ±300 Hz; 100.3 kHz for sidereal time, on special order.

Input voltage: 0.5 to 5 V rms.

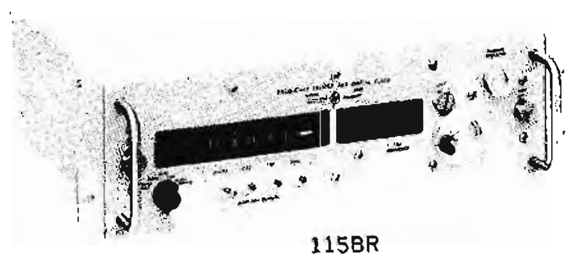
Pulse outputs: (see chart).

Accuracy: same as input frequency.

Input impedance: 300Ω nominal.

Auxiliary output: amplitude, 0.25 V rms minimum; source impedance, approx. 1200Ω; frequency, 100, 10 and 1 kHz (60 Hz on special order).

Time reference: 115BR is continuously adjustable, calibrated in 10 μsec increments; numerical display from 999.9 ms to 000.0 ms in-line vernier in 10 μs increments. H20-115BR has 1 μs increments and 999.99 ms vernier.



115BR

Effect of transients: will not gain or lose time because of: (1) ±300 V step function on 100 kHz input; (2) 0 to 50 V pulses, 0 to 500 pps, 1 to 10 μs duration on 100 kHz input; (3) ±4 V step in 26 V dc input.

Characteristic	Positive tick	Negative tick	Auxiliary pulse	Positive* 1 kHz pips
Pulse rate amplitude	1 pps +10 V** min.	1 pps −10 V** min.	1 pps +4 V min. open ckt, +2 V min. into 50Ω	1000 pps +4 V min.
Rise time	(H20) 0.5 μs max. 2 μs max.	(H20) 0.5 μs max. 2 μs max.	1 μs max.	2 μs max.
Duration	20 μs min.	20 μs min.	200 μs	20 μs min.
Jitter	(H20) 0.05 μs max. 1 μs max.	(H 20) 0.05 μs max. 1 μs max.	1 μs max.	1 μs max.
Recommended load impedance	4700Ω min. shunted by 200 pF max.	1 MΩ min. shunted by 100 pF max.	50Ω min. shunted by 5000 pF max.	1000Ω min. shunted by 1000 pF max.

Temp stability H20-115BR <0.02 μs change/°C

*Negative pulses available on special order.
**For any load impedance higher than minimum recommended.

Monitor meter: checks supply voltage, divider operation (100 kHz, 10 kHz, 1 kHz) and total clock current.

Power: 22 to 30 V dc, negative ground for operating with 106A,B or 107AR,BR, (may be selected by a switch); approximately 2.5 W; recommended supply, 5085A.

Environmental tests:*

The 115BR *Frequency Divider and Clock* has been prototype-tested to pass the following military environmental specifications.

1. **Temperature:** MIL-E-16400C, Class 4, Paragraph 4.6.7. (Nonoperating test limits: −40°C to −60°C.)
2. **Humidity:** MIL-E-16400C, Paragraph 4.6.8.
3. **Vibration:** MIL-E-16400C, Paragraph 4.6.14.
4. **Inclination:** MIL-E-16400C, Paragraph 4.6.14.
5. **Shock:** MIL-E-16400C, Paragraph 4.6.14.

The 115BR is an airtight and watertight instrument.

Dimensions: 115BR: 19" wide, 5¼" high, 12" deep behind panel (483 x 133 x 356 mm).

Weight: 115BR: net 35 lbs (15,8 kg), shipping 51 lbs (23,0 kg).

Accessories furnished: 113A-16E Cable, 6 feet long (1830 mm), connects 115BR or 115CR to 724BR, 725AR, or 5085A standby power supply.

Price: Model 115BR, $3000; Model H20-115BR, $3010.

FREQUENCY SYNTHESIZERS

Hewlett-Packard frequency synthesizers translate the stable frequency of a precision frequency standard to any selected one of thousands, even billions of frequencies over a broad spectrum that extends from dc to 500 MHz. The selected frequency is known to quartz crystal oscillator accuracy; resolution is as fine as 0.01 Hz; and a new frequency can be switched upon electronic command in 20 μs or from a keyboard as fast as the operator can push buttons. One synthesizer can do the work of a whole battery of oscillators and special-purpose signal generators and can do it better.

Synthesizers find application in many areas where the stability of a high-quality standard is required, including advanced communications, radio sounding, testing of frequency sensitive devices, and spectrum analysis.

The range of synthesized frequencies available is greatly extended with the Hewlett-Packard Synthesizer, Model 5105A/5110B, which covers 0.1 MHz to 500 MHz.

Hewlett-Packard Synthesizers

Model No.	Range	Minimum Step
5100B/ 5110B	0.01 Hz to 50 MHz	0.01 Hz
5102A	0.1 Hz to 1 MHz 0.01 Hz to 100 kHz	0.1 Hz 0.01 Hz
5103A	1 Hz to 10 MHz 0.1 Hz to 1 MHz	1 Hz 0.1 Hz
5105A/ 5110B	0.1 MHz to 500 MHz	0.1 Hz

All of the Hewlett-Packard Synthesizers offer digital selection from a pushbutton keyboard or by remote switch closure, and in addition, a search oscillator for continuously variable frequency selection. All derive their output frequency by the direct synthesis technique, one capable of translating the stability and spectral purity of the source to the selected output. All have a self-contained 1 MHz source, a precision quartz oscillator of excellent stability, and all can use in its place an external 1 MHz or 5 MHz standard.

Direct vs. indirect synthesis

Two basic approaches to frequency synthesis are "direct" and "indirect". Direct synthesis simply performs a series of arithmetic operations on the signal from the frequency standard to achieve the desired output frequency. In indirect synthesis, a master oscillator is phase locked to signals derived from the standard.

The direct synthesis approach has the pronounced advantages of permitting fine resolution, fast switching, and a spectrally pure output signal.

Indirect synthesis, on the other hand, can offer the advantage of lower cost for less stringent applications where use of the more sophisticated, high spectral purity, rapidly programmed, direct frequency synthesizer is unwarranted.

The synthesis operation

The 5100B/5110B and the 5105A/5110B synthesizers are made up of two completely solid-state units: the synthesizer proper, and the driver.

The driver contains a frequency source, a spectrum generator, and appropriate selective networks. The source is a high quality crystal oscillator housed in an oven. It is well protected from line voltage variations, and has an aging rate of less than 3 parts in 10^9 per day. A crystal filter at the oscillator output limits the noise bandwidth to about 150 Hz.

The spectrum generator is a step-recovery diode. Active filtering, synchronously tuned transistor stages and frequency dividers provide a series of fixed frequencies between 3 and 39 MHz which are fed to the synthesizer unit.

The synthesizer unit contains harmonic generators and suitable mixers, dividers, and amplifiers to derive the desired output frequency as a function of the fixed frequencies. The front-panel pushbuttons actuate a diode switching matrix. All frequencies appearing at the inputs to this matrix are always present. This is one of the key advantages of the direct synthesis method. The limitations on switching speed are just the time constants on the filtering circuits in the supply line to the switch and circuit bandwidths.

High-speed switching

The oscillogram of Figure 1 shows the speed which is typical of Hewlett-Packard synthesizers when they change output frequency under electronic command. The upper waveform is synthesizer output; the lower is the externally applied switching voltage. Note the virtual absence of dead time and switching transients.

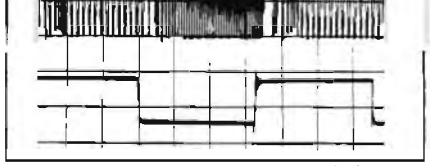


Figure 1. Switching speed, Model 5103A: 1.2 MHz to 2.7 MHz, 30 kHz switching rate. 5 μs/cm, 10 MHz Range.

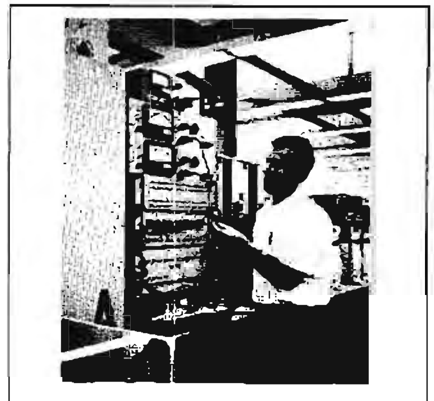


Figure 2. Stability monitoring equipment.

Signal purity

Two of the central design objectives for the Hewlett-Packard synthesizers were (1) virtual elimination of non-harmonically related spurious signals and (2) the reduction of noise to as low a level as possible. Noise appears as a small, random phase modulation which adversely affects the short-term stability of a signal.

Performance of the Model 5100B/5110B is typical of Hewlett-Packard synthesizers and attests to the attainment of these objectives: non-harmonically related signals are at least 90 dB below the selected frequency, and signal to phase noise ratio is greater than 54 dB (in a 30 kHz noise bandwidth centered on the signal, with a 1 Hz central band excluded).

At Hewlett-Packard, a considerable number of engineering years have been spent on problems of frequency stability and its measurement. Routine production line tests are made of frequency stability with the use of specially designed equipment of a sophistication not often found even in frequency measurement research laboratories. Figure 2 shows a multichannel short-term frequency stability monitor used to check each Hewlett-Packard synthesizer driver. This equipment monitors both rms and peak phase noise of all the driver outputs at the same time and shows an alarm light if any one of the set limits is exceeded. For additional information on the theory of operation, refer to Hewlett-Packard Application Note No. 96.

FREQUENCY SYNTHESIZER APPLICATIONS

Hewlett-Packard Frequency Synthesizers are signal sources (essentially multiple frequency standards) whose output frequency can be selected from a keyboard or by electronic command to a very high resolution. Such an instrument with its extremely high spectral purity and stability constitutes a powerful tool in a wide range of systems and scientific applications.

Communications

The high spectral purity of synthesizer output signals makes them ideal as local oscillators in receiver applications where frequency agility and/or narrow I.F. bandwidths are required of the receiver.

Their very stable output frequencies make these synthesizers suitable for use in homodyne receiver circuitry. The advantages of using a synthesizer in this application are simplicity and freedom from image problems, both of which plague many receiver designs.

Data handling systems in all areas of industry and military applications use magnetic tape as a storage medium, linking the receiver to the data processing and analysis equipment. However, magnetic tape is not without fault, introducing certain distortions to the data. A synthesizer may be used to eliminate the degrading effects wow and flutter have on information that is received and stored on magnetic tape. This use is facilitated by the ability of the user to bypass the internal crystal filter in the synthesizer driver section. The input reference frequency may be offset by as much as 0.25%, with the same percentage offset translated to any output frequency. Thus, a recorded reference channel on the tape can be used as the reference frequency of the synthesizer, and wow and flutter can be removed by comparing the data channel with a convenient synthesizer output frequency derived from the reference channel.

A surveillance receiver system which monitors multiple data channels by rapidly switching between channels is an ideal area of application for one of the Hewlett-Packard frequency synthesizers. With its rapid, highly repeatable switching capability, a synthesizer will serve as the local oscillator in this type of receiver, providing the proper local oscillator frequency for each channel under surveillance. A similar application arises in radio sounding applications, used to determine the maximum usable frequency allowed by ionospheric conditions. Since these conditions are always in a state of change, the ability of a synthesizer to generate test transmissions rapidly over the entire hf spectrum makes it an important tool for radio sounding.

The high spectral purity which characterizes the Hewlett-Packard synthesizers allows signal multiplication to microwave frequencies. HP synthesizers are ideal for use as the local oscillator in microwave communications systems.

A laboratory-type receiver capable of flat response over a broad range can easily be arranged with use of one of the synthesizers as the local oscillator, together with a broadband mixer and a narrow-band amplifier. For example, a combination of the HP 5105A/5110B Synthesizer, the HP 10514A Mixer, and the HP 415D SWR Meter exhibits an exceedingly flat response over the range 100 kHz to 500 MHz and a sensitivity greater than 10^{-16} watt.

Radar

The 5100B/5110B is capable of switching between output frequecncies in 0.01 Hz increments at a very fast rate; thus it is capable of making very good approximations of frequency versus time functions. This performance feature finds application in high performance "chirp" radar installations, which require an ultra linear sweep.

In doppler radar applications the Hewlett-Packard frequency synthesizer easily supplies all the necessary requirements for precise velocity measurements. The excellent stability of the synthesizer makes it ideal as the basic signal source in the transmitter, which requires stability capable of staying within a receiver bandwidth only a few cycles wide in the microwave region. A 5100B/5110B or another of the synthesizers also is well suited for use as the local oscillator in the doppler receiver, where the local oscillator must be capable of rapid change in order to keep the returning signal within the narrow receiver bandwidth.

NMR applications

Nuclear magnetic resonance spectroscopy methods are used to determine the qualitative and quantitative structure of molecules. In NMR, the strength of an applied dc magnetic field and the frequency of simultaneously applied rf field uniquely determine the spin-interaction of nuclei. In this application the broad frequency range and precise 0.01 Hz increments of frequency are very valuable.

Short-term stability measurements

Hewlett-Packard synthesizers are ideal for use in systems to evaluate short-term frequency stability. Often denoted as phase noise, short-term stability can be characterized by three measures: a phase noise vs. frequency of offset plot, a total measurement of instability over a frequency band, and statistical parameters. Their own excellent stability makes HP synthesizers ideal for use in systems to make these measurements on signal sources (such as oscillators) and on a variety of circuits: amplifiers, limiters, and filters. Systems for phase noise measurement utilizing the synthesizer offer a practical solution to problems of production testing. A synthesizer can serve as the frequency reference and also as the source of excitation for the circuit to be evaluated.

Synthesizer specials

Since their introduction in 1963, Hewlett-Packard synthesizers have found many unusual applications. Users have been quick to take advantage of synthesizer versatility and have shown great ingenuity in applying synthesizers to many research, manufacturing, and field instrumentation needs that otherwise could have been met only by costly laboratory-designed equipment.

Where none of the standard synthesizers can serve the need, however, Hewlett-Packard engineers in the synthesizer design group stand ready to apply their special knowledge to select, adapt or modify synthesizers to meet a customer's special requirements. It often proves to be the case that needs can be met with instruments built on the production line to narrowed environmental specifications, or with faster switching speed, or with changed output frequency ranges. Whenever possible, the synthesizer group specifies simple modifications that can be made at relatively low cost to the customer, thereby avoiding the far greater expense of special engineering design. Where necessary and warranted, though, this group will devise and build special synthesizers. Discuss your requirements with your Hewlett-Packard field engineer.

FREQUENCY SYNTHESIZERS
Broad frequency coverage, dual-range
Models 5102A, 5103A

The HP Models 5102A and 5103A Frequency Synthesizers increase synthesizer capability, providing instruments with dual-output frequency ranges of 100 kHz and 1 MHz (5102A), and 1 MHz and 10 MHz (5103A).

The 5102A provides output frequencies from 0.01 Hz to 100 kHz and from 0.1 Hz to 1 MHz in increments of 0.01 Hz and 0.1 Hz respectively. Output frequencies from 0.1 Hz to 1 MHz in increments of 0.1 Hz, and from 1 Hz to 10 MHz in 1 Hz increments are provided by the 5103A. Both instruments synthesize the output frequency from a single frequency source, translating the stability of the source to the output frequency via a direct synthesis technique. A very stable quartz oscillator, provided with each synthesizer, or an external 1 MHz (or 5 MHz) frequency standard may be used as the frequency source.

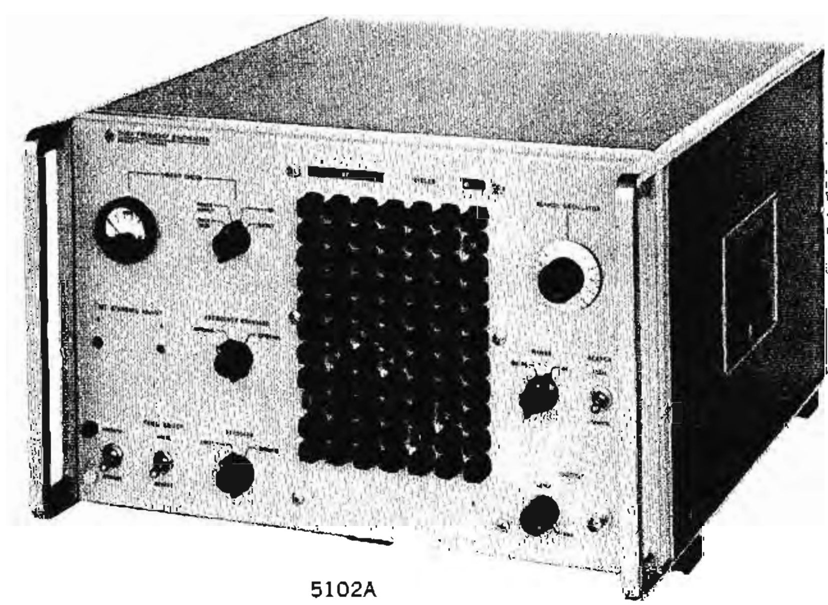
A Level control on the front panel allows continuous adjustment from 300 mV to 1 volt rms, of frequencies greater than 50 Hz available at the front-panel BNC. For frequencies below 50 Hz, the signal is taken from a rear-panel Low Level output BNC. Frequencies available at the rear-panel BNC have a signal strength of approximately 80 mV for the 5102A and 20 mV for the 5103A.

Dual-range feature

The two distinct (dual) frequency ranges of the 5102A and 5103A provide the user with extended capability at minimum cost and without sacrifice of a convenient module size. The upper range extends the frequency capability of each model, at the same time retaining high levels of stability and spectral purity. The higher frequency capability has frequency increments that are the same percentage of the range maximum as in the lower frequency range. The choice of frequency range is dependent on the maximum frequency required and is selected by the Range switch located on the front panel. The Range switch also positions a moveable label bar, conveniently indicating the decimal value of each column of pushbuttons. For both ranges the output frequency is selected three ways.

With the Frequency Select switch in the Local position, the output frequency is selected by seven columns of pushbuttons, arranged for rapid frequency selection. A locking switch is provided to prevent accidental operation of the pushbuttons once they are set. In addition, the full range of each column may be continuously varied either manually or externally by a search oscillator. Any frequency or search oscillator position locally controlled may be remotely selected via rear-panel connectors to each of the front-panel pushbuttons. The Frequency Select switch is positioned in Remote for remote control. Combined local-remote operation also is possible with the switch in the Local position. Any column not locally selected may be remotely controlled. Less than 20 μs are required to switch between frequencies in the local mode of selection and also in the remote mode if proper impedance levels are selected for the remote controller. The switching speed is very rapid and accurate, due to the direct synthesis technique used, which eliminates slower, phase-locked loops.

The search oscillator provides continuous tuning in any selected column plus an external sweep capability. This is an L-C oscillator which allows the operator to continuously "search" any significant column from 1 MHz to 0.1 Hz either manually by a front-panel control or remotely by application of a suitable voltage. The typical voltage vs frequency characteristic is shown in Figure 1. The approximate slope is



5102A

10% of the selected column's range per V. The search oscillator may be frequency modulated from an external source at a maximum sine wave rate of 1 kHz while retaining the voltage control calibration.

If the search oscillator is used, the stability of the synthesizer output is determined by either that of the standard instrument or that of the search oscillator—depending on the column which is "searched."

Outputs from the 5102A and 5103A are very clean over the full frequency ranges. Careful design and solid-state modular construction yield the high order of spectral purity essential for applications requiring clean and stable frequencies.

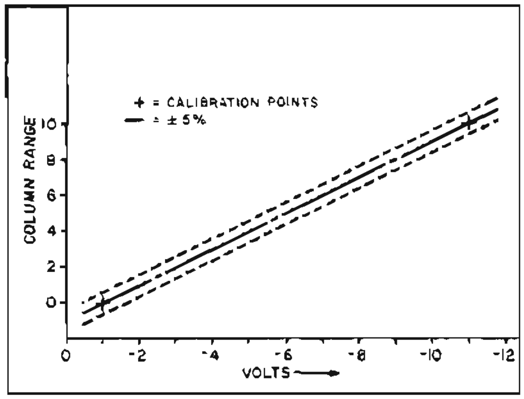


Figure 1.

Specifications

HP Model	5102A	5103A
Output frequency:	100 kHz range: 50 Hz to 100 kHz; 1 MHz range: 50 Hz to 1 MHz	1 MHz range: 50 Hz to 1 MHz; 10 MHz range: 50 Hz to 10 MHz
Output voltages:	Maximum output 1 V rms ±1 dB into 50Ω resistive load. Level control (front panel output BNC) provides a minimum of 10 dB continuously variable attenuation.	
Auxiliary outputs:	(1) Low level: dc to value of range, both ranges (rear-panel BNC); (2) f_0 + 30 MHz (f_0 is selected frequency, dc to 1 MHz, both ranges) rear-panel BNC; (3) 1 MHz frequency standard (rear-panel BNC)	
Auxiliary output voltage:	(1) Low level 80 mV rms (minimum) open circuit (2) f_0 + 30 MHz: 1 volt rms, ±2 dB into a 50Ω resistive load (3) 1 MHz: 1 volt rms, ±1.5 dB into a 50Ω resistive load	20 mV rms (minimum) open circuit
Digital frequency selection:	100 kHz range: 0.01 Hz to 10 kHz steps; 1 MHz range: 0.1 Hz to 100 kHz steps Selection by front-panel pushbutton or by remote contact closure; any change in frequency may be accomplished in <20 μs provided appropriate rear-panel connection is used	1 MHz range: 0.1 Hz to 100 kHz steps; 10 MHz range: 1 Hz to 1 MHz steps
Switching time:	<20 μs for any change in frequency	
Search oscillator:	Provides continuously variable frequency selection in any desired column over complete range of that column; manual by a front-panel control or by an external voltage (−1 to −11 volts)	
Signal-to-phase noise ratio (output)*:	(Output): 100 kHz range, >74 dB 1 MHz range, >64 dB (f_0 +30 MHz): >60 dB	(Output): 1 MHz range, >64 dB 10 MHz range, >54 dB (f_0 +30 MHz): >60 dB
Signal-to-AM noise ratio*:	(Output): 100 kHz range, >80 dB for frequencies above 30 kHz; 1 MHz range, >74 dB for frequencies above 100 kHz (f_0 +30 MHz): >80 dB	(Output): 1 MHz range, >74 dB for frequencies above 100 kHz; 10 MHz range, >74 dB for frequencies above 500 kHz (f_0 +30 MHz): >80 dB

RMS fractional frequency deviation:

(Output):

5102A 100 kHz range: Avg. Time	100 kHz Output Frequency	5102A 1 MHz range: Avg. Time	100 kHz Output Frequency	1 MHz Output Frequency	5103A 1 MHz range: Avg. Time	1 MHz Output Frequency	5103A 10 MHz range: Avg. Time	10 MHz Output Frequency
10 ms	3×10^{-6}	10 ms	1×10^{-7}	1×10^{-8}	10 ms	1×10^{-8}	10 ms	3×10^{-9}
1 s	3×10^{-10}	1 s	1×10^{-9}	1×10^{-10}	1 s	1×10^{-10}	1 s	3×10^{-11}

(f_0 +30 MHz):

5102A Averaging Time	Output Frequency	5103A Averaging Time	Output Frequency
10 ms	6×10^{-10}	10 ms	6×10^{-10}
1 s	1×10^{-11}	1 s	1×10^{-11}

HP Model	5102A	5103A
Spurious signals:	100 kHz range: >90 dB; 1 MHz range: >70 dB (below selected output for non-harmonically related signals)	1 MHz range: >70 dB; 10 MHz range: >50 dB
Harmonic signals:	>35 dB on all ranges, all outputs (with proper termination)	
Internal frequency standard:	1 MHz quartz oscillator	
Internal frequency standard aging rate:	less than ± 3 parts in 10^9 per 24 hours	
Stability of internal frequency standard (as function of ambient temp.): (as function of line voltage):	$\pm 2 \times 10^{-10}$ per °C from 0°C to +55°C $\pm 5 \times 10^{-11}$ for a ±10% change in line voltage (115 or 230 V)	
External frequency standard:	1 MHz or 5 MHz, 0.2 V to 5 V rms across 500Ω	
Standard input requirements:	stability and spectral purity of synthesizer will be partially determined by the characteristics of external standard if used	
Operating temperature range:	0 to +55°C	
Dimensions:	16¾" wide, 10-15/32" high, 16⅜" deep (425 x 266 x 416 mm)	
Weight; power:	net 75 lbs (34 kg), shipping 132 lbs (60 kg); 115 or 230 V ±10%, 50-400 Hz, 50W	
Price:	$7,200	$7,800

*In a 30 kHz band centered on the carrier, excluding a 1 Hz band centered on the carrier.

FREQUENCY SYNTHESIZER

100 kHz to 500 MHz in 0.1 Hz increments

Model 5105A

Advantages:

Frequencies from 100 kHz to 500 MHz
Push-button selection in 0.1 Hz increments, plus
Search oscillator
Remote programming
Switching speed typically 20 μs
Spurious 70 dB down
All solid-state, modular construction

Uses:

Offers new levels of spectral purity and stability for such applications as:
Accurate doppler measurements
Microwave spectroscopy
Narrow-band telemetry
Automatic testing of frequency-sensitive devices
Communications systems

The Model 5105A Frequency Synthesizer, a new member of the Hewlett-Packard group of synthesizers, extends frequency synthesis capability to 500 MHz. The 5105A provides push-button or remote selection of any frequency from 0.1 MHz to 500 MHz in steps as small as 0.1 Hz. The 5105A shares with the other Hewlett-Packard synthesizers the utilization of direct synthesis. This technique translates the stability and spectral purity of the source to the selected output, and in addition, provides a fail-safe output. The 5110B Synthesizer Driver supplies the 22 fixed frequencies required as input to the 5105A. The 5110B is capable of driving up to four 5105A Synthesizers. Source for the frequencies is a precision 1 MHz quartz oscillator of excellent stability. If desired for special applications, an external 1 MHz or 5 MHz frequency standard can be used instead. These features, plus others such as phase modulation input and variable output level, establish the 5105A-5110B as a precision variable frequency standard which brings a new capability to the frequency range 0.1 to 500 MHz.

Continuous Tuning, Sweep, FM

A search oscillator provides continuously variable frequency selection over the range of any one column except the tens and hundreds of megahertz columns (the left-hand two). Operation of a front-panel control manually tunes the search oscillator over the complete frequency range of the selected digit, that is, over incremental ranges from 1.0 Hz through 10 MHz. One of the advantages afforded by continuous control is the easy identification of an unknown frequency by beating it against the synthesizer output.

The search oscillator also may be controlled by application of a dc voltage (−1 to −11 volts, linearity ±5%) which enables remote operation and gives sweep capability.

The search oscillator can be frequency modulated from an external source (sinewave) at a maximum rate of 1 kHz while retaining the voltage control calibration.

Remote operation

The 5105A-5110B offers control flexibility never before possible in a precision frequency source of its range. Any frequency or search oscillator position available from the keyboard can be remotely selected and can be rapidly switched: in 20 μs, typically.

Rear panel connectors on the 5105A provide pins corresponding to each front panel pushbutton, a ground connection, and a −12.6 volt line for use in remote programming. A combination of remote and local programming may be used, if so desired.

No actual contact closure, such as a relay, is required. The −12.6 volts dc may be applied to the selected pin by electronic means.

The remarkably fast switching speed, valuable for such tasks as automatic digital frequency tracking, is one of the significant advantages of the direct synthesis method.

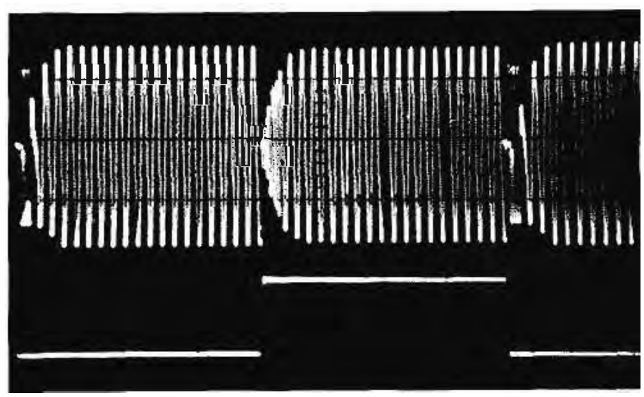


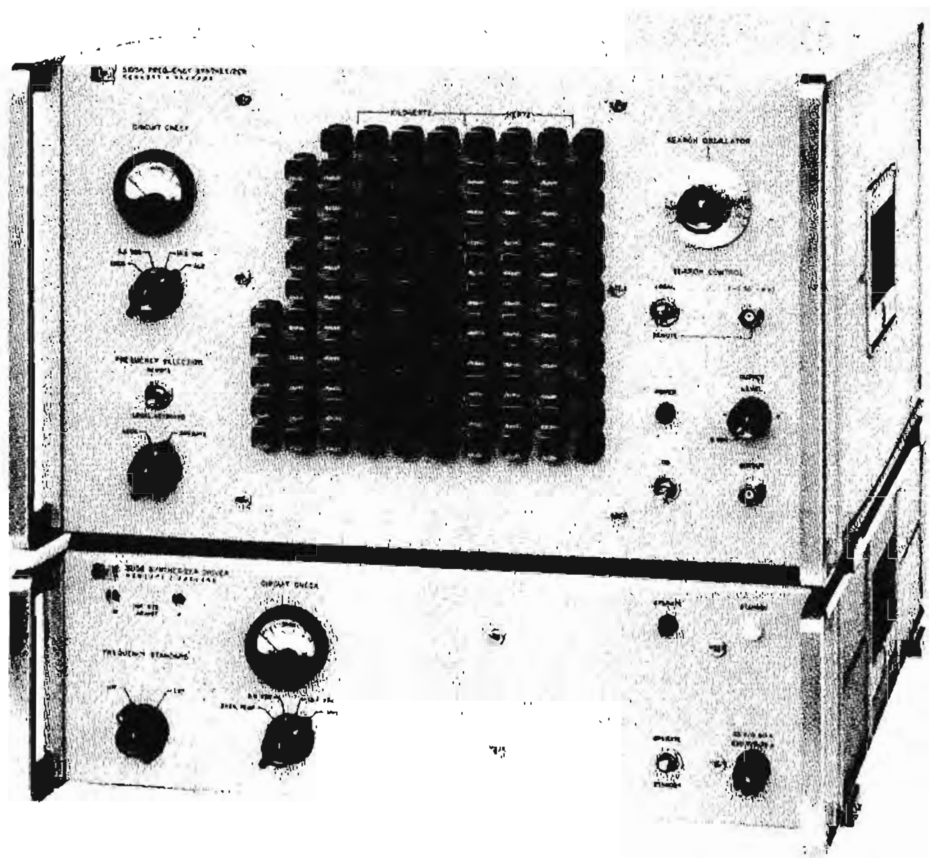
Figure 1. Synthesizer switching speed (25 μs/cm).

Fast switching

Figure 1 shows (upper trace) the 5105A-5110B output frequency switched between 399.8 MHz and 400.2 MHz with 400 MHz subtracted to display switching in greater detail. The sweep is 25 μs/cm. The lower trace is that of the switching waveform applied to the synthesizer.

Low noise performance

To achieve the excellent low-noise output specified for the 5105A-5110B Synthesizer over the full range requires the utmost care in design to identify and minimize noise sources followed by extensive testing at each stage of manufacture.



5105A, 5110B

Figure 2 shows phase noise distribution at 500 MHz. The ratio of output signal to single-sideband phase noise (in a 1 Hz bandwidth) is plotted against frequency of offset from the signal.

The noise performance reflected in this plot is remarkable for an instrument as complex and versatile as the 5105A-5110B, and demonstrates its suitability for applications where spectrum requirements are critical. One such application would be as a local oscillator in a single-sideband communications system, both for transmitters and for receivers.

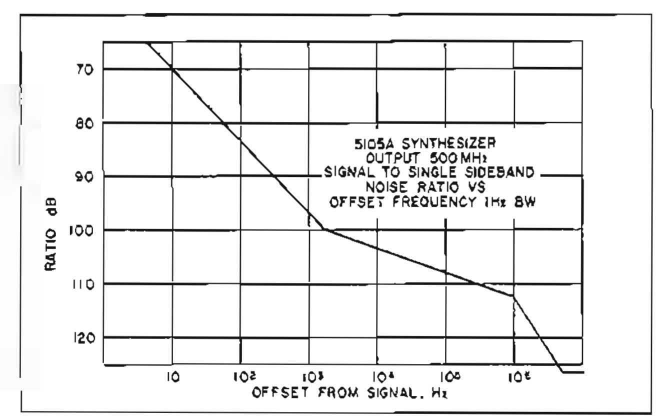


Figure 2. Log plot of phase noise.

Spectal purity and stability

Spurious signals are at least 70 dB below the selected output. This reflects the extremely high level of spectral purity and stability achieved for the 5105A-5110B by advanced design.

Many applications require that a signal be multiplied. If the frequency multiplying device is broadband, the ratio of total sideband power to signal power increases as the square of the multiplying factor; since total power is constant, the increased sideband power must come from the carrier. The spectrum begins to spread, owing to intermodulation.

To achieve a signal having a good spectrum after high multiplication requires that the original signal have the highest possible signal-to-phase noise ratio. The 5105A has a signal-to-phase noise ratio (measured in a 30 kHz band centered on the signal, excluding the 1 Hz central band) which is excellent:

At 1 MHz, 48 dB
At 100 MHz, 48 dB
At 500 MHz, 40 dB

Specifications

Specifications for the 5105A Synthesizer are presented on page 663. Specifications for the 5110B Synthesizer Driver are presented on page 664.

FREQUENCY SYNTHESIZER

DC to 50 MHz, 5 billion discrete frequencies

Model 5100B/5110B

Advantages:

- Digital frequency selection
- 0.01 Hz frequency increments
- Spurious 90 dB down
- Remote programming
- Switching speed typically 20 μs

The Hewlett-Packard Model 5100B/5110B Frequency Synthesizer provides any output frequency from 0.01 Hz to 50 MHz, selectable in steps as small as 0.01 Hz. The output frequency is derived from a precision single frequency source through direct synthesis, a technique which translates the stability and spectral purity of the source to the selected output. A precision 1 MHz quartz oscillator is provided, or an external 1 MHz or 5 MHz standard may be used.

Spectral purity

Particular care has been exercised in the design of the Model 5100B/5110B to insure that a very clean output signal is provided over the entire frequency range. A high order of spectral purity is essential for accurate doppler measurements, microwave spectroscopy, narrow band telemetry or communications, and similar applications. The design and construction of the 5100B/5110B make it possible to obtain output signals with a spurious content at least 90 dB below the selected output.

The 5110B Synthesizer Driver generates 22 spectrally pure signals from the standard signal. 21 of these frequencies are then fed to the 5100B Frequency Synthesizer by means of rear panel BNC connectors and are continuously available. The variable output signal is synthesized from these fixed frequencies by a series of arithmetic operations.

Fast switching

Since no phase-locked loops are involved, switching from one output frequency to another can be accomplished very rapidly, either from the front panel pushbuttons or remotely. Typically, 20 μs are required to change output frequency.

Remote control

Any frequency or search oscillator position that can be selected by front panel pushbuttons can also be remotely selected. Connectors located on the 5100B rear panel provide pins corresponding to each front panel pushbutton position, a ground connection, and a —12.6 volt line for use in remote programming. The —12.6 volts is available in two arrangements — continuous and switched. This lends additional versatility since it enables the use of a combination of remote and local programming.

An actual contact closure such as a relay is not required for remote control of the Synthesizer. The required —12.6 volts dc may be applied to the selected pin electronically.

Modular construction

Modular construction has been used throughout the 5100B/5110B. The modular concept enables the system to meet stringent demands regarding spurious signals since the isolation that it affords minimizes spurious coupling. It also enhances serviceability. Careful design and quality control insure that all modules are interchangeable from one instrument to another.

Search oscillator

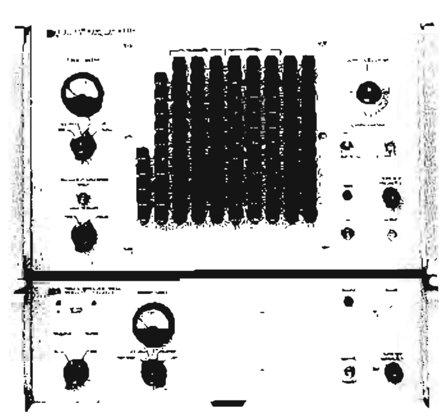
The search oscillator can be selected either locally or remotely and swept either locally or remotely. Besides facilitating searching for an unknown frequency, the search feature permits frequency modulation of the output at a maximum sinewave rate of 1000 Hz, phase locking the synthesizer into another system, or sweep operation with a sweep range as small as 0.1 Hz. The incremental range of the search oscillator is between 0.1 Hz and 1 MHz, depending upon the column selected for search. Any one of the right-hand eight columns may be searched.

Simple operation

Operation of the 5100B/5110B is straightforward. The output frequency is selected simply by depressing one pushbutton in each of the 10 columns of pushbuttons. Any frequency that can be selected by the pushbuttons can be programmed remotely. The Lock-Operate switch prevents accidental operation of the pushbuttons. The Circuit Check switch and meter on both the 5100B and 5110B provide quick and easy checks of internal circuits. The Frequency Standard switch selects either the 1 MHz internal quartz oscillator or an external frequency standard, if desired.

Specifications

The table on the facing page lists specifications for the 5100B Synthesizer. The 5110B Synthesizer Driver is presented on page 664.



5100B/5110B

Specifications
5105A, 5100B Synthesizers

<table>
<tr><th>Specifications</th><th colspan="5">5105A*</th><th colspan="4">5100B*</th></tr>
<tr><td>Output frequency</td><td colspan="5">100 kHz to 500 MHz</td><td colspan="4">dc to 50 MHz</td></tr>
<tr><td>Digital frequency selection</td><td colspan="5">0.1 Hz through 100 MHz per step. Selection by front panel pushbutton or by remote switch closure. Any change in frequency may be accomplished in 20 μs typically.</td><td colspan="4">0.01 Hz through 10 MHz per step. Selection by front panel pushbutton or by remote switch closure. Any change in frequency may be accomplished in 20 μs typically.</td></tr>
<tr><td>Output voltage</td><td colspan="5">Fixed: 0 dBm ±1 dBm into a 50 ohm resistive load. Variable: −6 dBm to ≧6 dBm into a 50 ohm resistive load.</td><td colspan="4">1 volt rms ± 1 dB from 100 kHz to 50 MHz. 1 volt rms +2 dB, −4 dB from 50 Hz to 100 kHz, into a 50 ohm resistive load. Nominal source impedance is 50 ohms. 15 mV rms minimum open circuit from 100 kHz down to dc, at separate rear output connector, source impedance of 10,000 ohms with shunt capacitance approximately 70 pF.</td></tr>
<tr><td>Search oscillator</td><td colspan="5">Provides continuous variable frequency selection with a selectable incremental range of 1.0 Hz through 10 MHz. Manual or external voltage (−1 to −11 volts) control with linearity of ±5%. The search oscillator may be externally swept up to a 1 kHz sinewave rate.</td><td colspan="4">Provides continuously variable frequency selection with an incremental range of 0.1 Hz through 1 MHz. Manual or external voltage (−1 to −11 volts) control with linearity of ±5%.</td></tr>
<tr><td>Phase modulation</td><td colspan="5">(rear panel input) ±3 radians maximum deviation; dc −1 MHz rate.</td><td colspan="4"></td></tr>
<tr><td rowspan="3">Signal-to-phase noise ratio</td><td colspan="5">Measured in a 30 kHz band centered on the signal (excluding a 1 Hz band centered on the signal) is greater than:</td><td colspan="4" rowspan="3">Greater than 54 dB in a 30 kHz band centered on the signal (excluding a 1 Hz band centered on the signal).</td></tr>
<tr><td>Output frequency—MHz</td><td>1</td><td>50</td><td>100</td><td>500</td></tr>
<tr><td>Ratio—dB</td><td>48</td><td>48</td><td>48</td><td>40</td></tr>
<tr><td>Signal-to-AM noise ratio</td><td colspan="9">(Above 100 kHz): Greater than 74 dB in a 30 kHz band.</td></tr>
<tr><td rowspan="4">RMS fractional frequency deviation (with a 30 kHz noise bandwidth)</td><td rowspan="2">Averaging time</td><td colspan="4">Output Frequency</td><td colspan="4">Output Frequency</td></tr>
<tr><td>1 MHz</td><td>50 MHz</td><td>100 MHz</td><td>500 MHz</td><td>1 MHz</td><td>5 MHz</td><td>10 MHz</td><td>50 MHz</td></tr>
<tr><td>10 ms</td><td>1×10^{-7}</td><td>2×10^{-9}</td><td>1×10^{-9}</td><td>6×10^{-10}</td><td>3×10^{-8}</td><td>6×10^{-9}</td><td>3×10^{-9}</td><td>6×10^{-10}</td></tr>
<tr><td>1 s</td><td>2×10^{-9}</td><td>4×10^{-11}</td><td>2×10^{-11}</td><td>1×10^{-11}</td><td>3×10^{-10}</td><td>6×10^{-11}</td><td>3×10^{-11}</td><td>1×10^{-11}</td></tr>
<tr><td>Spurious signals</td><td colspan="5">Non-harmonically related signals are at least 70 dB below the selected frequency.</td><td colspan="4">Non-harmonically related signals are at least 90 dB below the selected frequency.</td></tr>
<tr><td>Harmonic signals</td><td colspan="5">25 dB below the selected frequency, (applicable to fixed output when terminated in 50 ohms).</td><td colspan="4">30 dB below the selected frequency (when terminated in 50 ohms).</td></tr>
<tr><td>Dimensions</td><td colspan="9">16¾" wide, 16⅜" deep, 10-15/32" high (425 x 416 x 266 mm).</td></tr>
<tr><td>Weight</td><td colspan="5">net, 82 lbs (37 kg); shipping, 96 lbs (44 kg).</td><td colspan="4">net, 75 lbs (34 kg); shipping, 97 lbs (44 kg).</td></tr>
<tr><td>Equipment furnished</td><td colspan="5">Decade test cable: 05105-6054/55. Cable Assembly (connects 5105A Synthesizer to 5110B Driver) permits up to approx. 2.5 feet vertical separation.</td><td colspan="4">05100-6180 Decade Test Cable, 05100-6066 Output Cable, 05100-6212/13 Cable Assembly connects 5100B Synthesizer to 5110B Driver. Permits rack mounting a 5100B up to approx. 2.5 ft. above or below the 5110B Driver. A special-length-cable assembly will be required for other mounting arrangements.</td></tr>
<tr><td>Special cable</td><td colspan="5">Special cable available. Specify configuration and length (50 ft. max.). Cable is supplied in four-foot increments. Price: $40 per four-foot increment.</td><td colspan="4">If a special-length cable assembly is required, order spec C05-5110B. Specify configuration and length (max. separation 50 feet). Cable is supplied in four-foot increments only. Price: $40 per four-foot increment.</td></tr>
<tr><td>Price</td><td colspan="5">model 5105A, $9750. (Requires 5110B)</td><td colspan="4">model 5100B, $8150. (Requires 5110B)</td></tr>
</table>

*Requires 5110B Driver which has an internal frequency standard. When the 5110B Driver utilizes an external frequency standard, this will affect the stability and spectral purity of the output. Performance data stated above are based on the excellent internal frequency standard in the 5110B. The data are also an indication of synthesizer contribution to over-all performance when an external standard of less spectral purity than in the 5110B is connected to the 5110B.

SYNTHESIZER DRIVER

For the 5100B and 5105A Synthesizers

Model 5110B

The HP 5110B Synthesizer Driver supplies the HP 5100B and 5105A Synthesizers with 22 fixed, spectrally pure signals derived from a 1 MHz precision quartz oscillator.

The frequency synthesizer system comprising the 5105A Synthesizer and the 5110B Driver provides output frequencies from 0.1 to 500 MHz in increments as small as 0.1 Hz. The 5100B - 5110B system provides output frequencies from dc to 50 MHz in increments as small as 0.01 Hz. These synthesizers are described on pages 660-663.

The 1 MHz quartz oscillator which is the source for all output frequencies of the synthesizer driver is stable to 3 parts in 10^9 per 24 hours. To help maintain this excellent crystal stability, oven circuits are energized any time the instrument is connected to the power line. A circuit check meter allows verification of correct oven operation.

Where special requirements make it necessary that synthesized frequencies be derived from an external frequency standard, a rear panel connector on the 5110B accepts a 1 MHz or 5 MHz signal. The output spectural purity is partially dependent on the purity of the remote frequency standard.

These synthesizer drivers are each capable of driving up to four synthesizers. Drivers equipped in accordance with Options 02 through 04, for driving from two to four synthesizers, must have additional outputs not in use terminated in 50 ohms in order that full specified spurious performance be met.

5110B

Specifications
Synthesizer Driver 5110B
For the 5100B and 5105A Synthesizers

Output frequencies: Provides 22 fixed frequencies for Frequency Synthesizer operation; 3.0 through 3.9 MHz in 0.1 MHz steps (50 mV +1, −3 dB) 30 through 39 MHz in 1 MHz steps, 24 MHz, and 20 MHz (100 mV ±1.5 dB), 50Ω system. Note: 20 MHz is not used with the 5100B Synthesizer.

1 MHz buffered output (1 V ±1.5 dB into a 50Ω resistive load) available at rear panel connector.

Internal frequency standard:

Type: 1 MHz Quartz Oscillator.

Aging rate: Less than 3 parts in 10^9 per 24 hours.

Stability: As a function of ambient temperature: $\pm 2 \times 10^{-10}$ per °C from 0°C to +55°C. As a function of line voltage $\pm 5 \times 10^{-11}$ for a ±10% change in line voltage (rated at 115 or 230 volts rms line voltage).

Short term (with internal crystal filter): Adequate to provide the 5100B and 5105A performances noted on page 663.

Phase-locking capability: A voltage control feature allows 5 parts in 10^8 frequently control for −5 to +5 volts applied externally.

External frequency standard input requirements: 1 MHz or 5 MHz, 0.2 V rms minimum, 5 V maximum across 500 ohms. Stability and spectral purity of Frequency Synthesizer will be partially determined by the characteristics of the external standard if used.

Dimensions: 16¾" wide, 5-7/32" high, 16 ⅜" deep (425 x 133 x 416 mm).

Weight: Net, 54 lbs (25 kg). Shipping, 67 lbs (30 kg).

Operating temperature range: 0 to +55°C.

Interference: Complies with MIL-I-26600, Class 1 and 3, MIL-I-6181D.*

Susceptibility: Complies with MIL-I-26600, Class 1 and 3, MIL-I-6181D.

Power: 115 or 230 V ±10%, 50 to 400 cycles, 35 W.

Optional features: The Synthesizer Drivers are capable of driving up to four Frequency Synthesizers:

Option 02, outputs for driving two synthesizers, $125; Option 03, for three, $235; Option 04, for four, $345.

Accessories available: 10510A BNC termination, 50Ω. If Option 02-04 has been selected, outputs not connected to a Synthesizer must be terminated in 50Ω if full specified spurious performance is required. For each set of outputs not connected to a Synthesizer, 22 of these 50Ω terminations are required; thus, if Option 04 Driver is connected to only one Synthesizer, 66 would be required. Price, $5 each.

Special interconnecting cable sets are described on page 663.

Note: Small phase jumps may be experienced in additional synthesizer when first is switched in frequency.

Price: model 5110B, $4350.

*Interference compliance requires that the 5100B/5105A and 5110B are connected by a low inductance path such as adjacent rack mounting.

MODEL NUMBER INDEX *continued*

362 to 3304A

800

900

1000

2000

3000

MODEL NUMBER INDEX *continued*

3305A to 7034A

4000

5000

6000

7000

MODEL NUMBER INDEX *continued*

7035A to 17009B

8000

9000

00000-00610

10000

10500

11000

11500

12000-13000

15000-16008

17000

MODEL NUMBER INDEX *continued*

17012B to 60246B

19000-60000