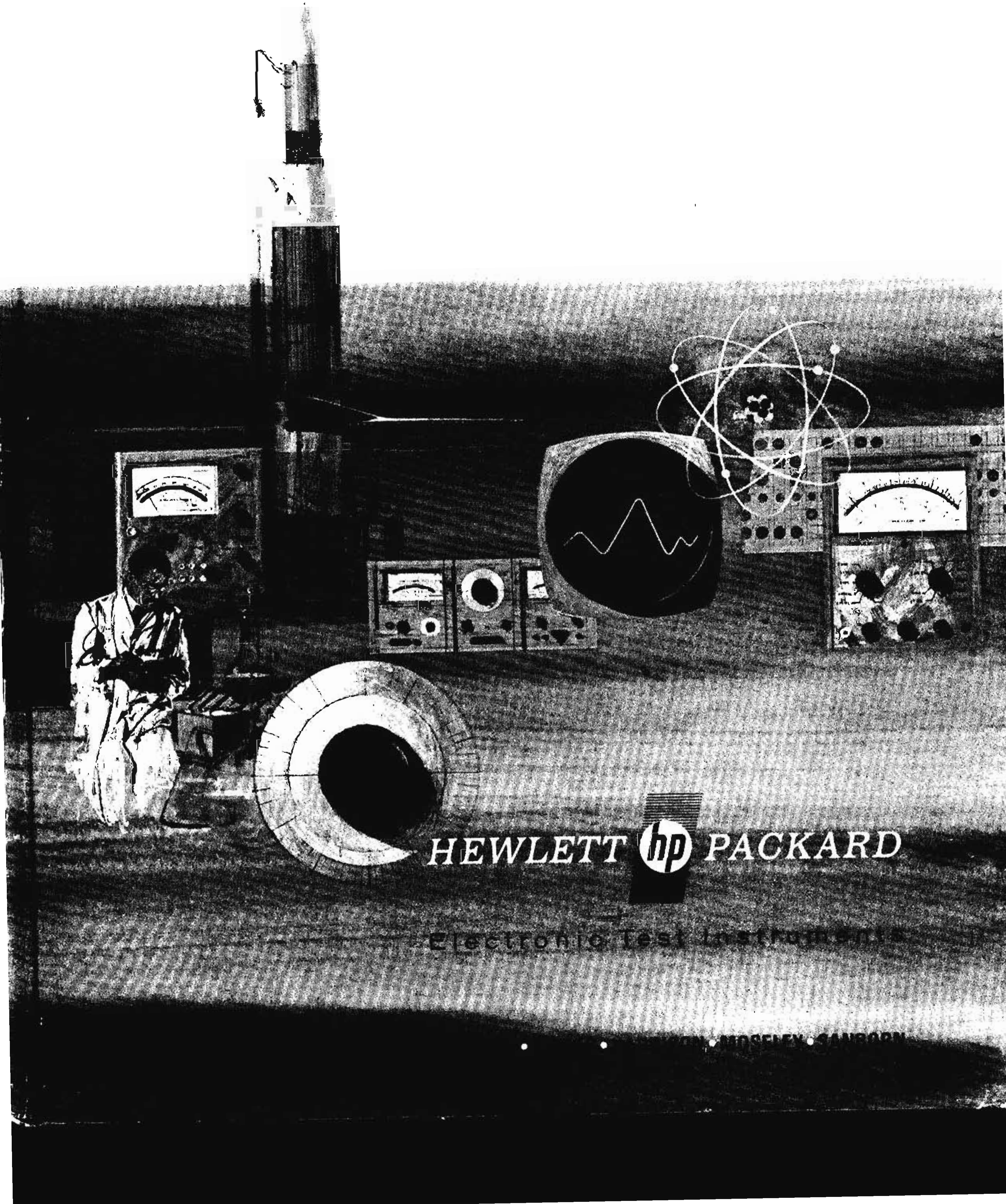

HEWLETT hp PACKARD
Electronic Test Instruments
MOSELEY · SANBORN

HOW TO USE THIS CATALOG

Three easy ways to find the information you need

FOR COMPLETE
APPLICATION & SALES
INFORMATION
CALL
Rudy Poucher
your
NEELY
AREA MANAGER
HEWLETT PACKARD
NEELY
Sales Division
2591 CARLSBAD AVE.
SACRAMENTO
482-1463

1. Check headings on opposite page for broad categories of instrumentation.
2. Use complete numerical index beginning on page 396 to locate specific equipment by model number (example—3400A RMS Voltmeter).
3. Use alphabetical index on pages 391-395 to locate equipment by name, title or type (example—digital voltmeter).

Other important information

This catalog provides detailed information on instruments available from Hewlett-Packard, including products of the Boonton, Dymec, Harrison, Moseley and Sanborn Divisions.

Detailed listings of general-purpose equipment grouped by functional categories begin on page 25. In addition, you will find abbreviated information on pages 15 through 24 describing certain special-purpose equipment manufactured by the various Hewlett-Packard divisions.

Placing your order

Page 2 contains time-saving suggestions for ordering.

Other Information on Hewlett-Packard products

In addition to data in this catalog, information about application and operation of hp equipment is available in hp data sheets, Application Notes, the Hewlett-Packard Journal and Measurement News. Data sheets and Application Notes are available on request. Both the Hewlett-Packard Journal (a monthly publication of the hp research and development laboratories) and Measurement News (a bi-monthly newsletter from your hp field office) are mailed regularly to anyone interested in keeping abreast of the latest developments in electronic test and measurement instrumentation. See pages 3-12 for more details.

Keeping up-to-date on Hewlett-Packard products

New Hewlett-Packard products, introduced after publication of this catalog, are described in the hp Journal and in Measurement News, advertised in the major trade publications, exhibited in major trade shows and demonstrated by hp field engineers. Data sheets on these new products will be sent promptly on request.

How to communicate with Hewlett-Packard

Hewlett-Packard products are manufactured in more than a dozen factories throughout the world. The Hewlett-Packard field sales office in your area is equipped to handle all your needs for information on any hp product, and for parts or service on the hp products you are already using. A complete listing of Hewlett-Packard field offices is just inside the back cover of this catalog. If there is no field office in your area, please contact:

United States
Hewlett-Packard
1501 Page Mill Road
Palo Alto, California 94304
Telephone: (415) 326-7000
TWX: 910-373-1267
Telex: 033 811

Canada and Latin America
Hewlett-Packard Inter-Americas
1501 Page Mill Road
Palo Alto, California, U.S.A.
Telephone: (415) 326-7000
TWX: 910-373-1267
Telex: 033 811
Cable: HEWPACK

Europe
Hewlett-Packard S.A.
54 Route des Acacias
Geneva, Switzerland
Telephone: (022) 42.81.50
Telex: 2.24.86
Cable: HEWPACKSA

Elsewhere
International Marketing Department
Hewlett-Packard
1501 Page Mill Road
Palo Alto, California, U.S.A.
Telephone: (415) 326-7000
TWX: 910-373-1267
Telex: 033 811
Cable: HEWPACK

All data in this catalog subject to change without notice. Prices f.o.b. factory in United States.

Hewlett-Packard Catalog No. 25, 4-65

Printed in U.S.A.

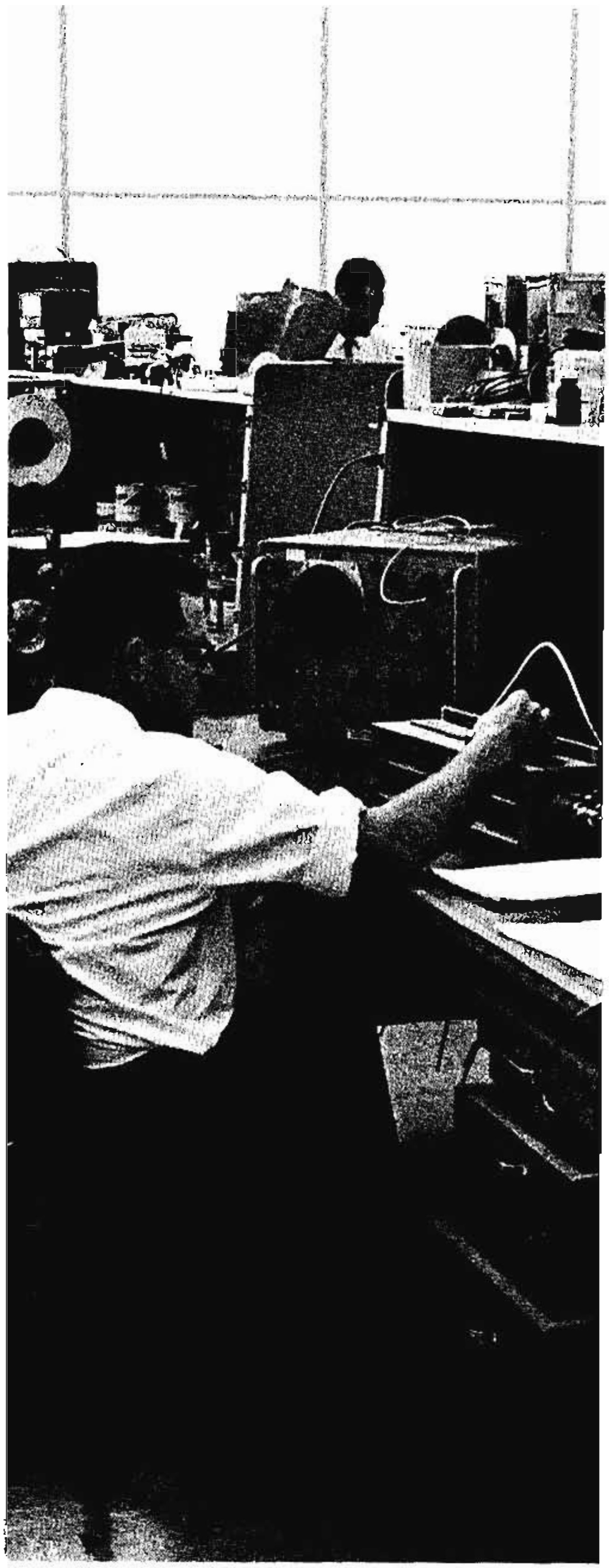
Instruments in this catalog are grouped by type or function. Most major groupings are preceded by technical information pages which summarize the measuring techniques involved and provide helpful information for selecting instruments best suited for specific jobs.

HEWLETT hp PACKARD

CATALOG LISTINGS FOR HEWLETT-PACKARD PRODUCTS, INCLUDING DYMEC, BOONTON, HARRISON, MECHROLAB, MOSELEY AND SANBORN DIVISIONS, HP ASSOCIATES.

Major instrument groups are listed below. Complete model number and descriptive indexes are at the end of the catalog as indicated by the thumb index positions.

ABOUT HEWLETT-PACKARD



Since its founding in Palo Alto, California, in 1939, Hewlett-Packard has grown from a two-man operation into a world-wide organization of more than 7000 people, with an annual sales volume exceeding $125 million.

The company and its affiliates now have more than a dozen manufacturing plants, including two in Western Europe and one in Japan. Sales and service offices are located in nearly every major city in the free world.

Although Hewlett-Packard's growth has been dynamic and far-reaching, the company has never altered its original objective — to make significant contributions to the specialized field of electronic instrumentation. To this end, it has concentrated its energies and resources on developing instruments which provide the greatest possible usefulness, accuracy, convenience, dependability and dollar value.

Among the principle categories of Hewlett-Packard instrumentation are oscillators, voltmeters, oscilloscopes, pulse generators, graphic recorders, data acquisition systems, waveguide test equipment, signal generators, electronic counters, frequency and time standards, impedance measuring instruments, power supplies, solid-state components, medical diagnostic equipment and instruments for chemical and nuclear measurement.

The market for the company's instruments covers a broad spectrum of science, business and industry. From electronic development laboratories to radio and TV studios, from chemical research facilities to aircraft plants, from banks to medical laboratories, from steel mills to space vehicle installations — Hewlett-Packard equipment is found in a wide variety of applications.

Now in its second quarter century of growth and progress, Hewlett-Packard intends to continue providing instruments which represent the utmost in fine craftsmanship — a standard of quality unmatched in the electronic test equipment field.

Hewlett-Packard Divisions and Affiliates

To provide the full advantage of specialized engineering and manufacturing know-how for each product, Hewlett-Packard operates through product-oriented divisions, each responsible for one or more types of instrumentation. The general manager of each division administers all aspects of engineering, manufacturing and marketing for a given product group.

Hewlett-Packard sales divisions, each responsible for local service in a defined geographic territory, are listed at the end of this catalog.

Two Hewlett-Packard divisions are at 1501 Page Mill Road in Palo Alto, California. Products of the *Frequency and Time Division* include electronic counters and precise frequency and time standards. The *Microwave Division* produces signal generators, waveguide and other specialized test equipment for use at microwave frequencies.

The *Loveland* (Colorado) *Division* manufactures voltmeters, oscillators, distortion analyzers and other general-purpose test equipment.

The *Colorado Springs* (Colorado) *Division* makes oscilloscopes, pulse generators and allied products.

Dymec Division, 395 Page Mill Road, Palo Alto, California, produces instruments and systems for acquiring and processing digital data, as well as specialized test equipment for other uses. Dymec was established in 1956 and acquired by hp in 1959.

Boonton Division, Green Pond Road, Rockaway, New Jersey, was founded in 1935 and acquired by hp in 1959. Products include impedance-measuring equipment, and special-purpose signal generators and test sets.

HP Associates, 620 Page Mill Road, Palo Alto, California was formed by hp in 1961 to conduct solid-state research and development and to market advanced semi-conductor components.

Harrison Division, 100 Locust Avenue, Berkeley Heights, New Jersey, was founded in 1954 and acquired by hp in 1961. Harrison Division produces highly regulated dc power supplies and related items.

Moseley Division, founded in 1951 as the F. L. Moseley Co., became affiliated with hp in 1958, and a division in 1964. Moseley Autograf X-Y Recorders and a broad line of laboratory and industrial strip-chart recorders are widely used throughout the world. Moseley Division is at 433 North Fair Oaks Avenue in Pasadena, California.

Sanborn Division, 175 Wyman Street, Waltham, Massachusetts, has been affiliated with Hewlett-Packard since 1961. Sanborn's medical group is a leading source of medical diagnostic apparatus; the industrial group produces a broad line of instruments and systems for measuring and recording physical phenomena.

Mechrolab, an hp affiliate since 1964, produces a prothrombin (blood-clot) timer, as well as a number of osmometers and other specialized instruments for measuring molecular weights of complex polymer chemicals. Mechrolab is located at 1062 Linda Vista Avenue, Mountain View, California.

Hewlett-Packard Inter-Americas, headquartered in Palo Alto, provides sales and service to Canada (through Hewlett-Packard (Canada) Ltd.), and to all of Latin America.

Hewlett-Packard S.A., in Geneva, Switzerland, is responsible for all hp activities in Western Europe. Factories in Bedford, England, and in Böeblingen, Germany, manufacture many of the individual instruments sold in Europe. Sales companies in each major country assure European customers of the same high level of applications assistance and service as in the United States.

SUGGESTIONS FOR ORDERING

Order by model number

When you order, please specify the catalog model number and name of instrument desired. For example, "Model 400D Vacuum Tube Voltmeter." To prevent misunderstanding, include significant specifications and specific instructions in your order whenever you desire special options or features such as special color, non-standard power line voltage, etc.

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 rack mounting. For example, "400DR." Catalog listings indicate availability of cabinet or rack mounting arrangements. Please be sure your order indicates which you desire.

Price and delivery information

Prices in effect at date of publication are listed in this catalog. All prices and other data are subject to change without notice. Prices are f.o.b. factory. Contact your nearest field sales office to confirm prices and to obtain current delivery information.

Where to send your order

Your order should be made out to the Hewlett-Packard Company and sent to the Hewlett-Packard field office in your area (see inside of back cover). Each field office has special communication channels to the Hewlett-Packard factories to assure prompt and efficient handling of your order. See additional information below if you are located outside the United States.

Local technical assistance

Technical assistance in selecting equipment and preparing orders is available, without charge, from field engineers at Hewlett-Packard sales offices in the United States and in principal areas throughout the world (see inside back cover for names and addresses).

Shipping methods

Shipments to destinations within the United States and Western Europe are made directly from local factories or warehouses. Unless specifically requested otherwise, express or truck transportation is used, whichever is cheaper and most serviceable to you. Small items are sent via 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 United States a consolidated air freight service provides the speed of air transport at surface rates. Ask your field engineer for details.

Terms

U.S. terms are 30 days net. Unless credit has already been established, shipments will be made C.O.D., or on receipt of cash in advance. See additional information below if you are located outside the United States.

Quotations

Upon request, quotations will be furnished to you by your local Hewlett-Packard sales office or the Hewlett-Packard Company. Prices will be specified on an f.o.b. factory basis unless otherwise requested. See additional information below if you are not in the United States.

Repairs and repair parts

See pages 3 through 12.

Additional information for customers outside the United States

Where to send your order

In many countries, your order can be placed directly on your local Hewlett-Packard distributor or representative (see inside back cover). Alternatively, your order can be made out to Hewlett-Packard Company, (Hewlett-Packard S. A. if you are in Western Europe or Hewlett-Packard Inter-Americas if you are in Latin America) and sent to the appropriate Hewlett-Packard office, either directly or through your local hp authorized sales office.

If no Hewlett-Packard representative or distributor has, as yet, been appointed for your area, your order should be placed directly on the offices listed above.

Shipping methods

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

Terms

Terms for orders from countries outside the United States 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 your local authorized Hewlett-Packard sales office, Hewlett-Packard, Palo Alto, California; Hewlett-Packard S. A., Geneva, Switzerland, or Hewlett-Packard Inter-Americas, Palo Alto, California.

SERVICE IN DEPTH—PROVIDED WITH EVERY HEWLETT-PACKARD INSTRUMENT

With electronic instrumentation, as with other products, the user expects service with his purchases, and he expects the manufacturer to stand behind its products after the sale. Satisfying this expectation is one of the manufacturer's primary responsibilities, and it is a responsibility which Hewlett-Packard long has recognized.

Even more than with consumer products, electronic measuring instrumentation *demands* this service. Purchase of equipment to check out a multi-million-dollar missile before launch or for monitoring critical physiological reactions of a patient during surgery *must* carry with it an assurance of accuracy and reliability. Not only must the manufacturer build quality and reliability into his product, but he also must have a service organization which can respond quickly and completely to the customer's needs.

Over the years, Hewlett-Packard has built such an organization. When the buyer of Hewlett-Packard equipment needs repair service, replacement parts or technical assistance, he need not correspond with a factory that may be several thousand miles away. More than 75 field offices located throughout the free world provide local service for the instruments manufactured by the Hewlett-Packard companies.

Many of the services offered by these hp field offices are discussed on the following pages. You will read about the depth of service you can expect from hp. Then check inside the back cover of this catalog to locate the Hewlett-Packard field office nearest you.

LOOK FOR THESE BEFORE-THE-SALE SERVICES

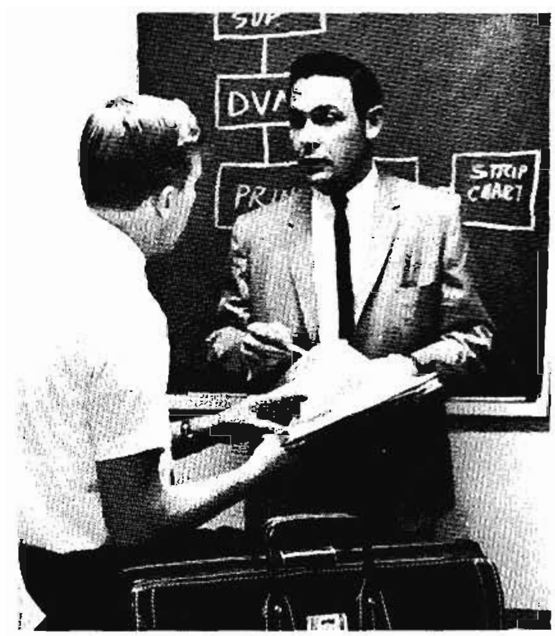
In addition to the usual (and some not so usual) after-the-sale services, your Hewlett-Packard Field Office also offers many services you may find helpful before you decide which piece of equipment to purchase.

Demonstration instruments

For many purposes, a data sheet giving complete technical specifications is all you require. There are, however, occasions when you like to have an instrument put through its paces — have a chance to see for yourself. Your hp field engineer will be happy to arrange a demonstration of Hewlett-Packard instruments for you. Also ask your field engineer when an hp demonstration van will be in your area. These vans offer you a chance to see and evaluate instruments from all of the Hewlett-Packard divisions in working displays.

Specials

With such a broad product base, hp is capable of modifying standard instruments to meet a wide variety of special applications. Divisionalization of the product groups permits a flexibility in our manufacturing methods, and provides potentials unequaled in the industry. If you have a unique application and cannot find a standard instrument to do the job, check with your hp field engineer. He is always ready to work with you in any way possible.



Staff engineers

When you pick up your telephone, the quickest, most efficient source of technical assistance and application information is your hp field office staff engineer. To ensure that there is always someone available who talks your language, your staff engineer spends all of his time in the office, ready to answer your call. He is the in-office counterpart of your field engineer and directly assists him in giving you the finest possible service. If you have an application question or if you need technical information on hp products, just give him a call.

APPLICATIONS AND MAINTENANCE TRAINING FOR YOUR TECHNICAL PERSONNEL

When purchasing test equipment, ease of maintenance is always a consideration. Many purchasers, of course, have repair and calibration facilities and prefer to maintain their hp equipment at their plant. By taking advantage of Hewlett-Packard's product training program, you can have factory trained technicians in *your* service department.

Two types of training are offered for your supervisory and key electronic maintenance personnel — field service seminars and factory seminars.

Field service seminars

Generally held at the local field office, field service seminars cover a given product area such as oscilloscopes, signal generators, voltmeters, etc., and last for one or two days.

These seminars are usually conducted by engineers from the Hewlett-Packard product training group who are thoroughly trained in the instruments to be covered and experienced in instructional techniques.

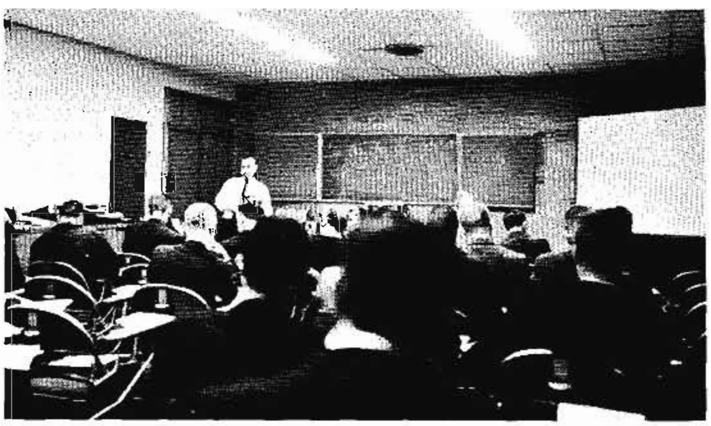
Factory seminars

Factory seminars offer broader coverage of groups of instruments and are held at the Hewlett-Packard factory. Older instruments, as well as the newer models, are covered and, where possible, a portion of the training is tailored to individual needs. Repair and calibration techniques are discussed during the one- or two-week seminar.

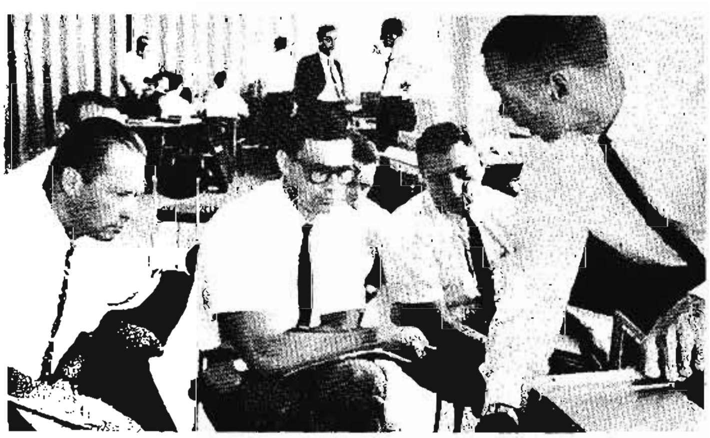
Seminar schedule and cost

Due to the program's popularity and the limited number of trainees that can be accommodated at any one time, there is often a waiting list. Your hp field office will be glad to provide you with a schedule of upcoming seminars and make the necessary reservations.

Both the field seminars and the factory seminars are offered at no charge to you. Your only cost is for transportation, lodging and meals.



Field service seminars offer your service technicians the opportunity to receive maintenance training from factory engineers.



More intensive coverage of a group of instruments is available through the factory seminars.

A VARIETY OF TECHNICAL PUBLICATIONS—YOURS FOR THE ASKING

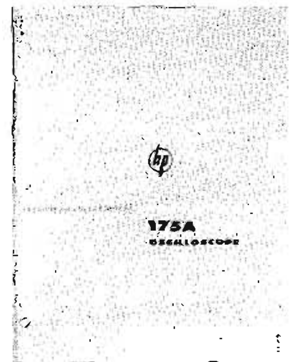
Hewlett-Packard willingly incurs the obligation to keep you informed of new measurement techniques, applications, new instruments, maintenance and service procedures. To do this, your hp field office offers a number of publications, each designed for a specific purpose.

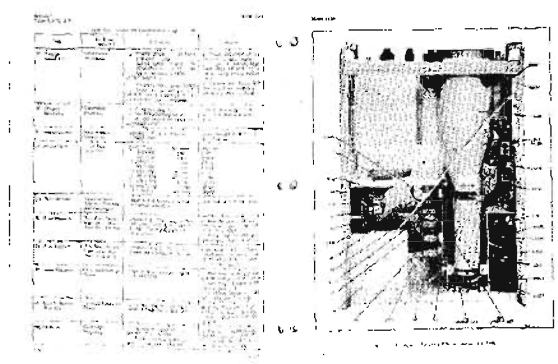
If you are interested in receiving any of the following publications, simply contact the field office nearest you.

Operating and Service Manuals

Operating and Service Manuals provide operating instructions, theory of operation, maintenance and calibration information, schematics and a table of replaceable parts. Although they are supplied with each new hp instrument, you may wish to purchase extra copies or replace your original copy if it has been misplaced. Manuals for current instruments are always available, and copies for many older instruments are quite often still in print.

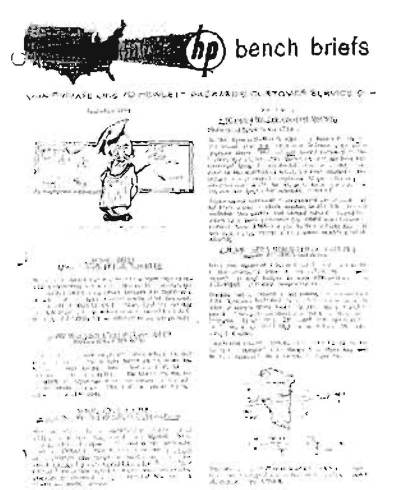
When ordering a replacement manual (usually $2.50 to $10), please give the instrument model number *and* complete serial number.

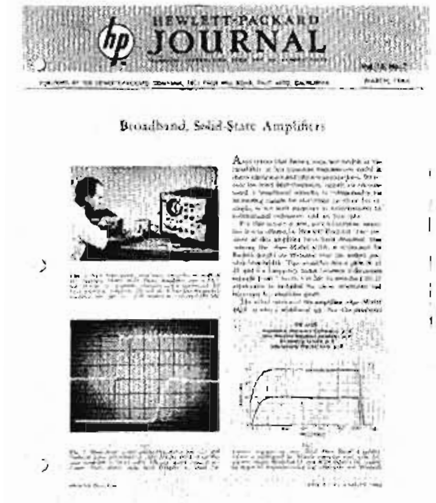




Bench Briefs

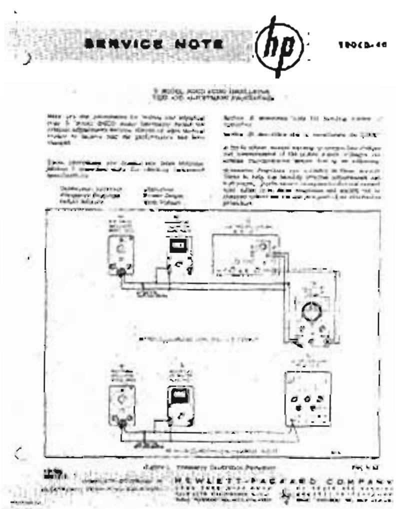
This newsletter briefly reviews new hp service information as it becomes available. Typical subjects include new modifications, service short cuts and parts information. Distributed by mail, Bench Briefs is sent to individuals directly concerned with repair and maintenance of hp instruments.




HEWLETT-PACKARD
JOURNAL
Broadband, Solid-State Amplifiers

Hewlett-Packard Journal

A monthly technical publication from the hp laboratories, the Journal brings you new measuring techniques and describes advances in the state-of-the-art for measuring instruments. To receive your copy of the Journal each month, just ask that your name be added to the Journal mailing list.


SERVICE NOTE
HEWLETT-PACKARD COMPANY

Service Notes

This series of technical publications is available for distribution to customers' facilities where hp instruments are repaired and maintained. Service Note topics include new or special calibration techniques, modifications and special repair procedures — all written in a detailed manner. Ask your hp field engineer for a copy of the Service Note Index.


APPLICATION NOTE 61
HEWLETT-PACKARD COMPANY

Application Publications

As the name implies, Application Publications deal primarily with uses of hp equipment. Because of their specialized nature, these Publications are distributed by individual request only rather than on a mailing list. Ask for the complete Application Publications Index so you may order those which are of interest to you.

Measurement News

Announcements of new instruments and Application Publications as they become available, as well as articles of local interest, are brought to you by your hp field office in this bi-monthly publication.

OFF-THE-SHELF DELIVERY FOR YOUR HP REPLACEMENT PARTS

Replacement parts play a key role in Hewlett-Packard's service-in-depth program. Prompt instrument maintenance, whether it's done in your shop or by one of the hp field offices, depends on the immediate availability of the necessary replacement parts. For this reason, extensive parts inventories are maintained throughout the field. Over 90% of the orders for hp replacement parts are shipped the same day they are received. To back up these inventories, Hewlett-Packard has developed a fast drop-ship procedure from regional centers to assure you of immediate response to your replacement parts needs.

Accessories and operating supplies

In addition to the usual individual replacement parts, accessories and operating supplies are also in stock ready for immediate delivery for the instruments manufactured by the Hewlett-Packard companies.

Modification kits

Like replacement parts, modification kits may be ordered by hp stock number from your nearby field office. Two publications from hp customer service, Service Notes and Bench Briefs (see preceding pages), keep you abreast of modifications which are available.

A complete inventory of replacement parts, accessories and operating supplies is maintained at your local hp field office.

These items make up an "Isolated Service Kit" for the Model 410B Vacuum Tube Voltmeter.

Proper parts identification means faster delivery to you. Call your hp field office whenever you need assistance.

Spare parts kits

Several types of parts kits are available to assure continuous operation from your hp instruments when they are being used in an isolated area, or where loss of the instrument use would be extremely critical. "Running Spares" and "Isolated Service" kits offer varying degrees of completeness, and you can pick the kit that most nearly satisfies your requirements.

Ordering replacement parts

When ordering replacement parts or operating supplies, please specify the following information to assure your getting the right part in the shortest possible time.

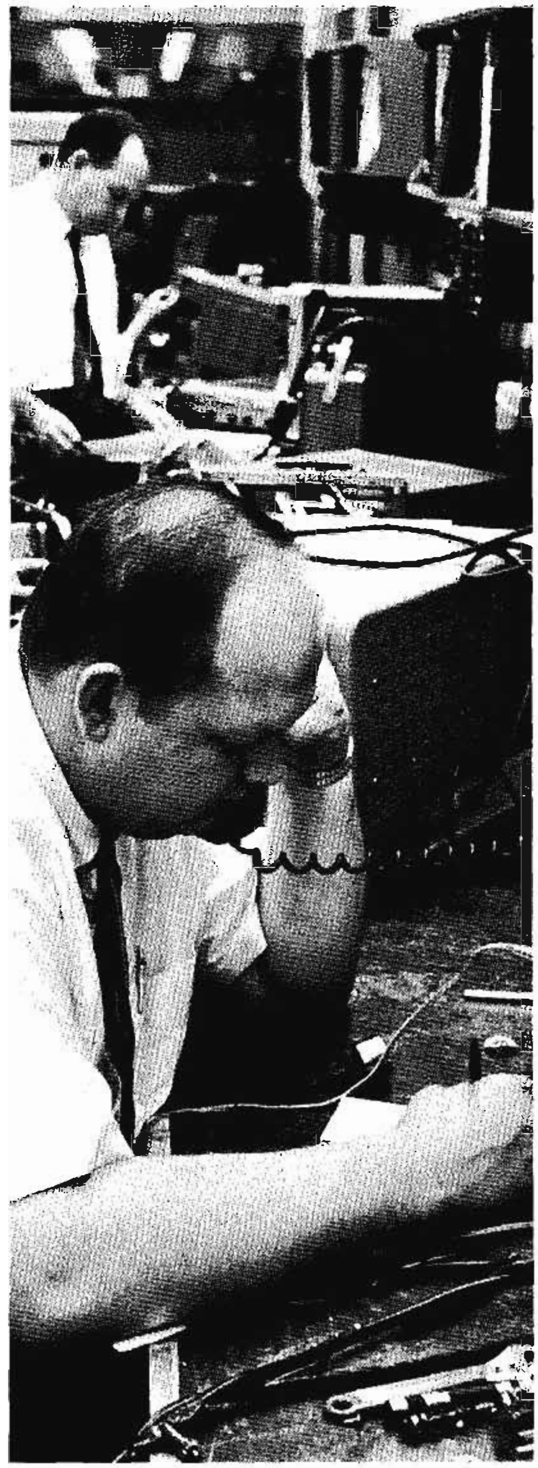
1. hp stock number for the part
2. a complete description of the part

This information is listed in the "Table of Replaceable Parts" in the Operating and Service Manual you received with your instrument.

If for some reason the hp stock number is unknown, please include the instrument model number *and* serial number, a complete description of the part, its function and its location within the instrument.

INSTRUMENT SERVICES WHEN YOU NEED THEM

The Hewlett-Packard field office is not just a point of contact, a mere passer of messages. The service departments located at more than 40 of the field offices have fully equipped, factory-trained repair and maintenance groups prepared to offer you immediate assistance on your Hewlett-Packard instruments.



Many times, maintenance information can be handled easily over the phone.

Instrument recalibration

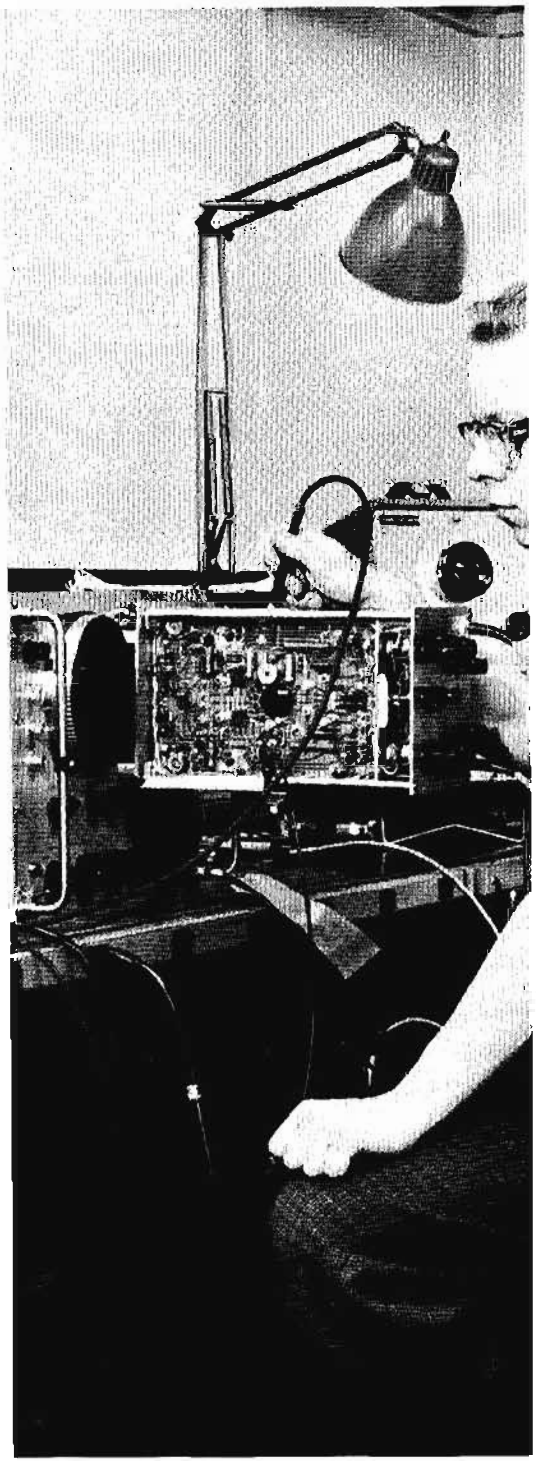
To insure continued reliability, the proper operation of any electronic instrument should be routinely verified from time to time. The Operating and Service Manual for each hp instrument provides the information required for field recalibration. If it is not convenient for you to recalibrate your hp instrument, contact your nearest hp field office.

Standards calibration and traceability to NBS

Special "standards calibration" services also are available. These services are in addition to the precision recalibration services mentioned above, and include a calibration report on each equipment item calibrated. The report contains (1) a description of measurement conditions, (2) the measurements made and accuracy, and (3) demonstration of traceability to the National Bureau of Standards (where applicable).

Repair and maintenance

When your hp instrument is not functioning properly, you usually need service fast. Whether it is routine maintenance or emergency repair, the field service department is staffed and equipped to do the job quickly.



Factory-trained senior technicians offer fast, dependable service for in- or out-of-warranty repairs.

Instrument overhaul

Older hp instruments that have been in operation for a number of years can be brought up to meet the specifications of the current production instruments of the same model. If your particular model is no longer being manufactured, overhaul will put it in a condition equivalent to when it was originally purchased.

Modification

The characteristics of your standard hp instrument can occasionally be modified to satisfy special requirements, or an older instrument that has been in the field for some time can be up-dated by one of many modifications available through the field service department. Most modifications can be easily performed in your plant by your technicians (see Modification Kits, page 8).

Other instrument services available

Hewlett-Packard instrument services, of course, go beyond the usual repair and calibration. Service contracts are available through your hp field office, and systems installation is provided when needed.

Returning your instrument for service

When returning an hp instrument to your hp field office for service, following the three suggestions listed will help get it back to you in the shortest possible time:

1. Send complete instructions telling what you would like done to the instrument (repair, overhaul, certify — with NBS traceability, etc.).
2. If the instrument needs to be repaired, include complete information about the "symptoms."
3. Indicate the address to which the instrument is to be returned, plus the addresses to use for correspondence and billing purposes.

AN ORGANIZATION DESIGNED TO SERVE YOU

Publications, replacement parts, training, staff engineers, instrument maintenance and calibration, demonstrations, "specials"— all offered by your hp field office. This would not be possible, of course, without some solid back-up. Hewlett-Packard's service organization backs up the field office with regional service centers, and it backs up the regional service centers with service engineers in the manufacturing divisions.

Regional service centers

Regional service centers are now located in Rockaway, New Jersey, and Palo Alto, California, with more expected in the near future. In addition to the usual repair and replacement parts back-up, the regional service centers maintain highly specialized equipment not available at all local service departments for repairs and calibration. These centers also stock the seldom-called-for replacement parts for older hp instruments. In this way, you are guaranteed the same fast service for all your replacement parts.

Staffed by people with many years of factory and field office experience, the regional service centers provide technical back-up, as well. A complete microfilm library is maintained at each service center for the instruments produced by the hp divisions, with parts lists, production changes (and the serial numbers involved), modifications and service techniques included.

Manufacturing divisions

An important member of each manufacturing division's marketing group is the service engineer. It is his function to see that new instruments developed by his division have service considerations built in, to keep abreast of the latest modifications available and repair techniques used and to see that this information is passed to the regional service centers and the field offices. A specialist in his particular group of instruments, he also provides additional technical back-up.

Warranty

The Hewlett-Packard warranty not only guarantees you an instrument which will perform to published specifications, but also expresses our pride and confidence in the materials and workmanship which have gone into that instrument. It is a warranty backed by over 25 years of experience in the electronics industry and an organization designed to serve you.

"All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from 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. No other warranty is expressed or implied. We are not liable for consequential damages."

Service engineers, armed with a complete microfilm library on Hewlett-Packard products, provide necessary technical back-up.

Service begins as the instruments are being developed in the lab.

Figure 1. Full rack width cabinets stack one atop the other.

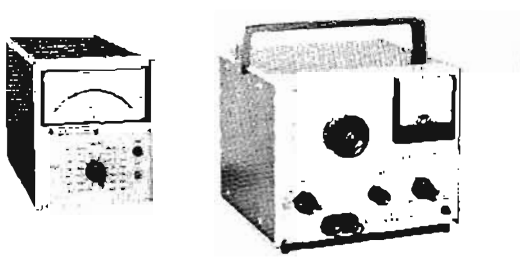


Figure 2. Standard configurations include cabinets one-third and one-half full rack width. Accessory handle 11057A is shown on half-width instrument.

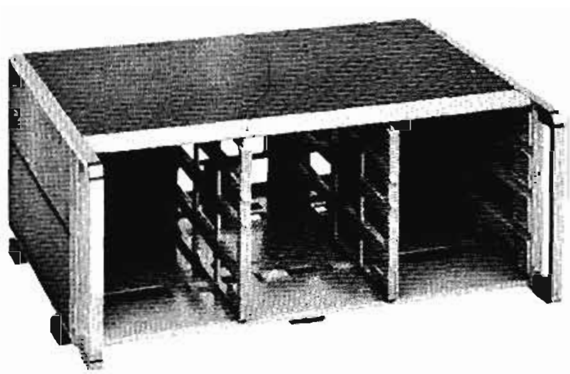


Figure 3. Hewlett-Packard 1051A Combining Case.

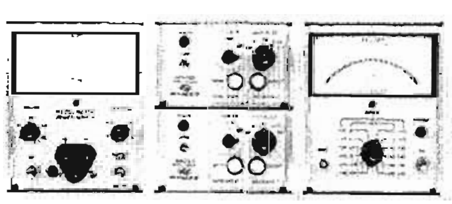


Figure 4 Here one hp instrument, one Harrison Division instrument and two Dymec Division instruments are mounted in an hp rack adapter frame.

HEWLETT-PACKARD MODULAR ENCLOSURE SYSTEM

Versatile instrument packaging

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. Extension slides are available for use in rack mounting these instruments to provide complete accessibility for quick, convenient servicing. 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.

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

Extension slides (see Figure 6)

0403-0050 Slides, closed length 16-7/32" (412 mm), maximum travel 20¾" (527 mm), $50.

0403-0051 Slides, closed length 22-7/32" (564 mm), maximum travel 26¾" (680 mm), $55.

0403-0052 Adapters and Brackets for full-module instruments over 3½" high (89 mm), $20.

0403-0054 Adapters and Brackets for full-module instruments 3½" high (89 mm), $15.

Joining brackets (see Figure 8)

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, $20.

Accessory handles (see Figure 2)

11056A Handle for any one-third module instrument, $5.

11057A Handle for any one-half module instrument, $5.

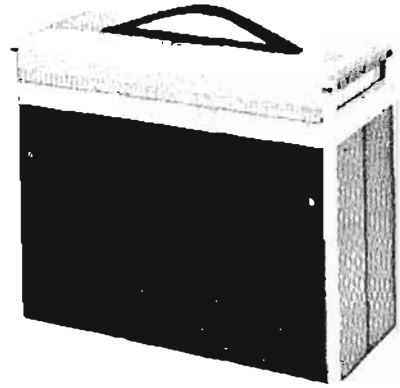


Figure 5. Instrument covers quickly convert full-width cabinets to easily carried portable units.

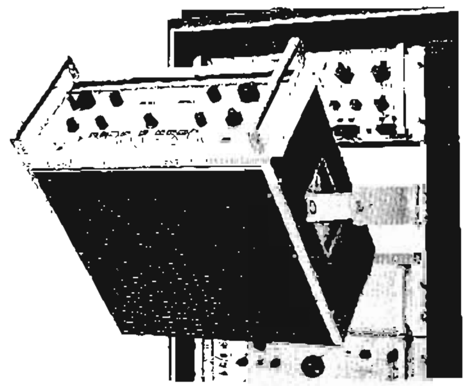


Figure 6. Extension slides permit easy access to rack mounted instruments.

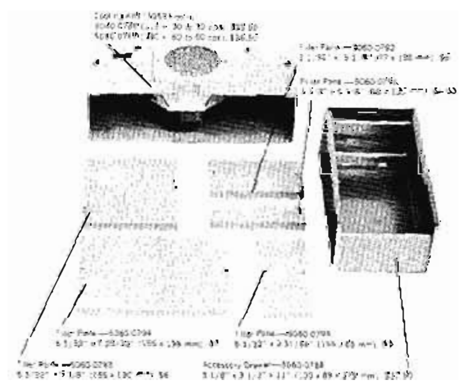


Figure 7. Combining case accessories.

Figure 8. Joining brackets effectively weld instruments into a single physical unit.

HEWLETT-PACKARD INSTRUMENTS FOR SCIENCE & INDUSTRY

New instruments are constantly emerging from the expansion of technology in Hewlett-Packard's growing family of affiliates and divisions. These are not only for traditional electronic applications, but increasingly are contributions toward better instrumentation for science and industry at large. Representative of hp developments beyond those purely electronic are the chemical instruments described here. For further details on these and other such products, contact your Hewlett-Packard field engineer.

Measure molecular weights rapidly, precisely, 100 to 5,000,000

Mechrolab 300 Series Vapor Pressure Osmometers. Number average molecular weights between 100 and 20,000 are precisely determined in 20 minutes or less with 300 Series Vapor Pressure Osmometers. Operating on the principle of vapor pressure lowering of solvent by solute, these instruments automatically provide 2-minute readings at progressively changing osmotic concentrations. Excellent results can be obtained using microliter volumes of sample. Thermostats and probes are available for operation at 25, 37, 50 and 65°C (upper limit). The Mechrolab Auxiliary Sample Chamber, which can easily be connected to all new and existing 300 Series instruments, effectively doubles the work capacity and flexibility of each instrument. Prices: Mechrolab 301A (25 to 65°C), $2690; Mechrolab 302 (25 to 130°C), $3150; Mechrolab 300 Auxiliary Sample Chamber, $1275.

Mechrolab 500 Series High-Speed Membrane Osmometers. These instruments provide precise osmotic and oncotic measurements of high molecular weight polymers and proteins, capable of measuring osmotic pressures to ±0.01 cm of solvent. The 500 Series instruments automate manual methods of membrane osmometry and allow complete determination of molecular weights in one hour or less. Three models permit work at high or low temperatures—from 5°C to 130°C. Prices: Mechrolab 501 (ambient to 65°C), $4225; Mechrolab 502 (ambient to 130°C), $4975; Mechrolab 503 (5 to 65°C), $5550.

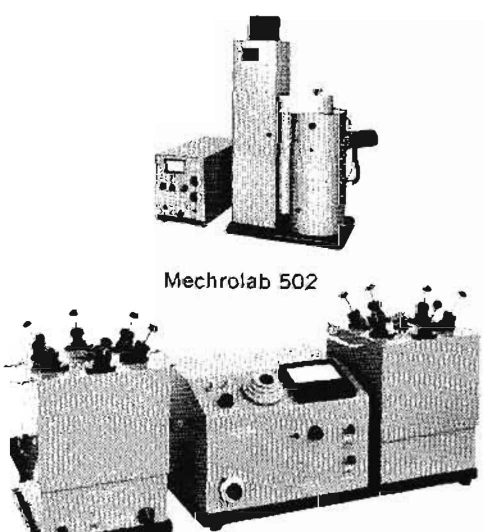
Mechrolab Model 801 Auto-Viscometer. This instrument automates intrinsic viscosity measurements for the first time and increases precision of measurement by a factor of 10. The 801 provides automatic influxing and timing, four channels for sequential operation and digital display of efflux times. Most types of capillary U-tube viscometers can be used with the Model 801. An extremely precise constant temperature bath, Model 805, holds temperature uniform within ±0.005°C. It is included with the 801 Auto-Viscometer, but also may be ordered separately for use in other applications. Prices: Mechrolab 801 Auto-Viscometer, on request; Mechrolab 805 Constant Temperature Bath, on request.

8400A Microwave Spectrometer

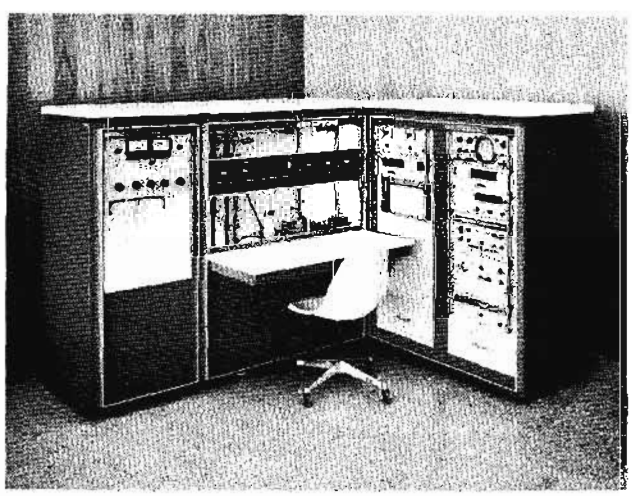
Identify molecular species, determine compounds in mixtures quantitatively. The hp Model 8400A Microwave Spectrometer, by measuring absorption frequencies in X-band, will yield molecular structure information such as the determination of bond angles, internuclear bond distances, dipole moments of molecules and intra-molecular effects such as nuclear quadrupole interactions and hindered rotations. From application of new microwave techniques, Model 8400A makes it possible to determine precisely the intensity coefficient—both peak and integrated—of the absorption curve. With this information, the precise amount of sample in the Stark cell can be calculated. Features of the fully-integrated spectrometer:

- Rapid absolute intensity coefficient measurements
- Microwave power at the Stark cell is leveled automatically throughout spectrum sweep
- Frequency-calibrated recorder chart
- Direct counter readout of microwave frequency
- Modular construction

Each Microwave Spectrometer System consists of three related consoles. One contains the vacuum equipment, which exhausts the Stark cell prior to sample injection; the second includes sample chamber and most microwave circuitry: the electronics, control and recording equipment is in the third console. For full details contact Microwave Division, Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304.


Mechrolab 502

Mechrolab 301A


hp 8400A

5259A Frequency Converter

The hp Model 5259A Frequency Converter converts your 5243L or 5245L Electronic Counter (see page 46) to a 1012 mc frequency counter. It retains the stability and accuracy of the basic counter by using a multiple of the 10 mc signal from the counter time base to beat with the unknown signal. The 5259A operates from 458 to 1012 mc. With 5259A installed, basic measurement ranges of the counter are retained. Measurements to 20 mc (5243L) or 50 mc (5245L) are obtained by moving counter sensitivity control off "plug-in" position, connecting measured signal directly to counter input.

Specifications, 5259A

Input voltage range: 100 mv to 1 v rms.

Input impedance: approximately 50 ohms.

Weight: net 5 lbs (2,3 kg); shipping 9 lbs (4 kg).

Accessory furnished: 10503A Cable, 4 ft. (1220 mm) long, male BNC Connectors.

Price: hp 5259A, $550.

525D Frequency Converter

The hp Model 525D Frequency Converter converts your 524B, C or D Electronic Counter (pages 64, 65) to a 1010 mc frequency counter. It retains the stability and accuracy of basic counter by using a multiple of the 10 mc signal from the counter time base to beat with the unknown signal. The 525D operates from 460 to 1010 mc and also retains 524 basic measurement ranges and functions as an amplifier, increasing 524 sensitivity to 20 mv from 50 kc to 10.1 mc.

Specifications, 525D

Input voltage: 20 mv rms min., 50 kc to 10.1 mc, 100 mv rms min., 460 to 1010 mc.

Resolution: 0.1 cycle to 1000 cps, depending on gate time.

Input impedance: approximately 700 ohms 50 kc to 10.1 mc; approximately 50 ohms 460 to 1010 mc.

Weight: net 5 lbs (2,3 kg); shipping 9½ lbs (4,3 kg).

Price: hp 525D, $550.

4260A Universal Bridge

Fast, accurate measurements of R, C, L, D and Q are easy with the hp 4260A. In-line readout, automatic decimal indication and simplified controls make the 4260A especially suitable for production testing and general measurement uses. New electronic orthogonal null eliminates repetitive operations, removes ambiguity from D and Q measurements.

Specifications, 4260A

Seven ranges: C, R, L, 1 pf to 1000 μf, 10 milliohms to 10 meg, 1 μh to 1000 h; D (dissipation factor) of series C, 0.001 to 0.1; D of parallel C, 0.05 to 50; Q of series L, 0.02 to 20; Q of parallel L, 10 to 1000.

Accuracy: C, ±1% ±1 pf, 1 pf to 100 μf; ±2%, 100 μf to 1000 μf; R, ±1% ±10 milliohm, 10 milliohm to 100 K; ±2%, 100 K to 1 meg; ±5%, 1 meg to 10 meg; L, ±1% ±1 μh, 1 μh to 100 h; ±2%, 100 h to 1000 h; D of series C, ±7% ±0.001; 1/D of parallel C, ±7% ±0.02; Q of series L, ±7% ±0.02; 1/Q of parallel L, ±7% ±0.001.

Measurement frequency: 1 kc for L and C; 20 cps to 10 kc applicable with external oscillator; dc only for R measurement.

Oscillator: internal, 1 kc ±2%, 10 v rms max.

DC supply: internal, 40 v, 20 ma max.

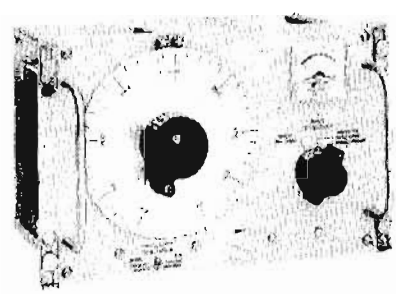
Detector: internal, tuned at 1 kc (flat amplifier used with external oscillator).

Electronic orthogonal null: eliminates D, Q adjustments in series L and parallel C measurements; accuracy equals normal operating condition ±0.5%.

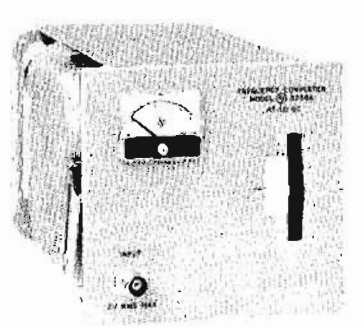
Dimensions: 6½" high, 7¾" wide, 12" deep (165 x 197 x 305 mm).

Weight: net 12 lbs (5,4 kg); shipping 16 lbs (7,2 kg).

Price: hp 4260A, on request.



525D



5259A

AVAILABLE MID-1965

4260A

MEDICAL INSTRUMENTS FOR CARDIAC, BLOOD, METABOLISM ANALYSIS

Simplify the acquisition of reliable diagnostic information

500 Viso-Cardiette Electrocardiograph

Provides simpler recording of clear cardiograms in the presence of moderately high interference levels and abnormally high skin resistances. Offers two speeds (25 and 50 mm/sec), three sensitivities (1/2, 1 and 2X normal), automatic stylus stabilization during lead switching, standard 5 cm lined chart and easy paper loading. Improved circuit provides better discrimination of heart signals from ac interference, a more stable baseline and better patient protection without fuses. Controls are functionally grouped and electrode cable tips are color-coded to a patient diagram on panel. Sanborn 500, $695; with matching 500-1100 Mobile Cart, $820.

75 Cell Counter

Accurate red or white blood-cell counts in less than 25 seconds. Pour sample, press lever and read meter calibrated in cells/cu.mm. Unique optical-electronic design samples 50 times number of cells sampled by manual methods. Sanborn 75, $1800.

202 Clot Timer

Sanborn/Mechrolab Clot Timer replaces human fallibility in blood coagulation end-point detection with precise, reproducible electronic determinations accurate to 0.3 second. Clotting time appears on numerical readout. Two tests can be run simultaneously. Sanborn/Mechrolab 202, $685.

74A,R,W Hemo-Diluter®

Semi-automatically provides proper dilutions of whole blood for the 75 Cell Counter, using separate fluid-handling systems for red cell and white cell dilutions. Sanborn Model 74A,R,W; Prices on request.

S-1000 Blood Analyzer

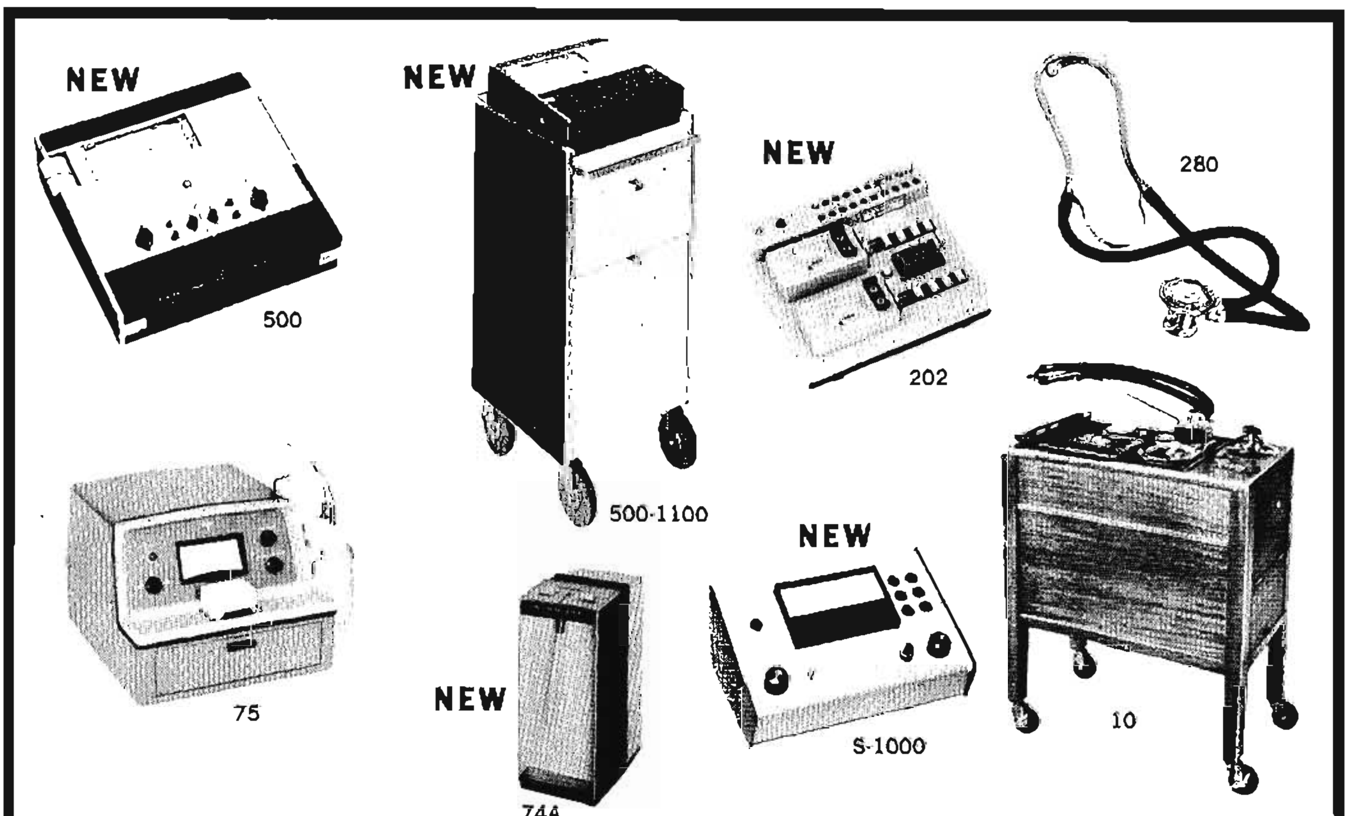
Sanborn/BMI Blood Analyzer measures cholesterol, hemoglobin, glucose inexpensively and with exceptional reproducibility and minimized possibility of operator error. Easy, non-technical operation. Simple procedures use one reagent and precalibrated disposable pipettes and cuvettes; Sanborn/BMI 3-test Analyzer, $380; 2-test, $340; single-test, $205 (hemoglobin, $179); plus cost of accessory kits.

10 Metabolism Tester

For fast determination of basal metabolic rate, the metabulator offers simple controls, continuous chart supply, easily changed CO_2 absorbent, and quick BMR calculation. All accessories can be stored in mobile cabinet. Sanborn Model 10, $642.50.

280 Acoustic Stethoscope

Extremely high acoustic efficiency clearly transmits low- and high-pitched heart sounds which are often faint or inaudible with other instruments. With adult diaphragm and 1⅜" open-bell, $19.75; with five chest pieces and three sets of ear pieces, $25.



780 SERIES PATIENT MONITORING AND RESUSCITATION MODULES

Flexible, compatible units for reliable bedside monitoring with remote option

Continuous, automatic monitoring can significantly augment staff care of patients in critical condition: more complete attention can be given all recovery room, intensive care and emergency room patients — with special care for those in most critical condition without lessening the attention to others . . . immediate visual and/or audible notification of distress conditions, or departure of conditions from preselected limits, enables prompt application of corrective or resuscitative procedures . . . and in certain cases, continuous monitoring with ECG recording can reveal cardiac irregularities now thought to be the precursors of ventricular fibrillation. Electronic monitoring, in short, lends vital aid to complete, continuous patient care and the speed with which distress symptoms are discovered.

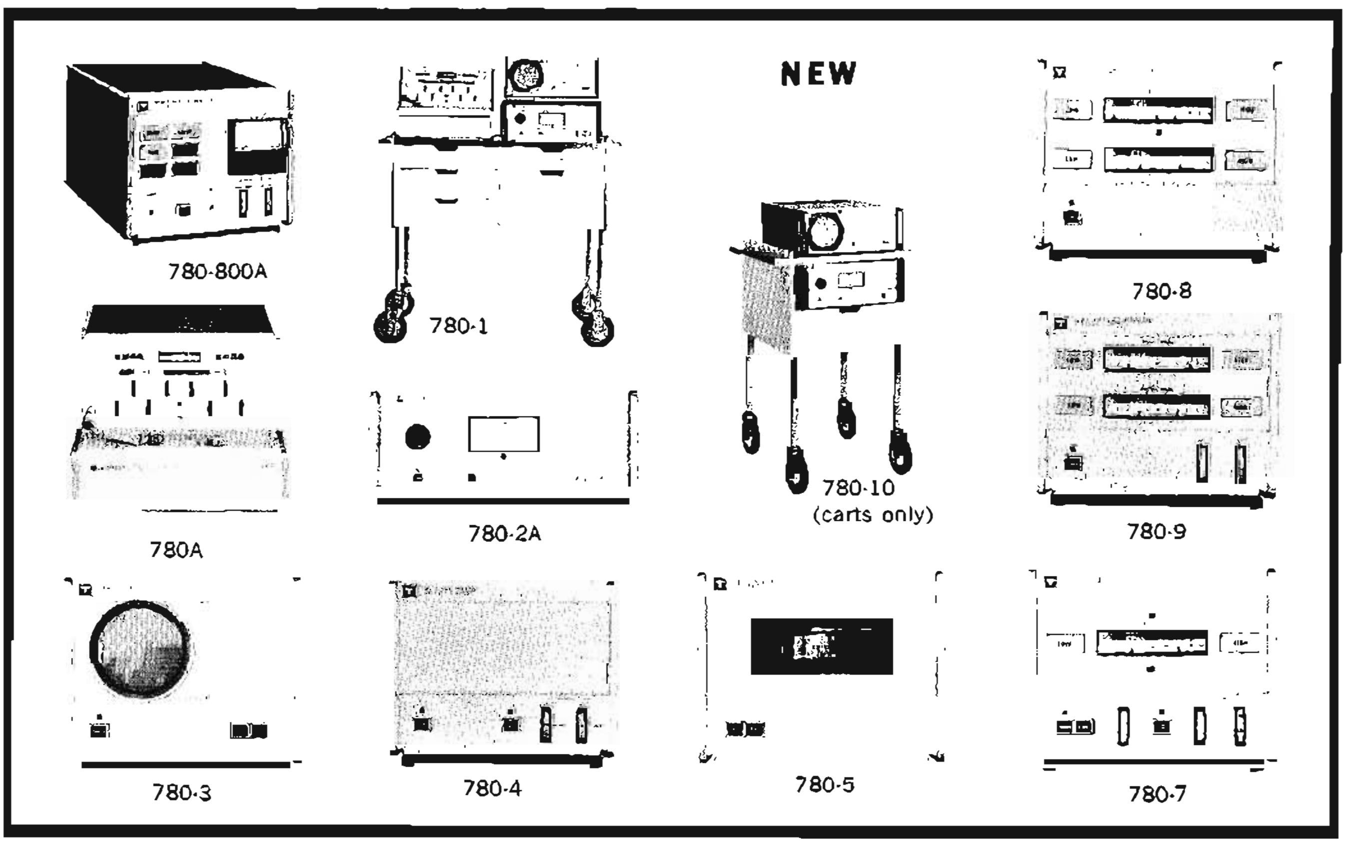
To meet the need for comprehensive, reliable instrumentation for a wide variety of monitoring requirements, Sanborn 780 equipment is designed as individual, separately usable modules, typically combined to form a system. Together, they offer the widest choice of different combinations of the conditions to be monitored at each bed and the number of beds . . . in compact shelf or mobile cart mounting . . . in optional alarm, display or recording at a remote central station. Modular units also provide the economy of buying only the specific units needed, with the freedom to change or expand capabilities later as experience may indicate . . . and the simpler servicing resulting from down-time restricted to a single module.

The design and operating characteristics of 780 instruments also reflects careful attention to patient comfort, safety and equipment protection. Continuous monitoring can be accomplished with minimum patient discomfort, freedom of movement within practical limits, and with audible alarms at remote central station only. Pacemaker and defibrillator employ fail-safe circuits and protective devices for patient and operator alike. All units are protected against electrical damage from defibrillator currents.

Hewlett-Packard Sanborn Division medical application engineers will be glad to supply detailed systems data and recommendations to meet the needs of your present or proposed patient monitoring facility.

Prices: 780A Viso Monitor, $1975; 780-800A Remote Indicator $250; 780-1 Resuscitation Cart, $345; 780-10 Mobile Cart, $195; 780-2A Defibrillator-Synchronizer, $1100; 780-3 3″ Viso-Scope, $495; 780-4 Pacemaker, $275; 780-5 Signal Delay, $450; 780-7 Patient Monitor (ECG, heart rate, pacing), $820; 780-8 Patient Monitor (respiration rate, temperature), $675; 780-9 Patient Monitor (systolic, diastolic pressures), $675.

Not shown: 780-6 5″ Viso-Scope, 780-11 Patient Selector, 780-12 Remote Alarm Indicator, 780-14 Respiration Transducer, 780-15 Wall-mount Bracket, 780-16 Ear Plethysmograph and 780-17 Remote Automatic Switching Unit.



MEDICAL RESEARCH INSTRUMENTATION

Simple operation, clear data presentation aid investigative techniques

4568 Poly-Beam Recording System

The Sanborn 4568 is a 6- or 8-channel optical oscillograph capable of high definition recording on 200′ rolls of 6″ or 6 cm white photographic chart paper, with traces across entire chart width or on a common zero line if desired. Wide adaptability is offered to handle many types of dc to 500 cps physiological variables, by the user's choice of specialized plug-in preamplifiers for each channel. Optional rapid developer for dry, completely developed records; ECG input panel for up to 4 channels of ECG recording, and oscilloscope, electronic switch and vector timer for vectorcardiography or other visual monitoring, permit wide usefulness of this single system. The 4568 may be purchased for 6 channels, later expanded to 7 or 8 channels. Price: Sanborn 4568 Basic Assembly without preamps, for 8 channels, $5060; preamps (one per channel required), $325 to $710 each.

764-1,-2 Recording Systems

The Sanborn 764-1,-2 are particularly useful in cardiac catheterization studies, for visual monitoring of up to 4 waveforms on a 17″ oscilloscope and simultaneous heated stylus recording (764-1) or photographic recording (764-2) to provide a permanent record for later study. Wide choice of miniaturized 760 Series plug-in preamplifiers equip the system for user's individual monitoring/recording requirements. System design assures accurate recording of exactly what is seen on scope screen, preserving uniform ratios between waveform amplitudes. Traces on both scope and chart may be positioned for best clarity and comparison. Price: Sanborn 764-1 Basic Assembly, $4550; Sanborn 764-2 Basic Assembly, $4580; preamps (one per channel), $135 to $500 each.

130 Cardiac Output Computer

The Sanborn 130 automatically computes area of primary circulation curve when used with indicator dilution techniques, provides data in lighted numeral form in a matter of seconds, allows surgeon, diagnostician or researcher to make immediate decisions regarding further measurements while the procedure is in progress. Simple, rapid three-step operation yields numerical values which, by simple division, equal cardiac output in liters/min. Readable from 30′; Start and Reset controls operable remotely; BCD output for printer, analog/digital computers; baseline sensing circuit eliminates need for zeroing at start of each test. Price: Sanborn 130, $1550.

5601A Numerical Readout

The Sanborn 5601A displays four channels of physiological data, with three digits and decimal point per channel. Interchangeable modules and identifying plaques for each channel equip unit for temperature, pressure, heart rate, respiration rate and other slowly changing phenomena. Lighted decimal point in any channel can be made to flash in synchronism with occurrence rate of signal (e.g., heart or resp. rate). Brilliant numerals 0.6″ high clearly visible and readable up to 30′ away. Numeral "1" can be supplied in left channel as most significant figure, for temperature in °F. Standard hp full-module case facilitates stack or rack mounting. Output is available for digital recorders. Price: Sanborn 5601A, with any four 000-300 range plug-ins, $2100 (temperature channel, $100 additional).

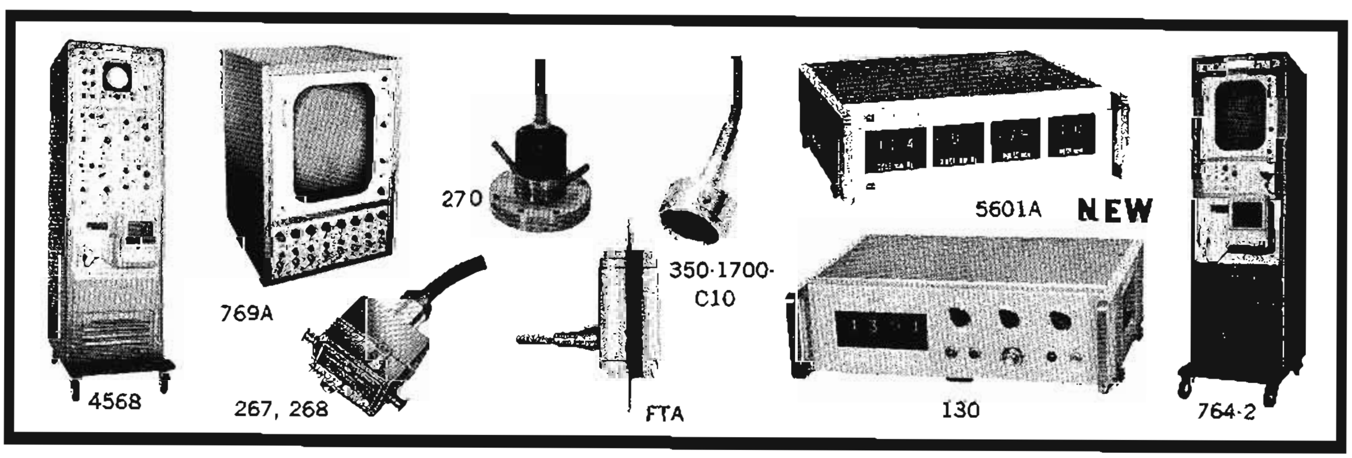
769A Viso-Scope

The Sanborn 769A Oscilloscope has 17″ (13½″ high) long-persistence screen and provision for up to 8 plug-in gating amplifiers, for clear presentation of up to 8 waveforms simultaneously. Amplifier controls for trace positioning, gain and amplitude. Optional plug-ins are available for x-y or vectorcardiograph display, slave operation of a second 769A scope. Polaroid filter and scope face tiltable forward 20° minimize reflections, assure best viewing angle. Automatic sweep speeds 3, 6 and 12 sec, manual 3, 6, 12 and 30 sec. Mounts on shelf or table, or on mobile cart, in rack or in ceiling swivel yoke with optional accessories. Price: Sanborn Standard 769A in cabinet with 8 gating amplifiers, $2125.

Sanborn Transducers

These devices for converting physiological data into analogous electrical signals include 267A and B, 268A and B single-ended or differential fluid pressure units for −40 to +40 mm Hg and −400 to +400 mm Hg ranges ($225, $250); 270 for bi-directional gas pressures from −100 to +400 mm H_2O ($295); 350-1700-C10 Contact Crystal Microphone for reproducing all heart sounds up to 1000 cps ($55); FTA Microforce units for sensing ±1 gm to ±100 gm forces with displacements up to 0.020″ ($200), plus many other types for measuring linear displacement, velocity and acceleration, minute surface and internal temperature variations, external measurement of internal membrane pressures, chest expansion and contraction, fingertip blood pressure pulse, disc, needle, fluid column and esophageal electrodes.

Note: For precision magnetic tape recording, see pages 384-389 for data on Sanborn 7- and 14-channel 3900 series system.



LINEAR MOTION, FORCE, PRESSURE TRANSDUCERS

Accurate, sensitive sensors, easy to use

Sanborn's extensive line of stock electromagnetic transducers on these pages and for medical application on page 19, offer designers of instrumentation and control systems a truly broad selection of accurate, reliable sensors for measuring linear displacement, low pressure, low force, linear velocity and other phenomena in both simple and complex applications.

Linear velocity

LVsyn® Linear Velocity Transducers are remarkably simple to set up and use for sensitive measurements of relative velocity. The basic LVsyn design eliminates the need for external excitation. DC voltages are generated by moving a high flux density permanent magnet in the bore of differentially wound coils. The voltage amplitude is proportional to core velocity. Resolution of an LVsyn output is unlimited—sensitivity over the rated stroke range is constant within 5%—temperature range between −50°F to +200°F. They 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.

Linear displacements

Linearsyn® (LVDT) Transducers produce an electrical output proportional to any physical parameter which is capable of conversion to a relative displacement between the transducer's core and coil assembly. Thirteen models, seven stroke ranges, various excitation frequency ranges and two diameter sizes offer designers an excellent stock selection for a variety of industrial and laboratory applications. When used with Sanborn or equivalent carrier amplifiers, linear displacements to 0.000001" may be resolved. Non-linearity error will not exceed 0.5% of total stroke; temperature range, −50° to 250°F. Linearsyns are shielded, immersible in non-corrosive fluids without damage, resistant to shock and vibration and void of friction and mechanical hysteresis.

7DCDT and 24DCDT Series (DC LVDT) dc excited, dc output linear displacement (±0.05" to ±3") transducers are extremely convenient to use for measuring, monitoring or controlling mechanical displacements. No external carrier system is required, and phase shift and balancing adjustments are not necessary. Each DCDT has a built-in carrier oscillator and phase-sensitive 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 total stroke. The 24DCDT's have approximately three times the sensitivity of the 7DCDT's and operating temperature to 250°F (7DCDT, 140°F). Nominal excitation is 6 v dc, 20 milliamps for the 7DCDT series and 24 volt dc, 38 milliamps for the 24DCDT series. They should be energized from a low-impedance, well regulated power source such as Sanborn 115 v, 60 cycle 6- and 24 v dc power supply Models TPS-11 (6 v dc) and TPS-12 (24 v dc). Each power supply is capable of exciting up to five DCDT's when used with Sanborn T41-11 Multiple DCDT Power Supply Adapter. Battery powered TPS-10 is available for 7DCDT's.

Dimensional gaging

GT Dimensional Gaging Transducers can be quickly set up to gage, classify or profile single or multiple-point machined dimensions in seconds. Pieces can be gaged to millionths repeatedly with these precision Sanborn miniature differential transformer transducers that feature zero hysteresis, high resolution and linearity. Rugged GT's meet AGD mounting dimensions for dial indicators and operate from −50° to +170°F. Non-linearity is less than 0.5% of total stroke; contact pressure is 6 oz and nominal carrier excitation is 6 volts at 2.4 kc. These miniature GT gages have 3/8" diameter stainless steel casing, replaceable contactor, precision bearings—terminations which will match Sanborn carrier amplifiers (GT-3-030-1), multiple gaging systems (GT-3-030-2); or with tinned leads only (GT-3-030).

Low-level forces

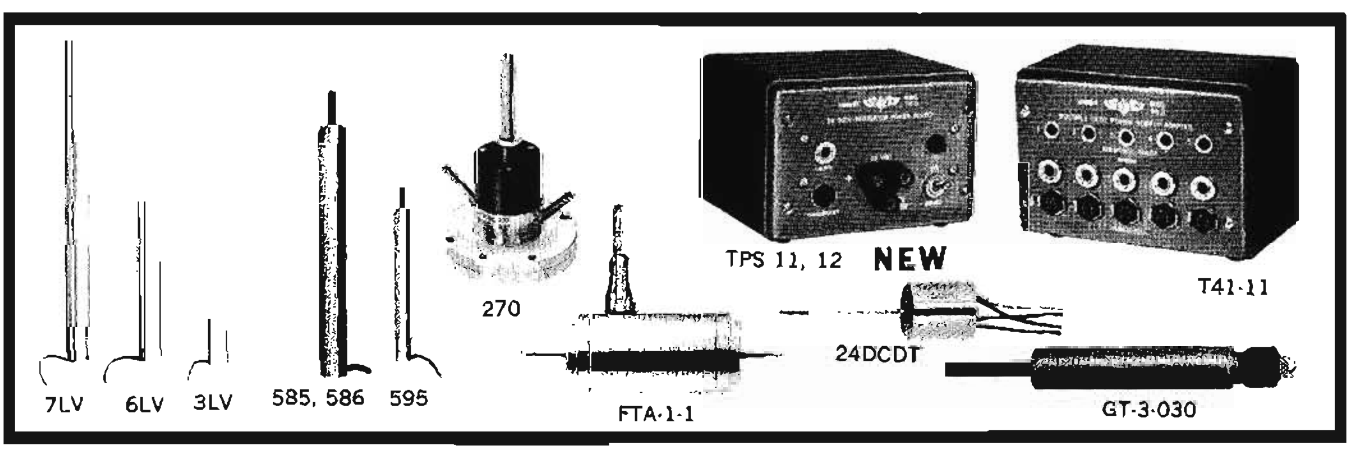
FTA low-level tension and compression sensing transducers (±1 to ±100 gm) are ideal for measuring buoyancy, discrete weights, small bearing torques, displacements and angles, as well as muscle contractions and other physiological motion (see page 19). These miniature "Microforce" transducers provide 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 over 0° to +170°F. Nominal excitation is 5 volts at 2.4 kc.

Gas pressure

The 270 is a highly sensitive and stable instrument for measuring low gas pressures. It was originally developed and is used in medical pulmonary studies (see page 19) but now also is replacing the 14 inch water manometer in many industrial and laboratory applications such as missile and airborne pneumatic control testing, and leak detection in vacuum and pressurized systems. The 270 has the same inherent advantages as other Sanborn differential transformer transducers (LVDT's), in addition to a relatively high natural frequency, low volumetric displacement (0.003 cu in full scale), high sensitivity (28 mv/vex), temperature operating range between 32° and 120°F and ability to measure either single-ended or differential pressures. Ratings are based on carrier excitation of 5 volts at 2.4 kc.

Optional accessory equipment

Sanborn 592-300, 115 v, 60 cps excitation source and demod for LVDT transducers, $150; Sanborn 311A Transducer Amplifier Indicator, $425; DCDT power supplies: Sanborn TPS-10, 6.5 v dc (w/battery), $42; Sanborn TPS-11, 115 v ac input, 6 v dc output (7DCDT), $150; Sanborn TPS-12, 115 v ac input, 24 v dc output (24DCDT), $175; Sanborn T41-11, Multiple DCDT Power Supply Adapter (7 and 24DCDT), $175.



Specifications, DCDT Transducers

Model	Sanborn 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
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
24 DCDT	2.5 K	3.5 K	5.2 K	5.5 K	5.6 K	5.6 K
Excitation (v dc) 7 DCDT	max. 7, min. 5					
24 DCDT	max. 28, min. 20					
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)
24 DCDT	0.87 (22.2)	1.12 (28.5)	3.21 (81.8)	3.71 (94.2)	4.71 (120)	10.52 (268)
Weight (gm) net	23	28	68	78	100	210
shipping	84	84	168	168	196	308
Price: 7 DCDT	$99	$104	$119	$132	$141	$162
24 DCDT	$146	$151	$164	$177	$186	$207

Specifications, Dimensional Gaging Transducers

Sanborn model	GT-3-030	GT-3-030-1	GT-3-030-2
Displacement range* (in)	±0.03	±0.03	±0.03
Sensitivity (mv/0.03 in/vex at 2.4 kc)	70	3±10%	2.6±1%
Impedance (ohms): input	180 + j280	180 + j220	180 + j280
output	260 + j260	50	50
Phase shift (at 2.4 kc)	20°	0°	0°
Dimensions	2.34" lg, 0.375" dia (59 x 10 mm)		
Weight (gm) net	200	300	300
shipping	500	800	800
Price	$115	$140	$170

*Working range ±0.04", accuracy 1%; total mechanical stroke ±0.1".

Specifications, Linearsyn Transducers

	Sanborn 585DT**					Sanborn 586DT					Sanborn 595DT**		
Sanborn model	-050	-100	-250	-500	-1000	-050	-100	-250	-500	-1000	-005	-025	-100
Excitation frequency std:	2.4 kc					60 cps					2.4 kc		
range:	400 cps — 10 kc					50 cps — 400 cps					400 cps — 20 kc		
Stroke range (inches)	0.05	0.1	0.25	0.5	1	0.05	0.1	0.25	0.5	1	0.005	0.025	0.1
Sensitivity*, (v/in./vex)	4.8	3.1	1.2	0.95	0.75	1.2	1.2	1.5	1.1	0.8	2.2	3.4	2.7
Impedance* (ohms) primary:	163	160	119	415	668	110	81	90	47	110	93	303	330
secondary:	213	780	880	302	600	2340	820	890	2020	1800	154	365	365
Vex* (max)	21	17	27	25	30	9	8	18	7	11	5	11.5	13
Dimensions inches (mm) diameter:	0.75 (19)	0.75 (19)	0.75 (19)	0.75 (19)	0.75 (19)	0.75 (19)	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)	1.94 (49)	3.31 (84)	4.88 (124)	6.88 (174)	1.63 (41)	1.94 (49)	3.31 (84)	4.88 (124)	6.88 (174)	0.90 (23)	1.09 (28)	1.09 (28)
Weight (gm) net	47	56	104	132	178	47	57	105	132	178	7.1	7.9	7.9
shipping	227	227	227	227	227	227	227	227	227	227	84	84	84
Price	$25	$35	$41	$50	$60	$25	$35	$41	$50	$60	$30	$27.50	$35

*At standard carrier frequency.
**For units supplied with 8' cable (w/connector and phasing unit) for direct operation with Sanborn 2.4 kc carrier amplifiers, add -BM to model number and $30 to price.

Specifications, Microforce Transducers

Sanborn 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 freq (cps)	65	130	390
Sensitivity (g) (% of f.s./g) radial:	0	0	0
axial:	21	5	0.6
Dimensions inches (mm)	1.37 lg, 0.75 dia (35 x 19)		
Weight (gm) net	FTA-X*, 90; FTA-X-1, 153		
shipping	760		760
Price	FTA-X*, $175; FTA-X-1, $200		

*FTA transducers without adapter for operation with Sanborn carrier systems; sensitivity ranges from 70 to 83 mv/vex at 2.4 kc; X = range in grams.

Specifications, LVsyn Transducers

Sanborn model	3LVA5	3LV1	6LV1	6LV2	6LV3	6LV4	7LV6	7LV9	7LV20
Sensitivity (mv/in/sec)	120 40*	90 35*	500 250*	500 250*	500 250*	500 250*	350 150*	350 150*	20 7*
Resistance (K ohms)	2	2.5	13	19	25	32	11.5	17	3
Inductance (henrys)	0.085	0.065	1.6	2.4	3.2	4	1.9	2.8	0.035
Stroke range inches (mm)	0.5 (13)	1 (25)	1 (25)	2 (51)	3 (76)	4 (101)	6 (152)	9 (229)	20 (508)
Dimensions inches (mm) diameter:	0.37 (10)	0.37 (10)	0.62 (16)	0.62 (16)	0.62 (16)	0.62 (16)	0.75 (19)	0.75 (19)	0.75 (19)
length:	3.16 (80)	4.22 (108)	5 (128)	7 (178)	9 (230)	11.25 (286)	15.75 (400)	22.75 (580)	30 (760)
Weight (grams) net coil	20	25	110	150	200	240	420	610	800
core	3.5	4.5	11	15	17	22	54	69	40
shipping	84	84	224	252	308	336	505	756	900
Price	$40	$45	$50	$55	$60	$65	$85	$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.

Specifications, Pressure (Gas) Transducer

Sanborn model	270
Differential pressure range psi (mm H_2O)	±0.5 (±350)
Common mode pressure psi (mm H_2O)	3(2000)
Sensitivity (full scale)* mv/0.5 psi/vex at 2.4 kc	28 mv/vex
Linearity error (full scale)	less than 1%
Hysteresis (applied pressure)	less than 1%
Differential performance, (applied pres., equal inputs)	output less than 0.01%
Acceleration sensitivity	0.005 psi (3.5 mm H_2O)/g
Dynamic response: square wave:	rise time, 5 ms; overshoot, 10%
sine wave: amplitude ratios:	0 — 20 cps, flat to 1%; 0 — 40 cps, flat to 5%
diff. balance:	0 — 20 cps, within 1%
Dimensions:	2.63" high, 2.75" dia (67 x 70 mm)
Weight:	net 1 lb (0.45 kg), shipping 2 lbs (0.9 kg)
Price:	Sanborn 270, with 8-ft cable/adptr/conn, $295

SOLID-STATE DEVICES

Components from HP Associates — diodes, photon-coupled devices

Step recovery diodes

Step recovery diodes offer the advantages of high-order, efficient, single-stage frequency multiplication and pulse sharpening to provide picosecond rise time.

High-order, efficient, single-stage harmonic generation is now possible with extremely simple circuitry, using step recovery diodes. The traditional varactor multistage chain problems resulting from the use of idlers are eliminated. The step recovery diode allows highly efficient generation of milliwatts of power at frequencies to X-band. It also allows an exceptionally low-noise, stable signal source, through using a crystal oscillator as a driving source. Typical results include the generation of hundreds of milliwatts at S-band to tens of milliwatts at X-band.

Step recovery diodes, while conducting in the forward direction, store charge. When the applied voltage is reversed, the diode conducts for a brief period in the reverse direction, until the stored charge is removed, and then abruptly ceases conduction. This is shown in Figure 1, with the very rich harmonic content of the picosecond transition shown in Figure 2.

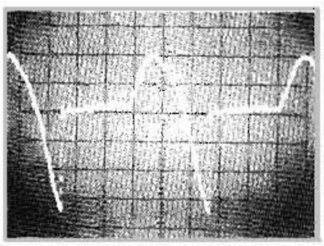


Figure 1.

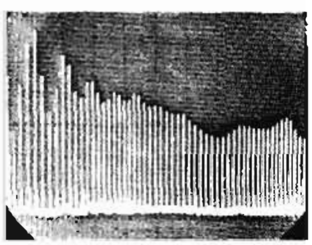


Figure 2.

Typical device specifications

Characteristic	Lifetime	Transition time	Capacitance	Breakdown voltage	Leakage current	Forward current	Inductance	Price 1-99 100-999
hpa 0112								
Min.	50			35		150		
Typ.		200					4.0	$18.75
Max.	130	300	3.0		50			$14
hpa 0114								
Min.	125			35		200		
Typ.		600					4.0	$18.75
Max.	300	750	10		50			$14
hpa 0251								
Min.	10		1.0	15		25		
Typ.		100					0.5	$75
Max.	60	150	1.6		10			$50
hpa 0253								
Min.	10		0.5	25		25		
Typ.		100					0.5	$125
Max.	60	150	1.1		10			$85
Units	nsec	psec	pf	v	na	ma	nh	

PIN diodes

The advantages of a new method of modulating/switching microwave signals and improved stability and reliability through surface passivation are offered by PIN diodes.

These devices make possible a new method of modulating microwave signals (Figure 3). When placed across a transmission line, the device acts as an absorption-type attenuator and allows sine-wave, square-wave and pulse modulation with no frequency-pulling of the signal source.

Turn-on times of less than 20 nsec for an on-off ratio of greater than 30 db are possible. Planar passivation insures long-term stability and reliability. The hpa PIN diodes are specially useful where the lowest possible residual series resistance and junction capacitances are required for high on-to-off switching ratios.

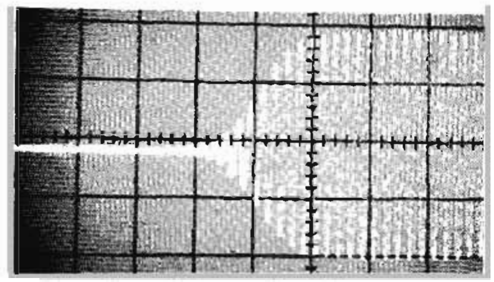


Figure 3. This oscillograph shows a 1 gc 100 mv rf carrier modulated by PIN diodes. It is shown turning on in less than 20 nsec. Sweep speed is 5 nsec/cm.

	hpa 3001	hpa 3002
Minority carrier lifetime, τ	100 nsec min.	100 nsec
Breakdown voltage, BV_R at $I_R = -10\ \mu a$	150 v min.	200 v
Capacitance, C at $V_R = -50$ V	0.25 pf max.	0.30 pf
Forward current, I_F at $V_R = 1$ V	100 ma min.	150 ma
Residual resistance, R_S	2.5 Ω max.	2.5Ω
Package	small glass	small glass
Price:	1-99 $15 100-999 $10	$17.50 $11.75

Microwave switch/variable attenuator

A 500 mc to 12.4 gc frequency range and high isolation, extremely low insertion loss are features of the microwave switch/variable attenuator.

The hpa 3501 Microwave Switch is ideal for such applications as ECM receiver switching and low-power antenna switching in phased arrays. Completely solid state, this single-pole, single-throw switch features a switching speed of 300 nsec open to closed, 100 nsec closed to open. As a variable attenuator the hpa 3501 can be used for power leveling and signal modulation applications. Size is 1-1/16" x 1" x ¾" (27 x 25 x 19 mm). Price: $275.

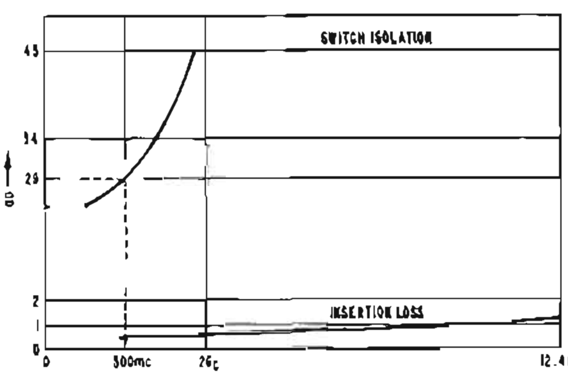


Figure 4. Microwave characteristics of hpa 3501.

Microwave mixer diodes

Offered by the microwave mixer diodes are the advantages of improved receiver sensitivity through lower noise characteristic and higher reliability and wider dynamic range.

These solid-state devices offer improvements in lower noise figure, higher reliability and wider dynamic range over normal microwave diodes (Figure 5). Conversion loss and noise figure at S-band are 1 to 2 db lower than corresponding parameters of the best available microwave diodes. Wide dynamic range is achieved because conversion loss and noise figure are relatively insensitive to local oscillator power variations over the range of 0.5 to 50 milliwatts. Product uniformity for both noise and conversion loss results from controlled junction surface and is extremely tight. This also results in the ability to accurately correlate microwave mixer performance with dc forward current measurements. For the first time, mixer performance can be predicted and desired performance easily selected.

Specifications, hpa 2150

Test frequency: 2000 mc.
Conversion loss L_0: 6 db max. (IF impedance, 100 ohms; RF load impedance, 50 ohms).
Output noise ratio, t: 1 max.
Local oscillator drive power, P_0: -1 to ± 5 dbm (zero dc bias); -10 to ± 20 dbm (20 μa dc bias).
IF impedance: 50 ohm minimum, 200 ohm maximum (impedance controllable by local oscillator drive power without degradation of noise).
RF impedance: 1.5 max. (vswr).
Forward current, IF: 50 ma max., $V_f = 1$ volt.
Capacitance, C_0: 1 pf max., f = 1 mc, $V_R = 0$.
Breakdown voltage, B_{VR}: 5 volts minimum.
Price: 1-99, $22; 100-999, $14.70.

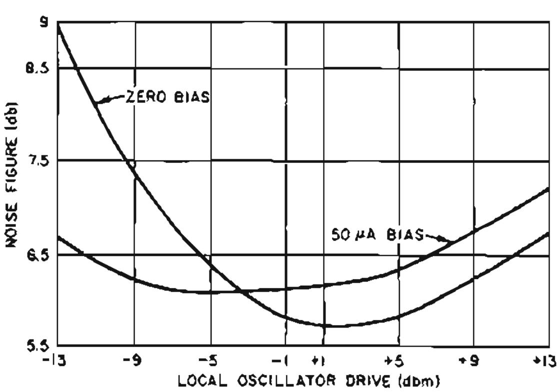


Figure 5. Microwave characteristics of hpa 2150 at 2 gc.

Opto-electronic devices

A new family of optoelectronic components has been developed that allows highly efficient circuit coupling with no electrical contact. These devices use photons as the signal carrier and employ a fiber optic light pipe to couple the signal, with the photon stream proportional to the signal current. Input and output circuits are separate, and the resistance between the light source and detector can exceed 10^{13} ohms.

Individual units also are available which use a fiber optic light pipe to couple the signal from/to the semiconductor chip to a 0.02 inch diameter circle on the surface of the glass. The configuration minimizes the need for external lenses, thereby providing great flexibility to the designer. The new components are intended for use as a fast strobe in the photographic and semiconductor industry, ultra-fast laser detectors, opto-mechanical couplers, displacement sensors, as well as card and tape readers.

hpa 4104 Gallium Arsenide Infrared Sources, $75.
hpa 4201 PIN Photodiodes, $55.
hpa 4202 Phototransistors, $125.
hpa 4301 Wideband Photon-Coupled Isolators, $145.
hpa 4302 Photon-Coupled Amplifiers, $250.

Hot carrier diodes

Hot carrier diodes feature improved resolution in high-speed sampling networks and lower noise uhf mixer and detector.

These diodes utilize a closely controlled metal semiconductor junction which provides virtual elimination of charge storage. The result is extremely fast turn-on and turn-off times ($\tau < 100$ psec) with excellent diode forward and reverse characteristics. This process results in lower noise characteristics and wider dynamic range (conversion loss and noise figure are relatively insensitive to local oscillator power variations over the range of 0.5 mw to 20 mw). Especially useful for mixer and detector applications to improve receiver sensitivity. Improved resolution in ultra-high speed sampling and switching networks is possible by combining the picosecond lifetimes, low capacitance and excellent forward to reverse characteristics of the device.

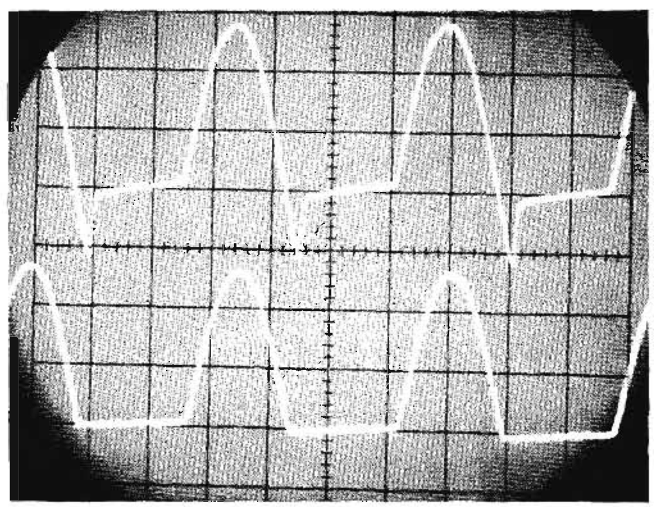


Figure 6. Comparison of recovery time with a conventional high speed 1 nsec switching diode (upper trace). Sweep speed, 10 nsec/cm; vertical sensitivity, 20 ma/cm; applied signal, 30 mc sine wave.

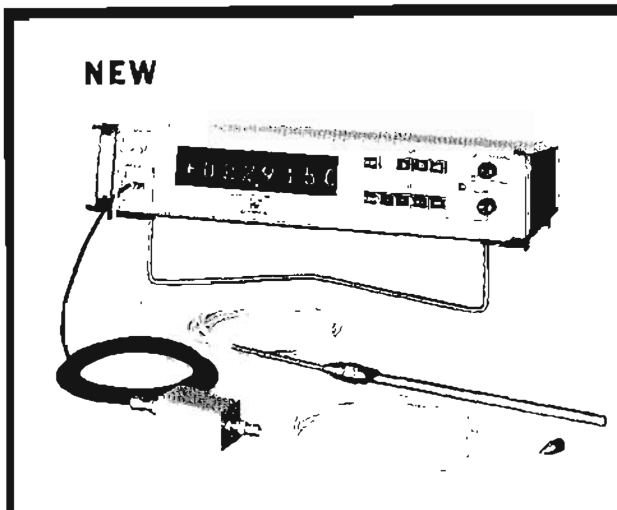
Typical device specifications

Characteristic	Forward current I_F	Forward current I_F	Breakdown voltage B_V	Leakage current I_R	Capacitance C_0	Effective minority carrier lifetime* τ (PS)	Price 1 to 99 / 100 to 999
hpa 2201 Min. / Max.	50	1	30	300	1	200	$9.60 each / $6.40 each
hpa 2202 Min. / Max.	50	1	20	500	1	200	$9.30 each / $6.20 each
hpa 2203 Min. / Max.	50	1	20	500	1.2	200	$8.70 each / $5.80 each
Units	ma	μa	v	na	pf	ps	
Test conditions	$V_F = 1$ v	$V_F = 0.4$ v	$I_R = 10$ μa	$V_R = 3$ v	$V_R = 0$		

* These diodes are too fast to measure in conventional circuits utilizing standard reverse recovery time measurements. Therefore, the effective minority carrier lifetime is specified as τ instead of T_{rr}. Devices are hermetically sealed in a miniature glass package 0.160" long, 0.070" in diameter, color coded.

DY-2800A, DY-2801A QUARTZ THERMOMETERS

Accurate, high-resolution temperature measurements with readout directly in degrees C or F



DY-2801A with DY-2850B and C Probes, DY-2830 Oscillator.

Operation of the DY-2800A and DY-2801A Quartz Thermometers is based on a new quartz crystal resonator which has a precisely linear frequency-to-temperature relationship. This frequency is measured digitally, using conventional electronic counter techniques.

The temperature range of the quartz thermometer is —40 to +230°C. Accuracy is equal to that previously found in high-quality platinum resistance thermometers, yet the instruments possess advantages common to digital devices: easy-to-read display directly in degrees C or F with simultaneous recorder electrical outputs. No bridge balancing is required, nor is reference to temperature conversion tables or curves.

The input has high immunity to electrical noise and cable resistance effects; sensing probes can be placed up to 1000 feet from the measuring instrument with full integrity of data; no reference junctions are required, and scanning devices are available to time-share multiple sensing probes. Two models are available. The DY-2800A is equipped with one probe, measures over a fixed sample time and provides a 4-digit readout (optional 5) and recording output. Resolution is 0.1°C or F (optionally 0.01°).

The DY-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. Signal polarity indication is provided. The 2801A includes the capability for operation as a 300 kc electronic counter.

Specifications, DY-2800A, DY-2801A

Temperature range: —40 to +230°C (—40 to +450°F).

Accuracy: determined by linearity and short-term stability.

Linearity (absolute): better than ±0.15°C (0.27°F) from —40 to +230°C, referred to straight line through 0 and 200°C.

Stability: short term: max. variation at constant temperature, <±0.0001°C (0.0002°F); long term: zero drift <±0.01°C (0.02°F) at constant probe temperature for 30 days; temperature cycling: from —40 to +230°C, reading at 0°C will not change by more than ±0.05°C (0.09°F); instrument ambient temperature: reading changes <0.001°C per °C change in ambient temperature 0 to 55°C.

Response time: response to step function of temperature, measured by inserting probe into water at dissimilar temperature flowing at 2 ft./sec: 63.2% of final value in <1 sec, 99% of final value in <4.6 sec, 99.9% of final value in <6.9 sec; figures apply to both DY-2850B and C probes.

Self-heating: <10 μw; contributes <0.01°C error.

Sample rate: interval between readings, adjusted at front panel from approximately 0.2 to 5 sec.

Display: DY-2800A: 4-digit in-line readout (optional 5-digit), decimal point and °C or °F; DY-2801A: 6-digit in-line readout, decimal point, °C or °F, and polarity indication.

Digital recorder output: BCD, 4-2'-2-1, positive-true, for each digit, decimal point and polarity; compatible with hp 562A Digital Recorder (see page 76) and Dymec couplers (see page 83).

External programming: measurement initiation, circuit closure to ground; (DY-2801A only) probe selection, T_1, T_2, or T_1-T_2 and resolution, 0.01°, 0.001° and 0.0001° may be selected by external circuit closures to ground.

Counter operation (DY-2801A only): frequency range, 2 cps to 300 kc; resolution 10, 1 and 0.1 cps; sensitivity, 0.1 to 10 v rms; input impedance, 1 M, 50 pf shunt; gate time, 0.1, 1 and 10 sec.

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

Power: 115 or 230 v ±10%, 50 to 60 cps; DY-2800A, 20 w; DY-2801A, 30 w.

Dimensions: 3½"high, 16¾" wide, 16-5/16" deep behind front panel (88 x 426 x 414 mm); adapter furnished for 19" rack mounting.

Weight: net 19 lbs (8,6 kg); shipping 24 lbs (10,9 kg).

Price: DY-2800A, with one Temperature Sensor (DY-2850B or C), $2250; DY-2801A, with two temperature sensors, $3250.

Options: Polarity indication for DY-2800A (standard on DY-2801A), add $125; analog output for strip-chart recorder, add $150; 5-digit readout for DY-2800A, add $150.

DY-2850B,C Temperature Probes

Probe environment: Measurand, gases and liquids non-reactive with the following materials: DY-2850B,C; 304 stainless steel, epoxy; temperature, —50 to —250°C (—60 to +480°F); pressure, 3000 psi max.; shock, to 10,000 g; vibration: to 1000 g at 1000 cps.

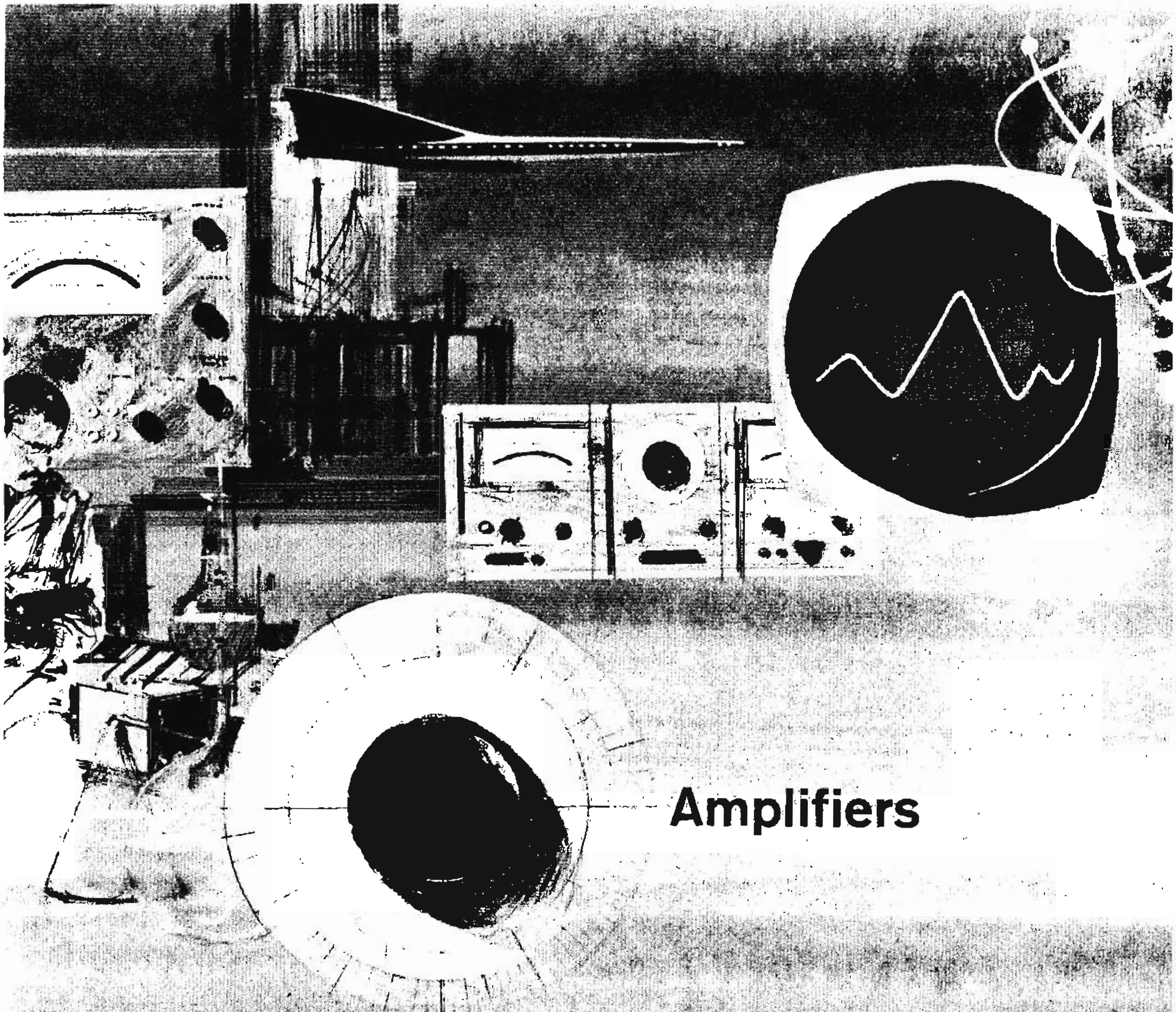
Dimensions: DY-2850B: tubular, nominally 0.375" OD (9,5 mm): standard insertion lengths of 2" and 6", special lengths to 24" at $50 extra; 9/16" hex mounting collar with ¼" NPT; attaches to sensor oscillator by 12' long coax cable in flexible full length 302 S.S. sheath. Mounting glands and thermowells available; special probes made to order. DY-2850C: tubular, nominally 0.375" OD by 1" long (9,5 x 25,4 mm); attached to oscillator by 12' long, 0.110" dia. Teflon covered coax cable.

Weight (includes cable): DY-2850B, net 10 oz (0,3 kg); shipping 2 lbs (1 kg); DY-2850C, net 3 oz (90 g); shipping 1 lb (0,5 kg).

DY-2830A Sensor Oscillator

Environment: ambient temperatures from —20 to +70°C (—4 to +158°F), watertight case.

Dimensions: 3" long, less connectors each end, 1-3/16" square (76,2 x 30 mm).



Amplifiers

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 signal sources from other circuits. In both cases, the amplifier supplies power under the control of the input signal and supplies that power to the output as increased voltage and/or as increased current.

No single amplifier has the bandwidth, gain, noise figure, stability and output capability required for every conceivable situation. Hewlett-Packard amplifiers are designed with the maximum number of applications in mind, while minimizing cost; specialized designs are offered where necessary, as in carrier amplifiers for 2400 cycle carrier transducers, and logarithmic amplifiers.

For discussion purposes, the hp amplifiers are divided into two groups: (1) ac amplifiers and (2) dc amplifiers. Actually, all dc amplifiers have some ac response; but they are classified separately due to the special techniques required to obtain stable dc amplification.

AC amplifiers

AC amplifiers are designed for applications requiring flat frequency response or short rise times. The hp pulse amplifiers (462A, 460BR) preserve pulse rise time and sag, while the hp general-purpose amplifiers (450A, 461A, 465A, 466A and 467A) preserve magnitude and waveform relations.

A simplified schematic diagram of the hp 465A AC Amplifier is shown in Figure 1. This amplifier has a large negative feedback factor, not only to reduce distortion and to broaden the frequency response, but also to insure gain stability.

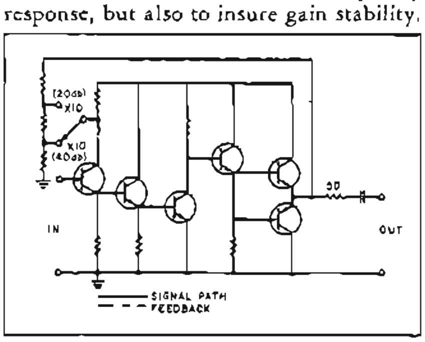


Figure 1. Simplified schematic diagram, hp 465A Amplifier.

A stable amplification factor (gain) is required when an amplifier is used to measure signals, and a large amount of feedback is necessary to reduce the effects of changes in transistor or tube parameters. Feedback lowers the output impedance, so that the amplifier performs as a constant-voltage source that is unaffected by the amount of current drawn by the output load. In the case of the hp 465A, a 50-ohm resistor is in series with the output to provide a true 50-ohm source.

Wideband ac amplifiers

The bandwidth of cascaded amplifiers is inherently limited by internal capacitances, which bypass high-frequency signals. Wide bandwidths have been achieved by use of the distributed amplifier configuration.

The hp Models 461A and 462A Wideband Solid-State Amplifiers are not distributed amplifiers. They use five cascaded stages, plus input and output emitter-followers to match 50-ohm coaxial lines. The 461A frequency-response extends to 150 mc. The 462A is rolled off along a Gaussian curve to preserve the waveshapes of complex waveforms. Rise time of the 462A Amplifier is <4 nsec.

DC amplifiers

High amplification of dc voltage levels requires special considerations. While high feedback stabilizes the gain of an amplifier to the point that the gain is determined almost entirely by the resistors in the feedback network, the dc level of an amplifier is not so easily stabilized.

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 then 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 to convert the dc to ac is to switch the amplifier input alternately to both sides of a transformer, as shown in Figure 2. This periodically inverts the polarity of the signal applied to the amplifier. The switches illustrated may be mechanical, transistor or photo-conductive. 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.

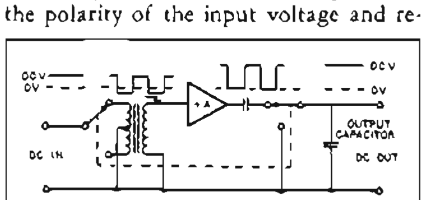


Figure 2. Modulated amplifier.

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 3.

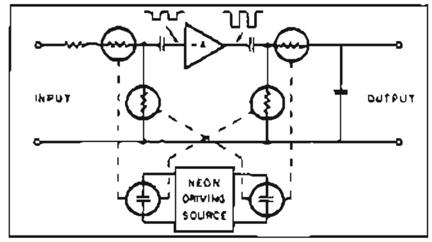


Figure 3. Amplifier with photoconductive modulator.

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.

Wideband dc amplifiers

Use of a modulator in a dc amplifier limits its frequency response. A common modulation frequency is 400 cps for bandwidths approaching 100 cps. Larger bandwidths become difficult to obtain when using the modulation technique, due to the practical concerns over intermodulation of the sampling waveform and the signal.

Another technique used to obtain wideband response with stable dc amplification is shown in Figure 4. The hp 467A Power Amplifier uses two parallel amplifiers, one for the dc and low-frequency components, and one for high-frequency components. Appropriate networks separate the two frequency bands. Feedback is employed to assure uniform gain at all frequencies from dc to 1 mc.

Yet another technique to obtain dc-stable, wideband response is to use a modulator-amplifier to *correct* for dc drift

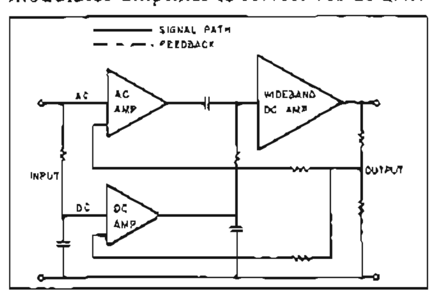


Figure 4. Simplified block diagram, 467A Power Amplifier.

in a wideband direct-coupled amplifier, as in the DY-2460A. The amplified signal is reduced in a divider network by the same amount it was amplified, then compared with the original input signal at the summing point. The *difference,* caused by drift, is amplified through a modulated amplifier, then applied to the direct-coupled amplifier to cancel the drift. (This is sometimes called a "chopper-stabilized" amplifier.)

Differential amplifiers

Differential 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).

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 and is floating. Therefore, differential amplifiers allow a bridge-type transducer to be used with a grounded power supply.

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 and, consequently, may circulate through a loop composed of a transducer, the signal leads and the internal capacitances shown lumped as C_d in Figure 5a. A ground loop, therefore, may inject interference into the signal path. A guard shield (Figure 5), which provides 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.

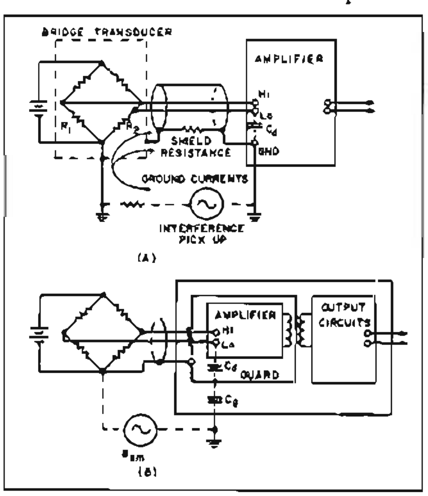


Figure 5. Guard reduces capacitance between signal leads and ground.

DC amplifiers, which use choppers, are able to couple the signal information out of the guard shield by means of transformers. Consequently, 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 voltmeters or other guarded equipment (e.g., Dymec DY-2411A and Sanborn 860-4300) continue the guard shield through the output.

Selecting an amplifier

An amplifier should be selected primarily for the intended application. 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. A differential amplifier is indicated for elimination of ground loops formed between input circuits and equipment connected to the output. The differential amplifier also 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 guarded amplifier is essential.

All of Hewlett-Packard, Dymec* and Sanborn* amplifiers described have been designed with the requirements of a maximum number of applications in mind. Each category of amplifier uses a different method to maximize performance over a specific group of applications while minimizing cost. An hp amplifier is available to meet your specific requirement. Refer to Figures 6 and 7 for relative functions and features. The extensive amplifier line of hp Sanborn Division is not included in the chart; comprising a wide variety of general-purpose and specialized types, it is described on pages 32, 33.

* Divisions of Hewlett-Packard

Model	Gain	Frequency response	Noise	Distortion	Input impedance (ohms)	Output impedance (ohms)	Applications	Refer to page
450A	20 or 40 db	±0.5 db 10 cps to 1 mc, ±1 db 5 cps to 2 mc	40 µv max.	<1%	1 megohm 15 pf	<150	general purpose	29
460AR	20 db	Gaussian curve 3 db point at 120 mc	<10 db	<5%	200	300	fast pulse	31
460BR	15 db	Gaussian curve, 3 db point at 120 mc	<6 db	<5%	200	200	terminal amplifier gives maximum voltage or power output	31
461A	20 or 40 db	±1 db, 1 kc to 150 mc	<40 µv	<5%	50	50	general purpose	30
462A	20 or 40 db	Gaussian curve, rise time <4 nsec	<40 µv	<5%	50	50	fast pulse	30
465A	20 or 40 db	<2 db down, 5cps to 1 mc	<25 µv	<1%	10 megohms 20 pf	50	general purpose	28
466A	20 or 40 db	±0.5db, 10 cps to 1 mc	75 µv	<1%	1 megohm	50	general purpose	29
467A	1, 10	±1% dc to 100 kc, ±10% dc to 1 mc	<5 mv	<0.01%	50 K/ 100 pf	5 milli	10 w peak power amplifier, —20 to +20 dc power supply	28

Figure 6. Hewlett-Packard amplifiers.

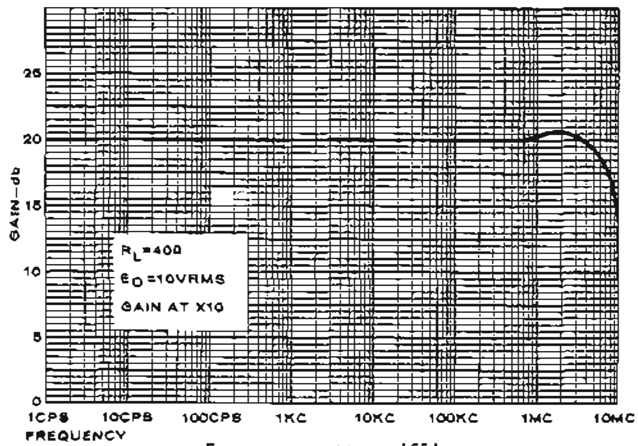
DY-2411A	+1, +10 programmable	dc	±2 µv	not applicable	10^{10}	<1.5	guarded dc data amplifier for DY-2401C DVM	148, 149
DY-2460A	1, 10, 100, 1000	dc	<4 µv	not applicable	10 K with variable gain plug-ins; 10^{10} with buffer	50 milli	general purpose operational	34
DY-2470A	10, 30, 100, 300, 1000	dc	<5 mv	not applicable	10^{10}	0.1	wideband differential	35

Figure 7. Dymec amplifiers.

465A, 467A SOLID-STATE AMPLIFIERS

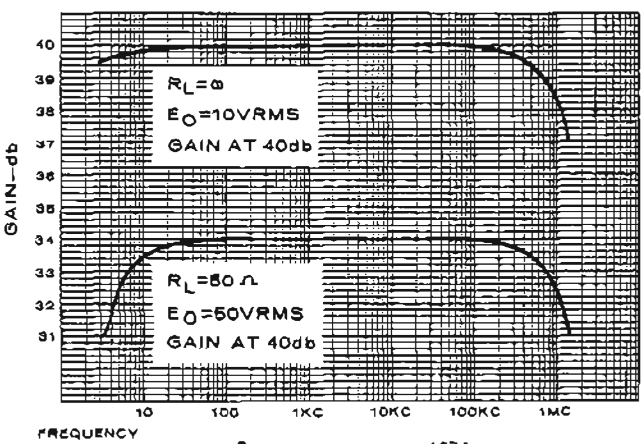
Precision general-purpose amplifiers

The hp Model 465A is general-purpose amplifier, and an ideal 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 cps to 1 megacycle. Either gain may be selected quickly with a switch on the front panel.

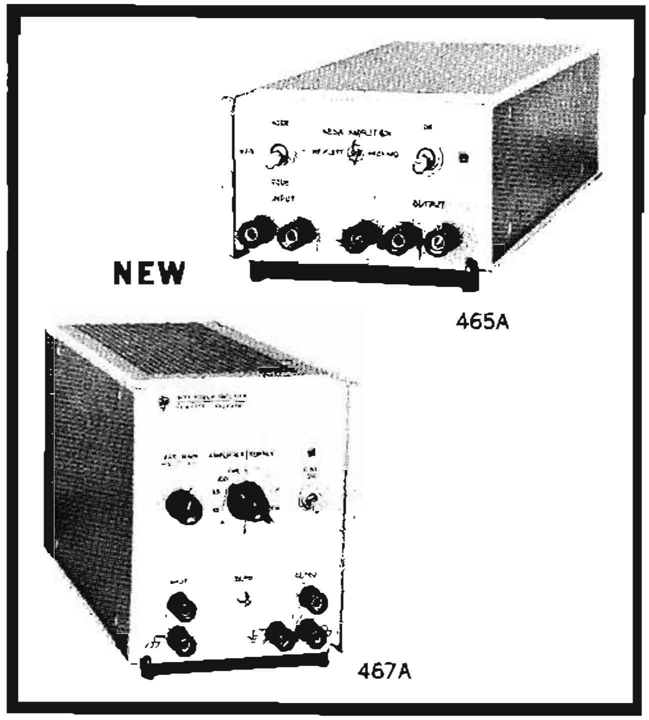


Frequency response, 465A

This solid-state amplifier is ideal for increasing the power output of solid-state oscillators or amplifiers (5×10^8 power gain). 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.



Frequency response, 467A



467A Power Amplifier

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 such as low distortion (<0.01%), low drift and high gain accuracy are obtained with high-tolerance components and multiple feedback techniques. The gain of the amplifier may be varied between one and ten by a front-panel switch which provides fixed gain steps accurate to ±0.3%. A variable gain control enables the user to set the gain anywhere between zero and ten with a resolution of 0.1% of full output. An output greater than ±20 volts peak and 0.5 amp peak is available from dc up to 1 mc. At full output the distortion of the 467A is less than 3% up to 1 mc. The amplifier is a three-terminal device isolated from chassis and may be floated up to 200 volts dc above chassis ground.

A front-panel switch converts the amplifier to a power supply that delivers ±20 volts dc at currents up to 0.5 amp. The output level is controlled by a potentiometer which permits voltages to be set to 0.1% of full output. Full output ranges of ±1, ±2, ±4, ±10 and ±20 volts are selected by a front-panel range switch.

	Tentative specifications, 465A	Specifications, 467A
Voltage gain	20 db (X10) or 40 db (X100), open circuit	fixed steps: X1, X2, X5, X10; variable: 0 to 10, resolution better than 0.1% of output
Gain accuracy	±0.1 db (±1%) at 1000 cps	±0.3%, dc to 10 kc with load of 40 ohms
Frequency response	±0.1 db, 100 cps to 50 kc; <2 db down, 5 cps to 1 mc	±1%, dc to 100 kc; ±10%, dc to 1 mc (fixed steps)
Output	>10 v rms open circuit; >5 v rms into 50 ohms (½ watt)	±20 v peak at 0.5 amp peak
Distortion	1%, 5 cps to 100 kc; 2%, 100 kc to 1 mc	<0.01% at 1 kc; <1% at 100 kc; <3% at 1 mc
Input impedance	10 megohms shunted by less than 20 pf	50 K ohms shunted by <100 pf
Output impedance	50 ohms	5 milliohms in series with 1 μh (front-panel connector only)
Noise	<25 μv rms referred to input (with 1 megohm across input)	<2 mv rms referred to output (input open circuit)
DC power supply		voltage range: ±20 v, ±10 v, ±5 v, ±2 v, ±1 v with continuously variable vernier between ranges; resolution: better than 0.1% output; current: 0.5 amp; line and load regulation: <10 mv change for ±10% line voltage change and 0 to 0.5 amp load change; current limit: approx. 800 ma; capacitor load: 0.01 μf or less does not cause instability; ripple: <5 mv p-p
Temperature range	0 to 50°C	0 to 50°C temperature coefficient: <±.05%/°C or 2 mv/°C, whichever is greater
Power	115 or 230 v ±10% 50 to 1000 cps 10 w at full load	115 or 230 v, ±10% 50 to 1000 cps, 35 w at full load
Dimensions	5⅛" wide, 3-7/16" high, 11" deep (130 x 87 x 279 mm)	5⅛" wide, 6½" high, 11" deep (130 x 165 x 279 mm)
Weight	net 4 lbs (1,8 kg); shipping 6 lbs (2,7 kg)	net 10 lbs (4.5 kg); shipping 16 lbs (5.2 kg)
Price	$190	$575

450A, 466A AMPLIFIERS

Offer 20 or 40 db gain

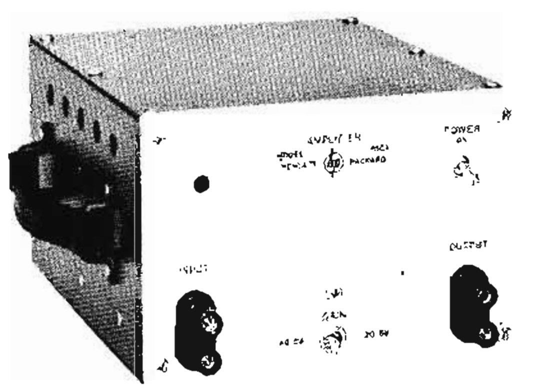
450A Stabilized Amplifier

Model 450A is a general-purpose ac-powered amplifier offering a highly stable 20 or 40 db gain at any frequency from 10 cps to 1 mc. The instrument is resistance-coupled, avoiding peaking or compensating networks. Optimum performance is obtained by clean, straightforward circuitry, plus inverse feedback. Phase shift is negligible; there are no spurious oscillations or resonances, and hum is minimized by a dc filament supply for input amplifier tubes.

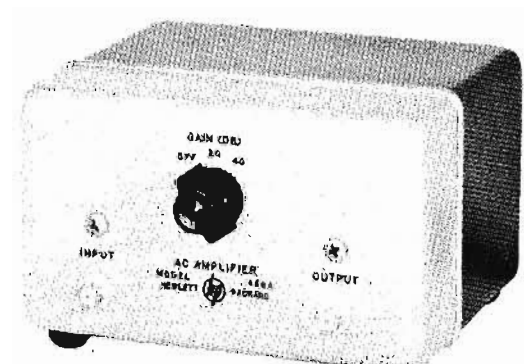
466A AC Amplifier

The hp Model 466A AC Amplifier is a highly stable, low-distortion, wide-range amplifier offering 20 or 40 db gain to increase sensitivity of oscilloscopes or voltmeters by 10 or 100. Flat frequency response renders the instrument appropriate for audio, ultrasonic or low rf measuring.

The 466A is powered by ac line voltage, or by batteries providing approximately 150 hours of hum-free service. The light weight and small size recommend it for field use.



450A



466A

Specifications, 450A

Gain: 20 db (X10) or 40 db (X100) ±0.125 at 1000 cps.

Frequency response: 40 db gain: ±0.5 db, 10 cps to 1 mc; ±1 db, 5 cps to 2 mc; 20 db gain: ±0.5 db, 5 cps to 1 mc; ±1 db, 2 cps to 1.2 mc.

Stability: ±2%, includes line voltage variation 115 or 230 v ±10%.

Impedance: input, 1 megohm, 15 pf shunt; output, less than 150 ohms.

Distortion: less than 1%, 2 cps to 100 kc at maximum output; approximately 2% above 100 kc.

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 volts ±10%, 50 to 1000 cps, 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 14 lbs (6,3 kg) (cabinet); net 11 lbs (5 kg), shipping 24 lbs (10,8 kg) (rack mount).

Price: hp 450A, $160 (cabinet); hp 450AR, $165 (rack mount).

Specifications, 466A

Gain: 20 db (X10) or 40 db (X100) ±0.2 db at 1000 cps.

Frequency response: ±0.5 db, 10 cps to 1 mc down 3 db; or less at 5 cps and 2 mc.

Output voltage: 1.5 v rms across 1500 ohms.

Output current: 1 ma rms maximum.

Noise: 75 μv referred to input, 100,000-ohm source.

Impedance: input, 1 megohm, 25 pf shunt; output, approximately 50 ohms in series with 100 μf.

Distortion: less than 1%, 10 cps to 100 kc; less than 5% to 1 mc.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 1 watt (supply normally furnished); battery operation optional: radio-type mercury batteries, TR234-316649 or equivalent, 3 required (hp #1420-0006); battery life approximately 150 hours.

Dimensions: 6¼" wide, 4" high, 6¼" deep (159 x 102 x 159 mm).

Weight: net 3 lbs (1,4 kg); shipping 7 lbs (3,2 kg).

Price: hp 466A, $165, ac operation.

Option 01: Batteries in lieu of ac supply, less $15.

461A, 462A AMPLIFIERS

40 db wide-frequency range, solid-state amplifiers

The solid-state hp 461A and 462A Amplifiers are ideal wherever wide frequency range, low distortion and portability are desired.

Unique features such as exceptional stability, wide bandwidth and linear amplification are obtained through ultra-high-speed transistors and multiple feedback techniques.

The hp 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 0.5 volt rms.

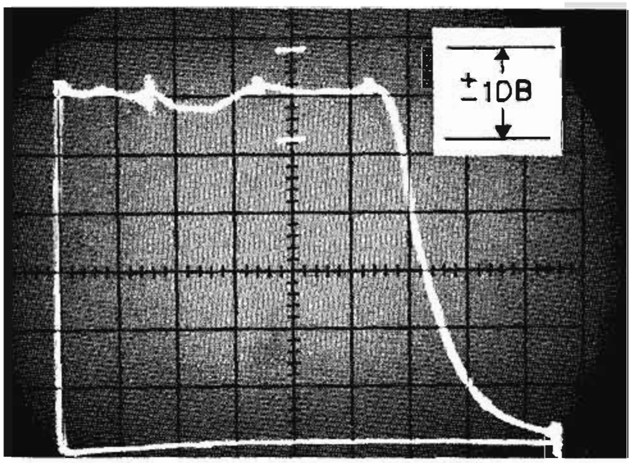


Figure 1. Frequency response curve of hp 461A markers shown from left to right are: 50, 100, 150 and 200 mc. Gain control set in 20 or 40 db position.

The ability of the 462A to amplify very fast pulses can be seen in Figure 2. The upper trace (A), shows a 20 nsec pulse applied to the input of the 462A Amplifier. The lower trace shows the same pulse amplified 40 db, as viewed on the hp 185B Sampling Oscilloscope.

This amplifier gives maximum usefulness for fast-pulse applications, television and vhf work. Used in conjunction with the hp 460 Wideband Amplifiers, the bandwidth of many oscilloscopes can be increased by direct coupling to the cathode-ray tube. The sensitivity of your voltmeter (true rms, average or peak) can be increased 40 db.

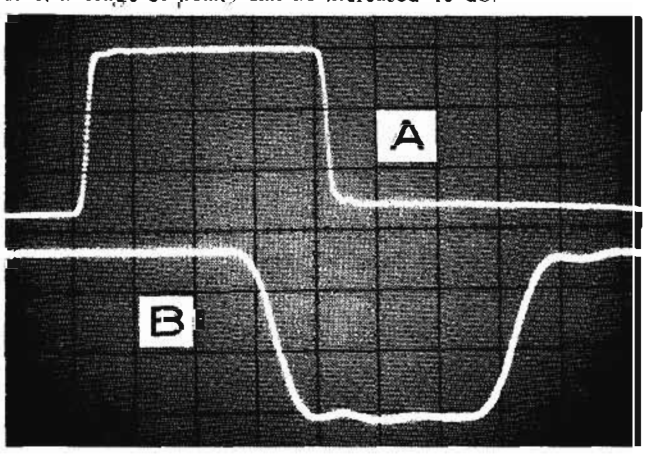


Figure 2. (A) input pulse to hp 462A (5 mv peak to peak), (B) output pulse of hp 462A (500 mv peak to peak); gain control set in 40 db position; sweep speed is 5 nsec/cm.

Specifications, 461A

Frequency range: 1 kc to 150 mc.

Frequency response: ±1 db, 1 kc to 150 mc, when operating into a 50-ohm resistive load (500 kc reference).

Gain at 500 kc: 40 db ±0.5 db; or 20 db ±1 db selected by front-panel switch (inverting).

Input impedance: nominal 50 ohms.

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 μsec for 10 times overload.

Specifications, 462A

Pulse response: leading edge and trailing edge: rise time, less than 4 nanoseconds; overshoot, less than 5%.

Pulse overload recovery: less than 1 μsec for 10 times overload.

Pulse duration for 10% droop: 30 μsec.

Equivalent input noise level: less than 40 μv in 40 db position.

Input impedance: nominal 50 ohms.

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: 3-14/32" high, 5⅛" wide, 11" deep (87 x 130 x 279 mm).

Weight: net 4 lbs (1,8 kg); shipping 6 lbs (2,7 kg).

Power: 115 or 230 volts ±10%, 50 to 1000 cycles, 5 watts.

Connectors: BNC female.

Accessories available: 11038A 50- to 200-Ohm Transformer, $27.50; 11048B 50-Ohm Feed-thru Termination, $10; Combining Cases: 1051, $78, or 1052, $82 (each holds six 461A, 462A amplifiers).

Price: hp 461A, $325; hp 462A, $325.

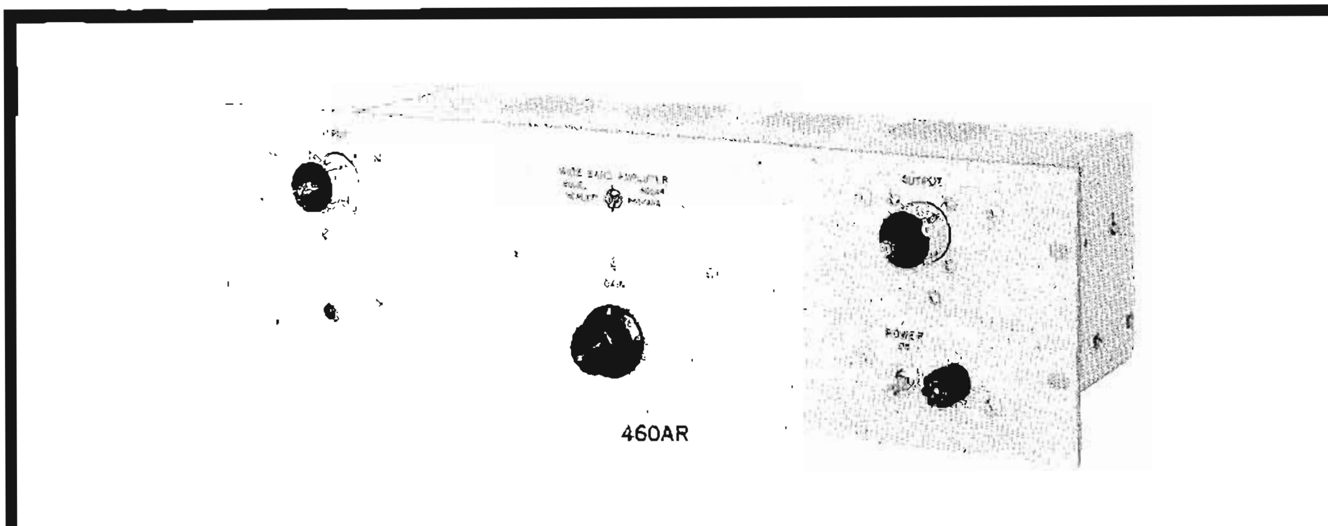
460AR,BR WIDEBAND AMPLIFIERS

Wideband, distortion-free, fast-pulse amplifiers

The hp 460 Amplifiers make it possible for you to obtain at moderate cost true amplification of fast pulses at power levels sufficient to operate scalers, counting meters and cathode-ray tubes.

The 460AR Wideband Amplifier is used fundamentally to provide voltage gain (approx. 20 db). Its companion equipment, hp 460BR, is designed as a *terminal amplifier* to give maximum voltage or power output. The amplifier's short rise time of 3 nsec, combined with zero overshoot, insures distortion-free amplification of pulses faster than 10 nsec. The 460BR cascaded with the 460AR provides linear amplification of 16 volts peak output and, with two 460BR's, pulse amplification of 110 volts open circuit.

This unusual combination gives maximum usefulness for fast-pulse nuclear radiation problems, television, vhf, uhf or shf work. It also means the bandwidth of your standard oscilloscope can be increased to over 100 mc and voltmeter sensitivity multiplied by 10. In cascade or singly, the amplifiers offer further convenience as general-duty, wideband instruments for all types of laboratory problems.



460AR

Specifications, 460AR

Frequency response: high frequency: closely matches Gaussian curve when operating into a 200-ohm resistance load, 3 db point is 120 mc; low frequency: off approx. 3 db at 20 kc when driven by a 200-ohm generator and operated into a 200-ohm load; off approx. 3 db at 100 kc when driven by a 0 source impedance and operated into a 200-ohm load; off approx. 3 db at 3 kc when operating into an open circuit (i.e., crt plates); with 410B and 11011A, ±1 db, 200 kc to 200 mc.

Gain: nominally 20 db into 200-ohm load; control range, 6 db.

Sinusoidal output: approx. 8 v peak open circuit; approx. 5 v peak into a 200-ohm load (<5% distortion when terminated into 200 ohms).

Maximum pulse output: +8 v (+ input), −20 v (− input) unloaded; +3.2 v (+ input), −8 v (− input) loaded.

Impedance: 200 ohms input, 300 ohms output.

Noise figure: less than 10 db.

Delay characteristics: approximately 20 nsec.

Rise time: nominally 3 nsec (10% to 90%); no appreciable overshoot.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 50 watts.

Dimensions: 19" wide, 5-7/32" high, 7" deep (483 x 133 x 178 mm).

Weight: net 12 lbs (5,4 kg); shipping 18 lbs (8 kg).

Price: hp 460AR, $225.

Accessories available

11006A Patch Cord, 200 ohms, 2' long, $27.50.
11007A Patch Cord, 200 ohms, 6' long, $31.50.
11008A Panel Jack for 200-ohm cables, low capacitance, $10.
11009A Cable Plug for 200-ohm systems, $7.50.
11010A 50-ohm Adapter, Type N to 460, 50-ohm termination, $17.50.
11011A Adapter, bayonet sleeve for connecting 410B vtvm to output of 460A amplifiers, $40.
11012A Connector Sleeve joins two 11009A Cable Plugs, $7.50.
11013A Adapter for connecting to 5 XP crt, $11.50.
11015A Adapter, Type N to 460, 200-ohm termination, $17.50.
11016A Adapter, Type N to 460, no termination, $15.
11017A Adapter 410B vtvm to 460, 200-ohm termination, $35.
8120-0014 Cable, 200 ohms, specify length; per foot, $2.25.

Specifications, 460BR

(Same as 460AR except as follows)

Gain: nominally 15 db into 200-ohm load.

Sinusoidal output: approx. 8 v peak, 200-ohm load; 16 v peak, open circuit.

Maximum pulse output: +16 v (− input), −110 v (+ input) unloaded; +8 v (− input), −60 v (+ input) loaded; (+8 v input required for −110 v output); linear: +16 v (− input), −16 v (+ input) unloaded; +8 v (− input), −8 v (+ input) loaded.

Duty cycle: 5%.

Impedance: 200 ohms, input and output.

Delay characteristics: approximately 16 nsec.

Noise figure: less than 6 db.

Price: hp 460BR, $275.

860-4000, -4200, -4300 DATA AMPLIFIERS

For precision wideband, narrow-band or differential amplification

Advantages:

Floating operation or input, output isolation
High gain, low noise
Excellent overload recovery
Linearity to ±0.01% of full scale

860-4000 FIFO Differential DC Amplifier

The Sanborn FIFO (floating input-floating output) Model 860-4000 is a solid-state 10 kc bandwidth dc amplifier designed especially to isolate and amplify high-frequency signals from wideband transducers. Because of its high gain (1000), it is particularly useful for extracting low-level signals from large amounts of common mode noise. A single FIFO used with an input scanner can amplify data from many transducers, or the outputs of any number of FIFO's may be sampled. Alternate Model 860-4000P features grounded output isolated from the input and has an output capability of ±10 volts at ±100 ma. It can drive high-frequency galvanometers. Both models have a high common mode rejection ratio and an exceptional recovery time.

860-4200 Floating Wideband DC Amplifier

Sanborn Model 860-4200 is a fully solid-state 3-terminal potentiometric input dc amplifier featuring a dc to 50 kc bandwidth. The amplifier provides high precision data acquisition from thermocouples, strain gage bridges and other resistance bridge transducers.

860-4300 Narrow-Band Differential DC Amplifier

Model 860-4300 is designed to amplify low-level signals from thermocouples, strain gages and other resistance bridge transducers. This completely solid-state, low noise amplifier successfully combines a floating input which allows measurement of low-level signals even though complicated by ground loops, high gain and zero stability; and a floating output (isolated from input) which eliminates ground loop problems with terminal equipment. Typical outputs for these data amplifiers include digital voltmeters, tape recorders, oscillographs, oscilloscopes and other readout devices.

These amplifiers also are offered in convenient 2- and 8-unit modules for rack mounting, and as an individual amplifier in a portable case. Power supplies are included. Two-unit modules with individual power supplies are available in a 3½" high, 19" wide (89 x 483 mm) panel for rack mounting, or you can mount eight amplifiers in a 7" high, 19" wide (178 x 483 mm) rack with a Sanborn eight-channel power supply in the rear. Sixty-four amplifiers, a blower unit and a master power panel take only 66½" (1789 mm) of front-panel space.

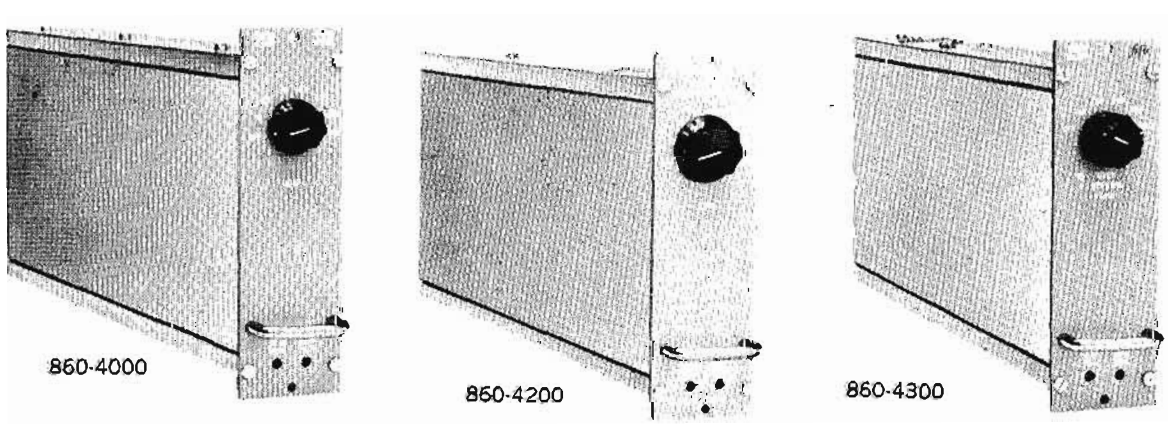
Specifications*, 860-4000

Gain: 1000, 500, 200, 100 and 50 (does not invert phase in standard model) with smooth gain control; stability: ±0.05% at dc for 40 hours, ±0.01% change °C; accuracy: ±0.5% at dc; ±0.1% available on special order; trim: any gain setting can be trimmed to within ±0.03%.

Input: isolated from ground and from output; impedance: 100 megohms min. at dc, 0.001 μf shunt.

Common mode rejection: (1000 ohms in either input lead): 160 db at dc, 120 db at 60 cps, 100 db at 400 cps.

Common mode tolerance: ±300 v dc or peak ac.



Bandwidth: dc to ±5% at 5 kc; −3 db at 10 kc.

Rise time: *for step input, 250 μsec to 99.9% of steady state.*

Output: 860-4000, isolated from input and ground; 860-4000P, grounded output isolated from input; impedance: 860-4000, 60 ohms; 860-4000P, 0.5 ohm or less (power output is at ground potential).

Output capability: 860-4000: ±10 v across 1000-ohm load, ±5% for specified gain; 860-4000P: ±10 v at 100 ma.

Linearity: ±0.1% of full scale at dc; full scale is 10 v.

Noise (referred to input at gain of 1000): 1 μv p-p, dc to 3 cps; 3 μv p-p, dc to 20 cps; 10 μv p-p, dc to 200 cps; 3 μv rms, dc to 1 kc; 5 μv rms, dc to 10 kc; 7 μv rms, dc to 30 kc.

Drift: ±2 μv referred to input, ±0.01% of full scale at the output at a constant ambient temperature for 40 hours.

Temperature coefficient of drift: 860-4000: ±1 μv/°C referred to input, ±0.002% of full scale/°C at the output. 860-4000P: ±1 μv/°C referred to input, ±0.01% of full scale/°C at output.

Overload recovery: for 500% overload, 300 μsec to 1% of full scale output; for 20 v overload, 500 μsec to 10% of full scale output, 1 msec to 1% of full scale output.

Specifications*, 860-4200

Gain: 1000, 500, 200, 100, 50, 20 and 10 (does not invert phase); accuracy: ±0.25% at dc; stability: ±0.01% at dc at constant ambient temperature for 40 hrs; trim: any gain step can be trimmed to at least ±0.04% of correct value.

Input impedance: 100 megohms at dc in parallel with no more than 0.001 μf.

Isolation between input and case: 150 megohms at 60 cps.

Bandwidth: dc to 50 kc within 3 db.

Output impedance: less than 0.2 ohms.

Output capability: ±10 volts and ±100 ma.

Noise: 7μv rms referred to the input, gain 1000.

Drift: ±0.02% of full scale at the output at constant ambient temperature for 40 hours, ±0.002% of full scale at the output/°C.

Non-linearity: no more than ±0.01% of 10 volt output.

Zero trim: ±50 mv at the output.

Specifications*, 860-4300

Gain: 1000, 500, 200, 100, 50, 20 and 10; accuracy: ±0.5% at dc; stability: ±0.03% at dc with constant ambient temperature for 40 hours; ±0.01% change/°C; trim: any gain setting can be trimmed to within ±0.02%, covers ±3% range.

Input: isolated from ground and from output; impedance: 1 megohm minimum, independent of gain.

Common mode rejection: (for 1000 ohms in either input lead) 130 db at 60 cps; 160 db at dc.

Common mode tolerance: 220 v rms.

Bandwidth: dc to ±1% at 30 cps; dc to 3 db down at 100 cps.

Rise time: 20 msec to 0.1% of final value for a step input.

Output: isolated from input and from ground; impedance: 75 ohms.

Output capability: ±5 v at 2.5 ma.

Linearity: ±0.05%; (±0.03% for 0 to +5 v or 0 to −5 v).

Drift: ±2 μv at constant ambient temperature for 40 hours; ±0.2 μv/°C referred to input.

Zero trim: ±30 mv at output.

Overload recovery: 200 msec from ±10 v overload; differential input voltages of ±60 v peak will not damage input circuitry or chopper.

Noise: 3 μv p-p referred to input for gain of 1000 (wideband).

Ripple: (peak, due to signal) 0.04% of signal.

General specifications, all models

Power: 115 v ±10%, 50 to 400 cps; 860-4200, 860-4300 approx. 5 watts; 860-4000, 14 watts.

Dimensions: (all amplifiers): 7" high, 2" wide, 14¾" deep (178 x 51 x 379 mm); 8800-02A, 8800-04A, 868-700 (8-channel rack mounts and power supplies) 7" high, 19" wide, 20-55/64" deep (178 x 483 x 530 mm); 860-200 (2-channel extended-front module): 3½" high, 19" wide, 19⅛" deep (89 x 484 x 486 mm); 860-200A (2-channel flush-front module) same as 860-200 but depth is 20-55/64" (530 mm); 860-1400 (1-channel portable case): 8¾" high, 3¼" wide, 21⅞" long (222 x 83 x 556 mm).

Weight: 860-4000, 860-4000P, 860-4200: net 6 lbs (2,7 kg), shipping 10 lbs (4,5 kg); 860-4300: net 4 lbs (1,8 kg), shipping 6 lbs (2,7 kg); 8800-02A, 8800-04A, 868-700 (8-channel rack mounts and power supplies): net 30 lbs (13,5 kg), shipping 35 lbs (15,8 kg); 860-200, 860-200A (2-channel modules): net 17 lbs (7,7 kg), shipping 20 lbs (9,1 kg); 860-1400 (1-channel portable case): net 5 lbs (2,3 kg), shipping 7 lbs (3,2 kg).

Prices: Sanborn 860-4000, $825 (Sanborn 860-4000P, $900); Sanborn 8800-04A, $700 (8-channel power supply and frame); Sanborn 860-500AF, $275 (1-channel power supply); Sanborn 860-4200, $600: Sanborn 868-700, $360 (8-channel transfer chassis), Sanborn 860-700, $70 (1-channel transfer chassis); Sanborn 860-4300, $425: Sanborn 8800-02A $650 (8-channel power supply); Sanborn 860-500A, $225 (1-channel power supply).

For all amplifiers: Sanborn 860-1400, $100 (1-channel portable case); Sanborn 860-200, $115 (2-channel module, extended front); Sanborn 860-200A, $115 (2-channel module, flush front).

Other versions of 860-4300

Narrower bandwidths, lower output impedance, higher output, lower drift and other added capabilities listed below are readily available in other versions of Model 860-4300. Prices are determined by the exact nature of the added performance requirements and the quantity required. Contact your Hewlett-Packard sales office for complete information.

Output impedance: <0.5 ohms; when used with Model 8800-02A power supply, the low output side of all channels are connected together but not to ground; output connection does not ordinarily introduce objectionable noise; when used with commutators, as in multi-channel data acquisition systems, the output noise introduced will be negligible.

Output capabilities: ±5 v at ±5 ma to ±10 v at ±100 ma.

Dual-output provisions: two 5 ma, or one 5 ma and one 100 ma.

Frequency response: plug-in filters with 12 db/octive roll-off provide cutoff frequencies to 4 cps (smooths out noisy signals).

Linearity: ±0.03% of 5 v output (terminal).

Drift: ±1 μv at constant ambient temperature for 40 hours.

*Specifications based on source impedances to 1000 ohms and ambient temperatures from 15°C to 45°C. Amplifiers will operate in ambients to 60°C. Rate of ambient temperature variation not to exceed 10°C/hour. Amplifiers will operate with higher source impedances; performance degradiation will be in gain accuracy, noise specification and temperature coefficient of gain.

DY-2460A SOLID-STATE OPERATIONAL AMPLIFIER, DY-2461A PLUG-INS

Wideband, high-gain amplifier with plug-in versatility

Advantages:

Photoconductive chopper, all-transistor circuitry for maximum reliability
Fast settling time, rapid overload recovery for systems applications
Low zero drift—less than 1 µv per week
Low noise—less than 4 µv peak to peak

The Dymec solid-state DY-2460A Amplifier, moderately priced for exceptional value, achieves extremely high reliability on low-level measurements through a specially designed photoconductive chopper and all solid-state circuitry. Interchangeable plug-in units contain gain control circuits.

Specifications, DY-2460A

(without plug-in)

Open-loop gain (inverting): (minimum values with load impedance >1 K) 5 x 10^7 at dc; 7 x 10^3 at 40 cps; 1 at 1 mc.

Open-loop input impedance: (minimum values; shunt capacitance 60 pf max.) 1 M at dc; 150 K at 1 kc.

Open-loop output impedance: 10 ohms max., dc to 10 kc; 50 ohms max., 10 kc to 1 mc.

Input noise: (referred to summing point, <100 K to ground) 4 µv p-p max., 0 to 1 cps; 10 µv rms max., 0 to 1 kc.

Zero drift: (referred to summing point, <100 K to ground, 2-hr. warm-up) constant temperature, 1 µv/week max.; temperature coefficient, 0.5 µv/°C max.

Zero adjustment: (referred to summing point) ±5 µv.

DC output capability: voltage, ±10 v; current, ±10 ma, dc to 10 kc (6 db/octave decrease, 10 kc to 1 mc).

Overload: amplifier limiting, ±11 to ±12.5 v output; recovery, equal to rise time plus 20 µsec (5 ma max. to sum point).

Output load: max. capacitive load for stability, 0.1 µf for gain >10; 0.01 µf for gain <10; short circuit does not damage instrument.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 4 watts approx.

Dimensions: 3" high, 5" wide, 17" deep (76 x 130 x 406 mm).

Weight: (includes a plug-in): net 6 lbs (2.7 kg); shipping 12 lbs (5.5 kg).

Accessories available: hp 5060-1938 Combining Case, holds 6 amplifiers, $200; hp 5060-0792 Filler Panel, covers one panel opening in combining case, $3 each; hp 5060-0828 Control Panel Cover, converts combining case to carrying case, $23; hp 5060-0808 Adapter Frame, holds 3 amplifiers, $25.

Options: overload indication, front-panel lamp and output signal, order DY-2460A-M1, $480.

Price: Dymec DY-2460A (less plug-in), $445.

DY-2461A-M1 Data Systems Plug-in

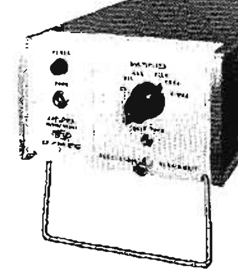
Gain (inverting): fixed settings, 10, 30, 100, 300, 1000 (X0 position shorts output); adjustment, ±2% on each range (front-panel screwdriver control).

Input resistance: 100 K ±0.2%, 50 pf nominal.

Output resistance: 50 milliohms maximum.

Bandwidth and settling time: (signal must be within output capability, see DY-2460A spec).

DC gain accuracy: see table; calibrated on X10 range, temp. range 10 to 50°C.



DY-2460A with DY-2461A-M1 Data Systems Plug-in

Gain	Min. 3 db bandwidth	Max. settling time to 0.1%	Accuracy
X10	25 kc	50 µsec	———
X30	15 kc	75 µsec	±0.5%
X100	5 kc	250 µsec	±0.5%
X300	1.5 kc	750 µsec	±1%
X1000	350 cps	3.5 msec	±1%

Price: Dymec DY-2461A-M1, $85; combined with amplifier, $530.

DY-2461A-M2 Bench-Use Plug-in

Gain (inverting): fixed settings, 1, 10, 100, 1000 (X0 position shorts output); vernier, extends gain each setting, from X1 to X10.

Input resistance: 100 K ±0.2%, 50 pf nominal.

Output resistance: 50 milliohms max.

Bandwidth and settling time: see table below (signal must be within output capability; see DY-2460A specs).

DC gain accuracy: see table; vernier at 1; temp. range 10 to 50°C.

Gain	Min. 3 db bandwidth	Max. settling time to 0.1%	Accuracy
X1	50 kc	25 µsec	±0.5%
X10	25 kc	50 µsec	±0.5%
X100	5 kc	250 µsec	±1%
X1000	350 cps	3.5 msec	±1.5%

Price: Dymec DY-2461A-M2, $125; combined with amplifier, $570.

DY-2461A-M3 Patch Unit Plug-in

Patch panel provides connections for up to 3 inputs and 1 feedback path. Inputs, output, circuit ground and chassis ground available at both front panel and rear connector; summing point available at front panel only; overload signal at rear only. Price: Dymec DY-2461A-M3, $75; combined with amplifier, $520.

DY-2461A-M4 Plus-One Gain Plug-in

Gain: X1; non-inverting.

DC gain accuracy: (includes linearity, long term stability, 10 to 50°C) ±0.005% into 1 K; ±0.0002% into 100 K.

Input resistance: 10^{10} ohms, for relative humidity up to 70% at 40°C.

Output resistance: 50 milliohms maximum.

Price: DY-2641A-M4, $35; combined with amplifier, $480.

DY-2470A DATA AMPLIFIER

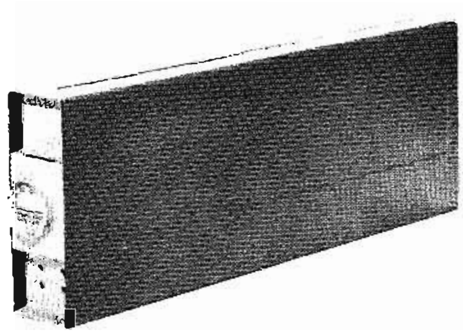
Solid-state, wideband differential amplifier

The DY-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 DY-2470A also applies directly to many general-purpose laboratory uses, both differential and single-ended.

The amplifier with its power supply is packaged in a unique molded dielectric case, so compact that ten instruments fit side-by-side in 5¼" of standard 19" rack space.

AVAILABLE MID-1965



Specifications

(unless noted, specifications hold after 30 min. warm-up at 25°C ambient, 1 K ohm source resistance, any unbalance)

DC gain: fixed steps: X0 (output shorted), X10, X30, X100, X300, X1000; optionally X0, X1, X10, X100, X1000, or other steps between 1 and 1000 available, up to 6 positions.

Gain accuracy (no load): at 25°C, ±0.02% initially ±0.005% per month stability; ±0.001% per °C maximum temperature coefficient.

Vernier adjustment (optional): ±1% trimpot, ±0.01% resolution; or X1 to X3.5 multiplier with dial calibrated to ±3% accuracy.

DC linearity: ±0.01% at gain of 1000, 0 to 10 v output.

Input impedance: 1000 megohms min., shunted by 5 pf max.

Zero stability (at constant 25°C): ±5 μv, ±0.5 na per day referred to input; ±20 μv per day referred to output; ±2 μv/°C, ±0.2 na per °C referred to input; ±10 μv/°C referred to output.

Noise: 0 to 100 cps: 5 μv p-p referred to input; +500 μv p-p referred to output; 1 cps to 50 kc: 5 μv rms, referred to input; +500 μv rms referred to output.

Common mode rejection: 120 db, to 60 cps.

Maximum input signal: ±11 volts, differential + common mode; up to ±20 volts can be handled without damage to instrument.

Output: ±10 volts, 0 to 100 ma; self-limits at approx. 11 volts, 125 ma.

Output impedance: 0.1 ohm +10 μh maximum.

Load capability: 100 ohms or 0.01 μf for full output; amplifier is stable and undamaged by short circuit or any capacitive load.

Slewing: 10^7 volts/sec referred to output, or 10^6 volts/sec referred to input.

Bandwidth: ±1 db, 0 to 10 kc, any gain step; ±3 db 0 to 50 kc any gain step; other fixed 3 db bandwidths between 0 to 50 kc and 0 to 100 cps optionally available.

Settling time: 100 μsec to within 0.01% of final value.

Overload recovery: settling time +100 μsec for inputs up to 10 times full scale; less than 1 msec for inputs up to 20 volts.

Overload signal (optional): output is −18 v without overload; 0 to −1 v with overload, 5 ma drive capability; also, front-panel indication.

Operating conditions: 0 to 55°C ambient temperature range; up to 95% relative humidity at 40°C.

Power: 115 or 230 v ±10%, 50 to 400 cps, approx. 5 w.

Dimensions: 1⅝" wide, 4-27/32" high, 15" deep (41 x 123 x 381 mm).

Weight: net 3 lbs (1,4 kg); shipping 5 lbs (2,3 kg).

Accessories available: combining case: contains up to 10 instruments in 5¼" of standard 19" rack space (mating connectors furnished with amplifier); bench stand: holds one amplifier upright and includes input/output connectors, power switch, pilot light, power cord; mating rear connector with power cord, input/output cables.

Optional modifications: 1% gain trim; 3.5 to 1 gain vernier; overload indicator with output signal; special gain steps.

Price: Dymec DY-2470A, price on request.

WAVE AND DISTORTION ANALYZERS

The choice between a wave analyzer and distortion analyzer depends on the kind of information desired. The wave analyzer is a narrow-band filter which is tuned to select and measure the strength of the individual components of a signal one at a time (Figure 1). (In the frequency range from 10 mc to 40 gc, wave analysis is accomplished with the hp 851A/8551A Spectrum Analyzer; see pages 214 through 217.) In contrast to the frequency selection of wave analyzers, the distortion analyzer is a narrow-band rejection filter which, when properly tuned, removes the fundamental frequency, so that the amplitude of the remaining components can be measured all at once (Figure 2). The distortion analyzer is used for fast, quantitative measurements of total distortion, whereas the wave analyzer provides detailed information concerning each harmonic and intermodulation product.

A signal becomes distorted whenever it passes through a non-linear circuit or network. Percentage distortion is defined as 100 times the ratio of the root mean square sum of the harmonics to the fundamental*.

$$\% \text{ distortion} = \frac{(A_2^2 + A_3^2 + A_4^2 + \ldots)^{1/2} \times 100}{A_1}$$

where A_1 is the rms amplitude of the fundamental and A_2, A_3, A_4, . . . are the amplitudes of the individual harmonics.

The distortion analyzer

The distortion analyzer, typified by the hp 330 and 331 Series, measures total rms distortion and provides a ready determination of percentage distortion. The procedure is fast and easy. The analyzer is first switched to the "Set Level" function, which converts the instrument to a broadband voltmeter.

The instrument's attenuators and amplifier gain then are adjusted to place the indicating meter's pointer on a reference mark. The function switch next is set to "Distortion," which places the rejection filter in the circuit. The operator tunes the filter to eliminate the fundamental frequency of the input signal, as noted by a dip in the meter's reading. The instrument now reads the rms sum of the remaining harmonic components, the attenuator being readjusted to bring the pointer up-scale.

The instrument is calibrated so that the final reading, referenced to the attenuator setting, shows percentage distortion directly or it can show distortion in terms of db units. This distortion, strictly speaking, is presented as the ratio of the sum of the harmonics to the value of the total wave, not to just the fundamental as shown in the equation. In the range where this instrument is used, however, the difference between this ratio and actual percentage distortion as defined previously is small, the difference being less than 0.5% for harmonic distortion as high as 10%.

The wave analyzer

The wave analyzer, as implied previously, is a highly selective voltmeter. In operation, a front-panel control is tuned to the frequency of the harmonic component to be measured, and the harmonic's voltage amplitude is then read directly on the front-panel meter. This information is useful, for instance, in analyses of waveforms obtained from vibration systems, where system resonance can be pinpointed by the presence of larger than normal harmonic components.

Hewlett-Packard wave analyzers are heterodyning tuned voltmeters, which means simply that the input signal is heterodyned to a higher intermediate frequency by an internal local oscillator. Filtering is performed in the IF amplifiers, so that the instrument's passband remains constant regardless of the instrument's tuning. Tuning the local oscillator shifts the various input signal frequency components into the passband of the IF amplifiers. The output of the IF amplifiers is rectified and supplied to the metering circuit.

A Hewlett-Packard designed and built tuning capacitor is used in the oscillator circuits. This capacitor provides a linear rotation versus frequency characteristic, which facilitates tuning, since the distance between frequency increments on the dial is constant throughout the tuning range of the instrument. With this tuning characteristic, close-spaced harmonics are separated as easily at the high end of the tuning range as at the low end.

Two attenuators insure that low-level harmonic content can be read with accuracy. The input attenuator is set according to the amplitude of the input signal, allowing maximum input amplitude without overloading of the linear amplifier and modulator. The second attenuator, in the metering circuit, permits the amplitudes of harmonic components to be read with accuracy throughout a 75 db range.

Automatic frequency control, an important feature of the new hp wave analyzers, greatly facilitates wave analysis. Because of the narrow bandpass of these instruments (less than 7 cps in the Model 302A), harmonic components are likely to drift out of the passband during measurement. The automatic frequency control locks the instrument's tuning to the frequency of the harmonic component, so that measurements are not affected by drift in the source signal.

*See Hewlett-Packard Application Note 15, "Distortion and Intermodulation," for a more complete discussion.

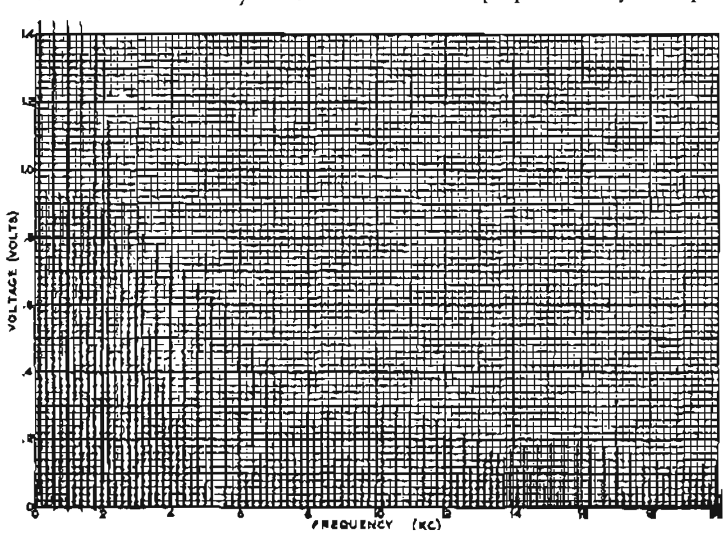


Figure 1. Harmonic analysis of slightly unsymmetrical square wave. Several harmonics were allowed to run off scale so the smaller, higher order harmonics are clearly visible.

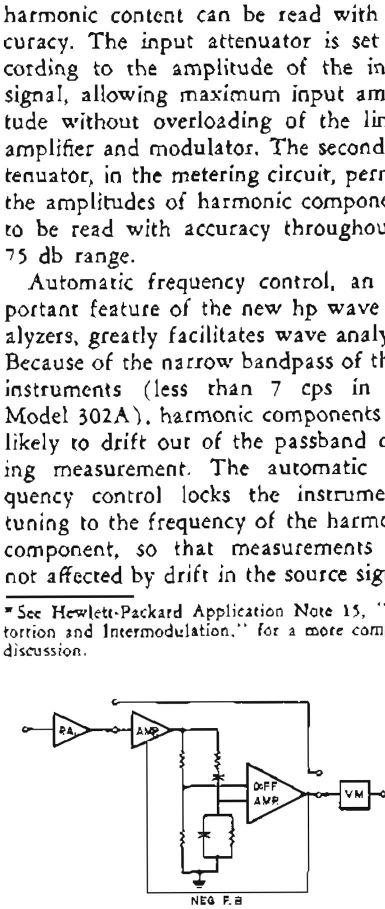
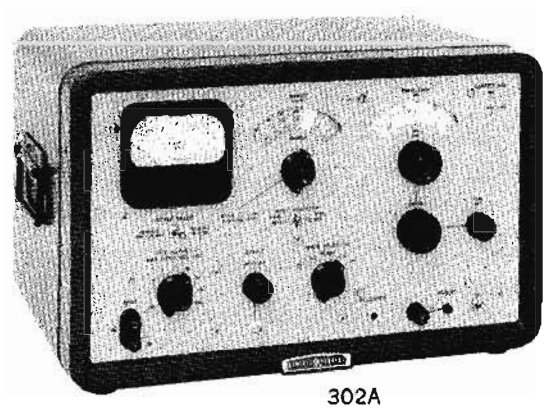


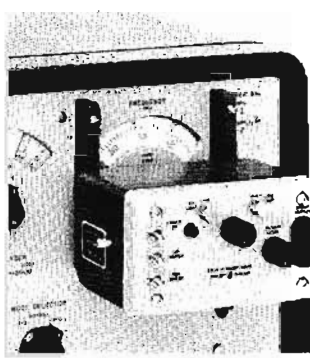
Figure 2. Block diagram of hp 331B Distortion Analyzer.

302A WAVE ANALYZER, 297A SWEEP DRIVE

Highly selective; measures wave components directly, 20 cps to 50 kc



302A



297A mounted on 302A

The hp 302A Wave Analyzer functions as a highly selective tuned voltmeter separating the input signal into its individual components so that each—the fundamental, harmonics and any intermodulation products—may be evaluated separately.

The instrument operates by mixing the input signal with an internal oscillator adjusted to provide a difference frequency of 100 kc. An automatic frequency control circuit maintains a constant difference frequency between the input and oscillator signals. This insures accurate measurements despite frequency drift in the input signal. After the input signal is mixed with a voltage from the internal oscillator, the 100 kc difference signal is passed through a narrow-band crystal filter, amplified and metered.

Frequency restorer

A frequency restorer circuit makes accurate frequency measurements possible at each component frequency of the input wave. The frequency restorer circuit supplies a sinusoidal signal at the frequency of the specific component to which the 302A is tuned. This signal can be measured on an electronic counter or observed on an oscilloscope. The amplitude of the restorer signal is determined by the level of the selected component.

Model 302A also is particularly useful for measuring small signals on noisy systems or transmission lines. When the mode selector is switched to "BFO" the instrument becomes an oscillator and tuned voltmeter automatically tuned by one control to the same or oscillator frequency. The selective tuned voltmeter then discriminates against the noise and measures the desired signal. Speed and accuracy of measuring are enhanced by a linearly calibrated tuning control giving the same "tuning feel" throughout the range.

Specifications, 302A

Frequency range: 20 to 50,000 cps.

Frequency calibration: linear graduation 1 division per 10 cps.

Dial accuracy: $\pm(1\% + 5$ cps).

Voltage range: 30 μv to 300 v full scale, 15 ranges in a 30, 100, 300 sequence; ranges provided by input attenuator and a meter range switch in steps of 1:3 or 10 db; meter range is indicated by a dial mechanically linked with the input attenuator; an absolute-relative switch, in conjunction with a variable 10 db control is provided for adjustment of intermediate values.

Warm-up time: none.

Voltage accuracy: $\pm5\%$ of full scale value.

Residual modulation products and hum voltage: greater than 75 db down.

Intermediate frequency rejection: intermediate frequency present in input signal rejected by at least 75 db.

Selectivity: ±3.5 cycle bandwidth at least 3 db down, ±25 cycle bandwidth at least 50 db down, ±70 cycle bandwidth at least 80 db down; beyond ±70 cycle bandwidth at least 80 db down.

Input impedance: determined by setting of input attenuator: 100,000 ohms on 4 most sensitive ranges; 1 megohm on remaining ranges.

Restored frequency output: 1 volt across 600 ohms at output terminals for full-scale meter deflection; output voltage proportional to meter reading; output level control provided; frequency response $\pm2\%$, 20 to 50,000 cps; output impedance approximately 600 ohms.

Oscillator output: 1 volt across 600 ohms at output terminals (mode selector in BFO); output level control provided; frequency response $\pm2\%$, 20 to 50,000 cps; output impedance approximately 600 ohms.

Recorder output: 1 ma dc into 1500 ohms or less at full-scale meter indication; for grounded or ungrounded recorders.

Automatic frequency control: range of frequency hold-in is ±100 cps minimum.

Power: 115 or 230 v $\pm10\%$, 50 to 1600 cps, 3 w (approx.); terminals are provided for powering instrument from external battery source; battery supply range 28 v to 18 v.

Dimensions: cabinet: 20¾" wide, 12½" high, 14½" deep (527 x 318 x 368 mm); rack mount: 19" wide, 10-15/32" high, 14" deep behind panel (483 x 266 x 356 mm).

Weight: net 43 lbs (19,5 kg), shipping 51 lbs (23 kg) (cabinet); net 35 lbs (16 kg), shipping 51 lbs (23 kg) (rack mount).

Price: hp 302A, $1800 (cabinet); hp 302AR, $1785 (rack mount).

297A Sweep Drive

The 297A is a motor drive unit designed to enhance the usefulness of the hp 302A or 310A Wave Analyzer. 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.

The 297A also may be used to drive other tunable devices through their ranges. An available stand 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 cps/sec.

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 volts 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 volts $\pm10\%$, 60 cps, 12 watts running or stalled.

Price: hp 297A, $350; hp H03-297A (230 v, 50 cps), $375.

310A WAVE ANALYZER

Permits easy analysis of fundamental, harmonics, intermodulation products

The hp 310A High-Frequency Wave Analyzer separates an input signal so that the fundamental, harmonics or intermodulation products can be analyzed. Any signal component between 1 kc and 1.5 mc may be selected for measurement. Additionally, a front-panel mode switch lets the 310A function as an efficient tuned voltmeter for accurately measuring relative or absolute signal levels, as a signal source for selective response measurements and as either an AM receiver or carrier reinsertion oscillator for demodulating single sideband signals.

High sensitivity of 10 μv full scale, combined with the wide dynamic range of 75 db, allows measurements of both weak harmonic components down to 1 μv and strong signals up to 100 v. A switch above the input attenuator can be flipped from Absolute to Relative to permit signal readings at any arbitrary point on the meter for relative-strength measurements of harmonic components.

Three bandwidths

Three bandwidths, selected with a front-panel control, increase the versatility of the 310A. The 200 cps bandwidth discriminates between harmonics for exact identification. The 1 kc bandwidth simplifies calculations of noise power per cycle bandwidth. The 3 kc bandwidth admits carrier channel signals for evaluation and is wide enough to pass intelligible voice signals, but contributes so little noise that even the 10 μv range can be used.

Tuning is linear throughout the 310A's range, with no band switching. Frequency can be read easily from a 4-place digital dial which has a resolution of better than 200 cps over the entire band, with any setting accurate to ±(1% + 300 cps).

Among the features which make the 310A more versatile are AFC, restored frequency output and a beat frequency oscillator. The AFC has a dynamic hold-in range of ±3 kc (at 100 kc) with response rapid enough to lock signals with drift rates in excess of 100 cps/sec. The restored frequency output contains only that part of the input signal to which the instrument is tuned and so may be counted for exact frequency determination. The BFO converts the 310A into a signal source-tuned voltmeter, with a single tuning control, ideally suited for making selective or narrow-band response tests on filter circuits and transmission systems.

Specifications

Frequency range: 1 kc to 1.5 mc (200 cps bandwidth), 5 kc to 1.5 mc (1000 cps bandwidth); 10 kc to 1.5 mc (3000 cps bandwidth).

Frequency accuracy: ±(1% + 300 cps).

Frequency calibration: linear graduation, 1 div per 200 cps.

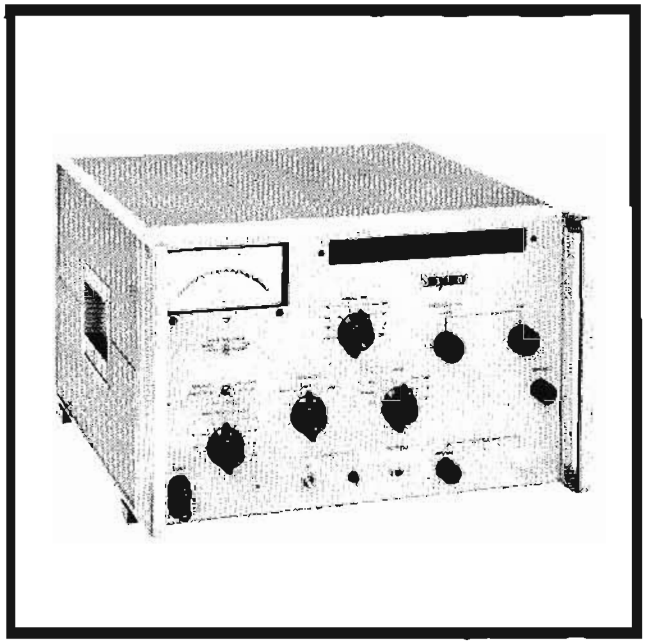
Selectivity: 3 IF bandwidths, 200 cps, 1000 cps and 3000 cps; midpoint of the passband (f_o) is readily distinguished by a rejection region 1 cps wide between the 3 db points.

	200 cps bandwidth	1000 cps bandwidth	3000 cps bandwidth
Rejection*	frequency (cps)	frequency (cps)	frequency (cps)
≥3 db	$f_o \pm 108$	$f_o \pm 540$	$f_o \pm 1550$
≥50 db	$f_o \pm 500$	$f_o \pm 2400$	$f_o \pm 7000$
≥75 db	$f_o \pm 1000$	$f_o \pm 5000$	$f_o \pm 17000$

*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: ±6% of full scale.



Internal calibrator stability: ±1% of full scale.

Dynamic range: greater than 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 K ohms on most sensitive range; 30 K ohms on next range; 100 K ohms on other ranges.

Automatic frequency control: dynamic hold-in range is ±3 kc, minimum, at 100 kc; tracking speed is approximately 100 cps/sec; locks on signals 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 volt (meter at full scale) across 135 ohms, with approximately 30 db of level control provided; output impedance approximately 135 ohms.

BFO output: 0.5 v across 135 ohms with approx. 30 db of level control provided; output impedance approx. 135 ohms.

Recorder output: 1 ma dc into 1500 ohms or less for grounded or ungrounded recorders.

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.

Power: 115 or 230 v ±10%, 50 to 1000 cps; approx. 16 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 44 lbs (21 kg); shipping 51 lbs (22,3 kg)

Accessories available: 11001A Cable Assembly, $5.50; 10503A Cable Assembly, $6.50; 10111A Adapter, $7; 297A Sweep Drive, $350; 11505A Bench Stand for 297A, $25.

Price: hp 310A, $2200.

Options

01. Internal frequency calibrator providing check points every 100 kc; interpolation accuracy (between check points): ±2 kc up to 1.4 mc, ±3 kc between 1.4 and 1.5 mc; add $105.

02. db scale uppermost on meter face and extended to −25 db; add $25.

331A, 332A DISTORTION ANALYZERS

Accurate distortion readings, 5 cps to 600 kc

The hp Model 331A Distortion Analyzer measures total distortion down to 0.1% full scale at any frequency between 5 cps to 600 kc; harmonics are indicated up to 3 mc. Model 331A includes a sensitive wideband solid-state voltmeter which may be used separately for general-purpose voltage and gain measurements. This instrument measures noise and hum as small as 50 microvolts over a wide range of level and frequency.

Distortion analyzer

The distortion analyzer consists of a broadband amplifier, a tunable frequency-selective rejection circuit and a high-impedance voltmeter. The solid-state rejection circuit utilizes a capacitively tuned Wien bridge network which provides greater than 80 db of fundamental rejection. Maximum input sensitivity at 0.1% distortion setting corresponds to 300 μv rms for measuring low-level residuals. Input impedance is one megohm for both voltmeter and distortion operation with a single input terminal being used for both modes of operation.

High-impedance voltmeter

The solid-state voltmeter section of the instrument employs a large amount of feedback to insure stability and flat frequency response from 5 cps to 3 mc. The voltmeter has 13 ranges in 10 db steps. Range is from 300 μv to 300 v rms full scale. The bandwidth is 5 cps to 3 mc for 1 mv to 30 v range, 5 cps to 500 kc for 100 v to 300 v range. The 300 μv range has bandwidth of 20 cps to 500 kc. The average-responding voltmeter is calibrated to the rms value of a sine wave.

The hp Model 332A is similar to Model 331A, but is provided with an amplitude modulation detector.

Specifications, 331A

Distortion measurement range: any fundamental frequency, 5 cps to 600 kc; distortion levels of 0.1% to 100% are measured full scale in 7 ranges.

Distortion measurement accuracy: harmonic frequency measurement accuracy:

Fundamental input less than 30 v

Range	±3%	±6%	±12%
100%-0.3% f.s.	10 cps-1 mc	10 cps-3 mc	
0.1% f.s.	30 cps-300 kc	20 cps-500 kc	10 cps-1 mc

Fundamental input greater than 30 v

Range	±3%	±6%	±12%
100%-0.3% f.s.	10 cps-300 kc	10 cps-500 kc	10 cps-3 mc
0.1% f.s.	30 cps-300 kc	20 cps-500 kc	10 cps-1 mc

Elimination characteristics

Fundamental rejection: > 80 db.

Second harmonic accuracy for a fundamental of: 5 to 20 cps, better than +1 db; 20 cps to 20 kc, better than ±0.6 db; 20 kc to 100 kc, better than −1 db; 100 kc to 300 kc, better than −2 db; 300 kc to 600 kc, better than −3 db.

Distortion introduced by instrument: <0.03% from 5 cps to 200 kc. <0.06% from 200 kc to 600 kc; meter indication is proportional to the average value of a waveform.

Frequency calibration accuracy: better than ±2% from 10 cps to 200 kc, better than −3% from 5 to 10 cps, better than +8% from 200 to 600 kc.

Input impedance: distortion mode: 1 megohm, shunted by less than 60 pf (10 megohms shunted by <10 pf with 10001A Probe); voltmeter mode: 1 megohm, shunted by 30 pf, 1 to 300 v rms, and 1 megohm, shunted by 60 pf. 300 μv to 0.3 v rms.

Input level for distortion measurements: 0.3 v rms for 100% 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 frequency range: 5 cps to 3 mc (300 μv range: 20 cps-500 kc.

Voltmeter accuracy

Range	±2%	±5%
300 μv	30 cps to 300 kc	20 cps to 500 kc
1 mv to 30 v	10 cps to 1 mc	5 cps to 3 mc
100 v to 300 v	10 cps to 300 kc	5 cps to 500 kc

Noise measurements: voltmeter residual noise on the 300 μv range: <25 μv rms terminated in 600 ohms; <30 μv rms terminated with a shielded 100 K resistor.

Monitor terminals: approximately 0.1 v rms output for full-scale meter deflection.

Output impedance: 2 K.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 4 watts; terminals are provided for external battery supply; pos. and neg. voltages between 28 and 50 v are required from each battery.

Weight: net 17¾ lbs (8 kg); shipping 23 lbs (10.4 kg).

Price: hp 331A, $590.

Specifications, 332A

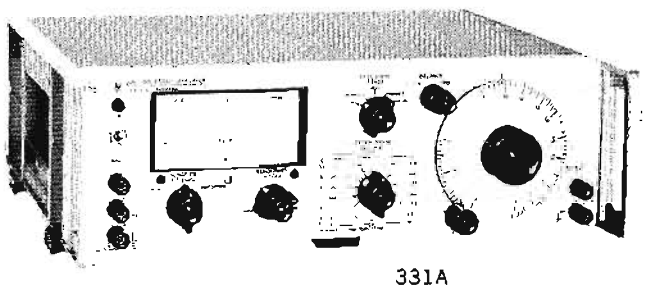
Same as model 331A except as indicated below:

AM detector: high-impedance dc restoring peak detector with semiconductor diode operates from 500 kc to greater than 65 mc; broadband input.

Maximum input: 40 v p-p ac or 40 v peak transient; AM distortion levels lower than 0.3% can be measured on a 3 to 8 v rms carrier modulated 30% in the standard broadcast band; distortion lower than 1% can be measured at the same level of carrier up to 65 mc.

Price: hp 332A, $620.

NEW



331A

330B,C,D DISTORTION ANALYZERS

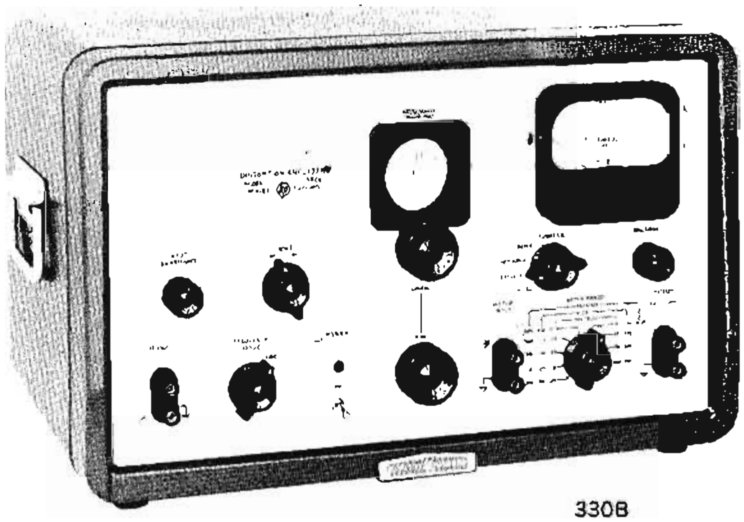
Accurate distortion readings 20 cps to 20,000 cps

The hp 330B Distortion Analyzer is actually four instruments in one. Model 330B measures total distortion at any frequency between 20 cps and 20 kc, measures audio noise of voltages as small as 100 microvolts, measures voltages over a wide range of voltage and frequency and measures audio frequencies with 2% or less error. The 330B includes a sensitive wide-range vtvm which may be used separately for general-purpose voltage and gain measurements.

Many broadcast stations have AM and FM detectors built into the monitors they use. When the detector is part of the station equipment, hp 330C can be used. The 330C is similar to Model 330D, except that the AM detector is omitted.

The hp Model 330D is similar to Model 330B, but is provided with an amplitude-modulation detector, as well as an indicating meter having ballistic characteristics conforming to Federal Communications Commission requirements, so that broadcast station tests and measurements may be easily made. In addition, the frequency response of the vtvm is reduced to eliminate errors caused by pickup of the rf carrier.

In combination with a high-quality audio signal generator, such as hp 206A (page 260) the distortion analyzer measures distortion, noise and audio frequency response of broadcast station equipment as required by the FCC.



330B

Specifications

Distortion measurement range: any fundamental frequency, 20 cps to 20 kc.

Frequency calibration accuracy: ±2% entire range.

Elimination characteristics: fundamental frequency reduced by more than 99.99% (80 db); second harmonic attenuation less than 17% (1.5 db) for fundamental frequencies 20 cps to 5 kc, less than 32% (3 db) for fundamental frequencies 5 to 20 kc.

Accuracy: residual frequencies are measured to within ±3% of full-scale value for distortion levels as low as 0.5%; meter indication proportional to average value of residual components; distortion introduced by instrument less than 0.1%.

Sensitivity: distortion levels of 0.3% are measured full scale; levels of 0.1% readable with good accuracy.

Distortion meter input impedance: approximately 200,000 ohms, 40 pf shunt.

Input level for distortion measurements: at least 1 volt rms.

Voltmeter sensitivity: full-scale sensitivities of 0.03, 0.1, 0.3, 1, 3, 10, 30, 100 and 300 v; 9 ranges spaced exactly 10 db; db scale: −12 db to +2 db, calibrated on zero level = 1 mw in 600 ohms.

Voltmeter frequency range: Model 330B, 10 cps to 100 kc; Models 330C and 330D, 10 cps to 60 kc.

Voltmeter accuracy: for line voltages of nominal value ±10% (104 v to 126 v), 330B within ±3%, 10 cps to 100 kc; 330C,D within ±3%, 10 cps to 20 kc, and ±6%, 10 cps to 60 kc.

Voltmeter input impedance: approx. 1 megohm, 37 pf shunt.

Noise measurement: full-scale reading of 300 microvolts; noise measuring frequency range, 10 cps to 20 kc; satisfactory readings can be made to −75 dbm.

Noise amplifier: 40 db gain ±1 db, 20 cps to 20 kc.

Oscilloscope terminals: maximum gain from AF input to oscilloscope terminals is 75 db with full-scale meter deflection.

Meter movement: Models 330C and 330D: VU ballistic characteristics to meet FCC requirements for AM, FM and tv broadcasting.

AM detector: Model 330D: linear rf detector rectifies the transmitter carrier; input circuit tunable from 500 kc to 60 mc in 5 bands; detector distortion is negligible.

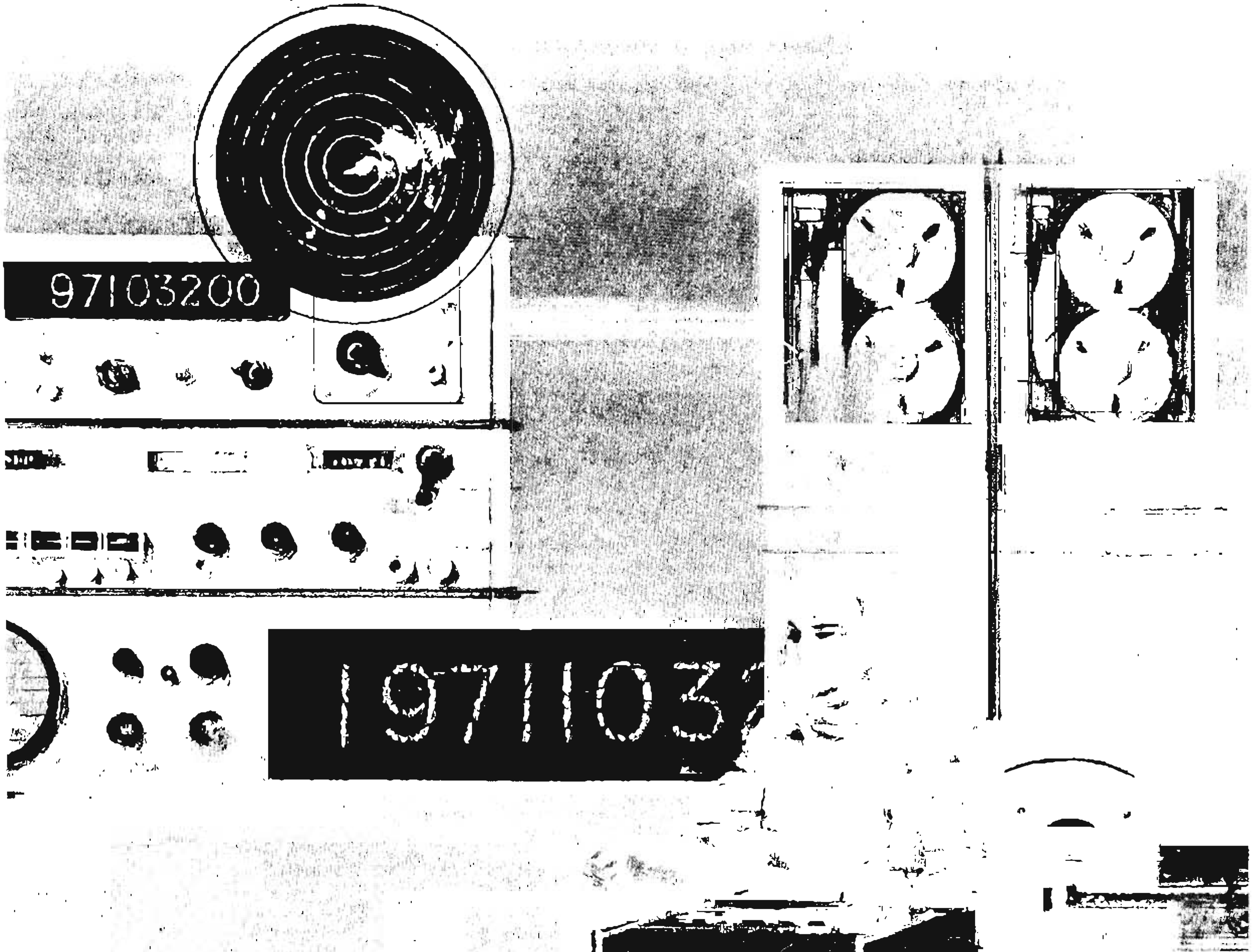
Power: 115 or 230 v ±10%, 50 to 1000 cps, approx. 90 w.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14¼" deep (527 x 552 x 362 mm); rack mount: 19" wide, 10½" high, 13⅝" deep behind panel (483 x 267 x 321 mm).

Weight: net 38 lbs (17,1 kg), shipping 48 lbs (21,6 kg) (cabinet); net 30 lbs (12,5 kg), shipping 42 lbs (19,9 kg) (rack mount).

Accessories available: 11000A Cable Assembly, $4.50; 11001A Cable Assembly, $5.50; 11005A Transformer (for bridging input), $80.

Price: hp 330B, $500 (cabinet); hp 330BR, $485 (rack mount); hp 330C, $525 (cabinet); hp 330CR, $510 (rack mount); hp 330D, $575 (cabinet); hp 330DR, $560 (rack mount).



Counters
Scintillation counting
Related equipment

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 mc Hewlett-Packard Model 524A), more than 12 years ago, hp has developed a broad range of both vacuum tube and solid-state counters with a wide variety of features. These counters and associated equipment can measure frequencies from 0 cycles per second to 40 gc, and time intervals from 10 nanoseconds to more than 100 days. The accuracy of these measurements can be as great as 3 parts in 10^9 per day.

An electronic counter is an instrument for comparing 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 is derived from the counter's internal oscillator. The oscillators in Hewlett-Packard counters are designed and built by hp and are exceptionally stable to ensure accurate measurements. All Hewlett-Packard counters are engineered for maximum reliability, accuracy and ease of operation.

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. The Hewlett-Packard 5245L (50 mc) solid-state counter offers the widest frequency range in a basic counter, the highest accuracy and the greatest flexibility because of several plug-ins available (for special applications). The hp 5211A,B are the least complex electronic counters for simple frequency and period measurements. The 5211A,B have a maximum frequency capability of 300 kc, a 4-digit neon readout, and a 0.1% accurate time base derived from the 60 cps power line. Hewlett-Packard has a wide range of counters between these two extremes with corresponding ranges of maximum frequency capability, accuracy, resolution and flexibility.

With this very complete line of electronic counters Hewlett-Packard also offers many input and output devices for these instruments. Included in the available accessory instruments are: digital recorders for automatic recording of counter measurements, digital clocks which control measurement intervals and supply information for simultaneous recording, digital-to-analog converters for obtaining analog records of digital measurements, and scanners for receiving the outputs from several electronic counters for display into a single recording device. Hewlett-Packard also manufactures magnetic and optical tachometers for rps measurement inputs to low-frequency electronic counters.

Counter operation

The electronic counter has several basic functional sections which can be interconnected in a wide variety of ways for making different types of measurements. Of these, the most important functional sections are: (1) the decade counting assemblies (DCA's) with numerical displays to totalize and display the count; (2) the signal gate, which controls count start and stop with respect to time, and (3) the time base, which supplies the precise increment of time to control the gate for a frequency or pulse train measurement. Other sections include: signal shaping, display control, logic control and binary coded decimal (BCD) output. 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 45.

Totalizing

Electronic counters can be operated in a totalizing mode with the main gate flip-flop controlled by the manual start-stop switch as shown in Figure 1. With the switch in Start, 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.

Frequency measurements

For direct frequency measurements, the input signal is first supplied to a signal shaper which converts the input signal (cw or pulses) to uniform pulses. The output of the shaper is then routed to decade counting assemblies (DCA's) through a gate controlled by the counter's time base as shown in Figure 2. The number of pulses totalized in the DCA's for the selected period of time represents the frequency of the input signal. The frequency counted is displayed on a numerical readout, with a positioned decimal point, and is retained until a new sample is taken. The Sample Rate control determines the display time of the frequency measurement being made and initiates counter reset and the next measurement cycle.

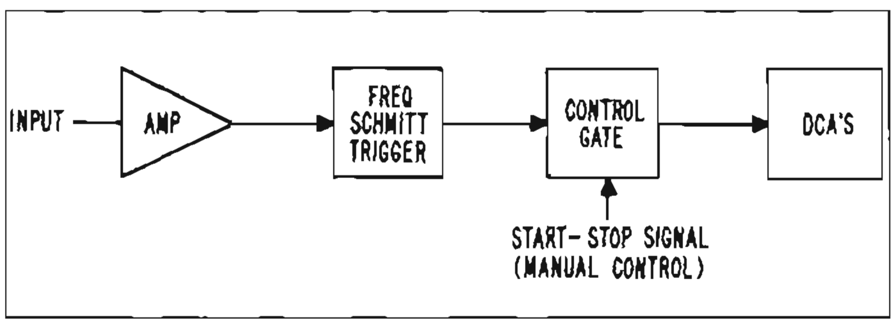


Figure 1. Function switch set to manual Start and Stop to determine interval for totalizing input signal.

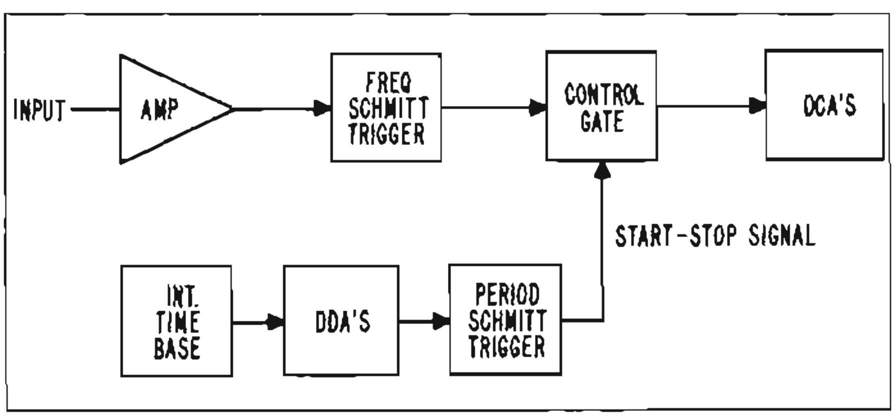


Figure 2. Function switch set to Frequency and gate time selected by time base switch.

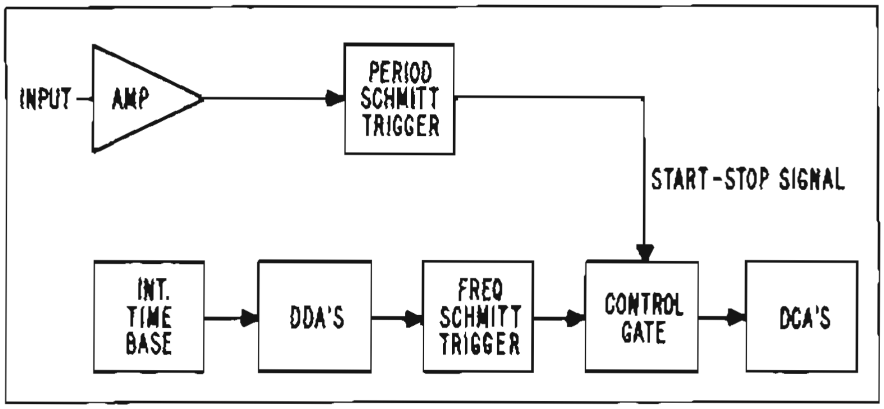


Figure 3. Function switch set to Period and counted frequency selected by time base switch.

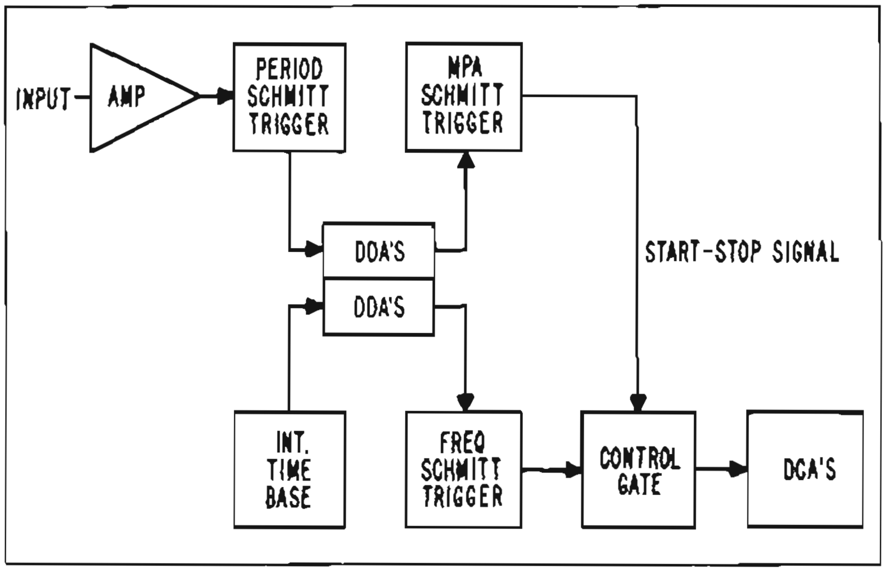


Figure 4. Function switch set to Period Average. Input signal controls gate for counting time base frequency.

The time base selector switch selects the gating interval, positions the decimal point and selects the appropriate measurement units.

Period measurements

Period measurements are made with the counter functions arranged as shown in Figure 3. The unknown input signal controls the 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 as trigger points for opening and closing the gate.

Period measurements allow more accurate measurements of unknown low-frequency signals because of increased resolution. For example, a frequency measurement of 100 cps on the 5245L, with a 10-second gate time will be displayed as 0000.1000 kc. A single period measurement of 100 cps on an hp 5245L with 10 mc as the counted frequency, would be displayed as 0010000.0 μsec. Thus, resolution is increased by a factor of 100. The accuracy here is also affected by the ±1 count ambiguity ± the time base accuracy ± the trigger error. (Accuracy is discussed on Page 45.)

Multiple period averaging

The effect of the ±1 count ambiguity and trigger error can be minimized by multiple period averaging (Figure 4). In the hp 5245L, for example, the function selector switch is ganged to the decade divider assemblies (DDA'S) so the input signal may be scaled in decade steps by factors up to 100,000 to reduce trigger error. The ±1 count ambiguity is also reduced by a factor of 10 for each decade of scaling selected for the input signal. In the low-frequency measurement example above, the counter would display 10000.000 μsec for a 100 period average. (The function 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 lower frequency signal for gate control while the higher frequency signal is counted, as shown in Figure 5. With proper transducers, ratio measurements may be applied to any phenomena 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.

Accuracy is ±1 count ± trigger error. The accuracy may be improved by using the multiple period averaging technique discussed above.

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 corresponding to the desired engineering units. For example: the hp 5214L Preset Counter or the hp 5245L Counter with hp 5264A Preset Plug-in can be set to a gate time of 600 milliseconds to cause an input from a 100-pulse-per-revolution tachometer to be displayed directly in revolutions per minute.

Scaling

The new hp 5245L solid-state counter may be used for scaling (dividing down) inputs by factors of 10, selectable in decade steps. In this mode of operation, the input is routed through the decade dividers with the scaled output available from the rear of the counter.

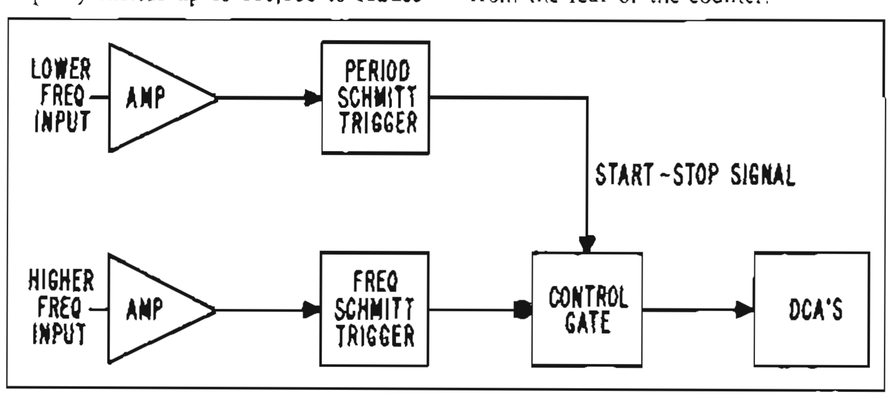


Figure 5. Function switch set to Period and time base switch to Ext. Lower frequency serves as gate control, while higher frequency replaces time base as counted frequency.

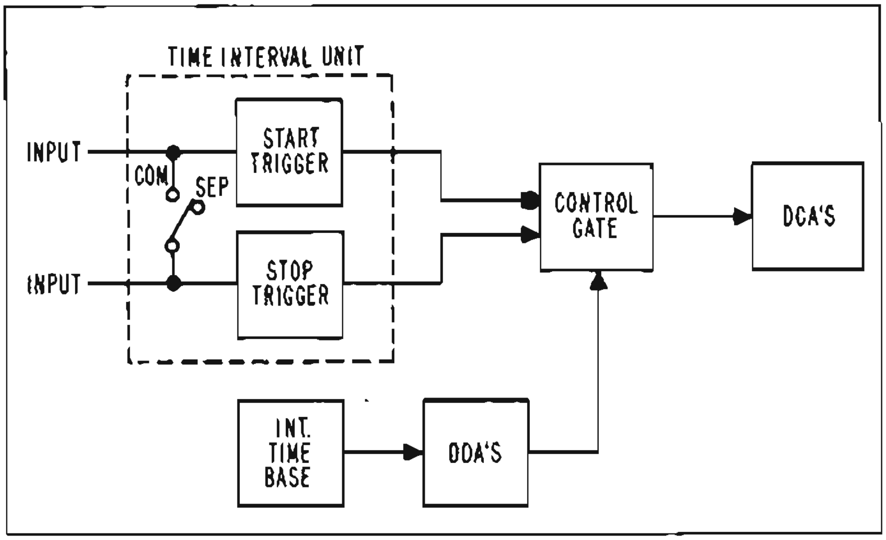


Figure 6. Start and stop signals derived from two sources or from different points of same waveform as selected by Com-Sep switch.

Time interval measurements

Time interval measurements are similar to period measurements, except that the trigger points on the single waveform or waveforms are adjustable. As shown in Figure 6, separate signals may be used as start and stop signals or, by switching the Com-Sep switch to "Com," measurements may be made from one point on a waveform to another point on the same waveform. Triggering polarity, amplitude and slope are selected for each channel independently. The time interval is displayed in units of microseconds, milliseconds or seconds. Accuracy is affected by the same factors which affect period measurements.

Extremely short time intervals (10 nanoseconds to 0.1 second) can be measured accurately with the 5275A Time Interval Counter. This instrument, using a 1 mc external frequency standard, multiplies the 1 mc to 100 mc to obtain 10 nanosecond time increments as the "counted" frequency, which results in exceptionally fine 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

Measurements of frequencies above the normal range of a counter are possible utilizing a series of heterodyne converter plug-in units (see hp 5245L). These plug-ins convert the unknown high frequency to a related frequency which is within the counter's basic range. The counter accuracy is retained, since a harmonic of the time base oscillator frequency is used as the heterodyning signal for the frequency conversion.

The heterodyning signal is mixed with the unknown signal and the difference frequency is fed into the counter for measurement as shown in Figure 7. The frequency converter's tuning control selects the 50 mc harmonic (Figure 7 is for an hp 5254A Frequency Converter) that gives a beat frequency output within the passband of the video amplifier (meter indication in the green). This frequency reading on the counter is then added to the setting on the dial of the converter's tuning control to give the unknown frequency.

Measurements up to 40 gc are pos-

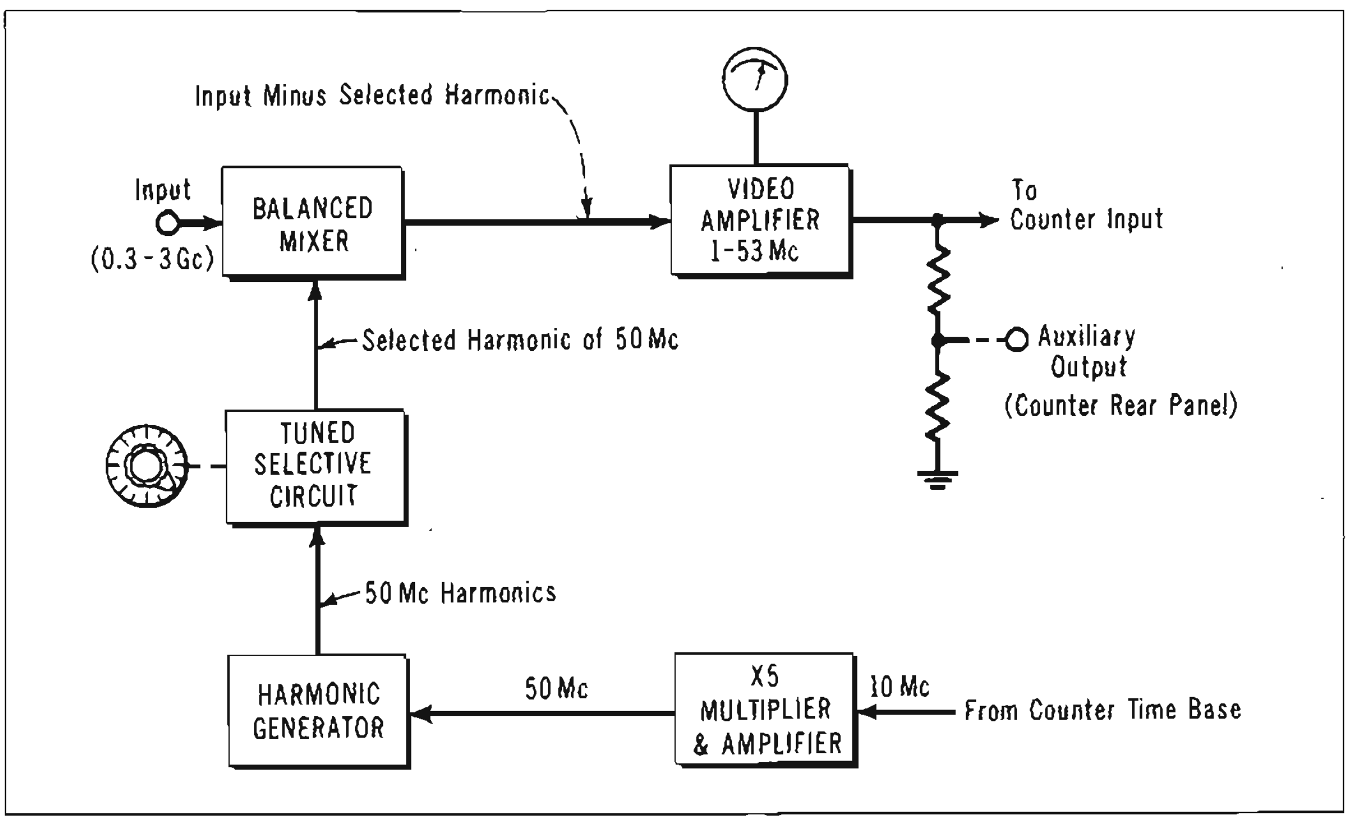


Figure 7. High-frequency measurements. Meter shows when converter is tuned to desired harmonic which generates a difference frequency within counter range.

sible with the addition of a transfer oscillator and related instruments[1] (to 15 gc with DY-2590A and to 40 gc with hp 540B). The DY-2590A operates in the 240 to 390 mc range and generates harmonics to at least 15 gc.

With a DY-2590A, an unknown signal is fed to a crystal mixer within the transfer oscillator, the oscillator is tuned to a submultiple of the measured frequency. A search light goes off when tuning achieves a zero beat (phase lock) between the measured frequency and one of the oscillator's harmonics. The counter, with appropriate plug-in, reads the transfer oscillator's fundamental frequency which, when multiplied by the harmonic number, gives a precise determination of the measured frequency. If the harmonic number is not known, it can be determined by a simple procedure involving a second reading at a higher setting of the oscillator's frequency.

Time-base oscillator accuracy

Hewlett-Packard's long experience in the manufacture of precision frequency standards has resulted in distinctly superior electronic counter time bases. Several innovations in quartz oscillator crystal design and manufacture have resulted from Hewlett-Packard's intensive development program, and hp's oscillator and counter designs have consistently led the field.

The time-base oscillators in hp high-performance counters have stabilities ordinarily found only in oscillators intended for use as frequency standards. As such, these counters (524C,D, 5243L, 5245L) often serve as in-house frequency standards, in addition to performing their assigned measurement tasks. The oscillator of the 5245L, for example, has an aging rate of less than ±3 parts in 10^9 per 24 hours (after 72 hours of continuous operation). A ±10% change in the nominal 115 or 230 volt ac line voltage can vary the basic frequency by no more than ±5 parts in 10^{10}. Ambient temperature affects the frequency by less than ±2 parts in 10^{10} per degree centigrade throughout the range from —20 to +50 degrees centigrade.

The accuracy of precision quartz oscillators is generally expressed by two parameters — long-term stability and short-term stability. The long-term stability (also called crystal aging rate or drift rate) refers to slow changes in average frequency with time due to secular changes in the resonator or other elements of the oscillator. This is usually expressed in fractional parts per unit time such as 3 parts in 10^9 per day. The drift rate of a crystal oscillator is predictable after an initial aging-in period and it generally assumes a linear characteristic. The slope of this line is the long-term drift rate of the oscillator. Various methods exist for determining this drift rate and for calibrating the oscillator to a desired standard. Refer to Application Note 52, "Frequency and Time Standards", which is available from hp upon request. Short-term stability refers to changes in average frequency over a time sufficiently short such that the change in frequency due to long-term effects is negligible. Short-term specifications on a counter's internal time base oscillator indicate the average effect of all noise on the counter's gate time accuracy. Thus, in the hp 5245L with 2 parts in 10^{10} rms for 1-second averaging there is no short-term contribution to the gate error for a frequency measurement.

The attainable accuracy of any electronic counter is limited by the time base oscillator stability, since the time base oscillator supplies the definitive time information for a measurement. The time base must be calibrated periodically, since the drift rate will cause a cumulative deviation in frequency which can result in a measurement error. Figure 8 graphically illustrates the attainable accuracy of the hp 5245L counter. Accuracy versus measured frequency is plotted and crossover points indicate areas below which determination of frequency is better performed by period measurement.

The ±1 count ambiguity is inherent in measurements made with an electronic counter because the gating is not normally coherent with the input signal. It is possible for the gate to open or close while an input pulse is passing through so that this pulse may or may not be included in the final count. The degree to which the ±1 count ambiguity affects measurement accuracy is determined by the factor 1/displayed count.

The accuracy of period measurements is affected by the trigger error (a function of the input signal-to-noise ratio and rise time), as well as being affected by the time base stability and the following formula: percentage error =

$$\pm\left(\frac{1}{f_{tb}/f_x} + 0.003 + \text{L.T.} + \text{S.T.}\right) \times 100,$$

where f_{tb} = time base frequency counted, f_x = sine wave input with 40 db signal-to-noise ratio, 0.003 = trigger error, L.T. = long-term stability of the time base oscillator, and S.T. = short-term stability of the time base oscillator. This total error is reduced by the number of periods averaged when multiple period average operation is selected.

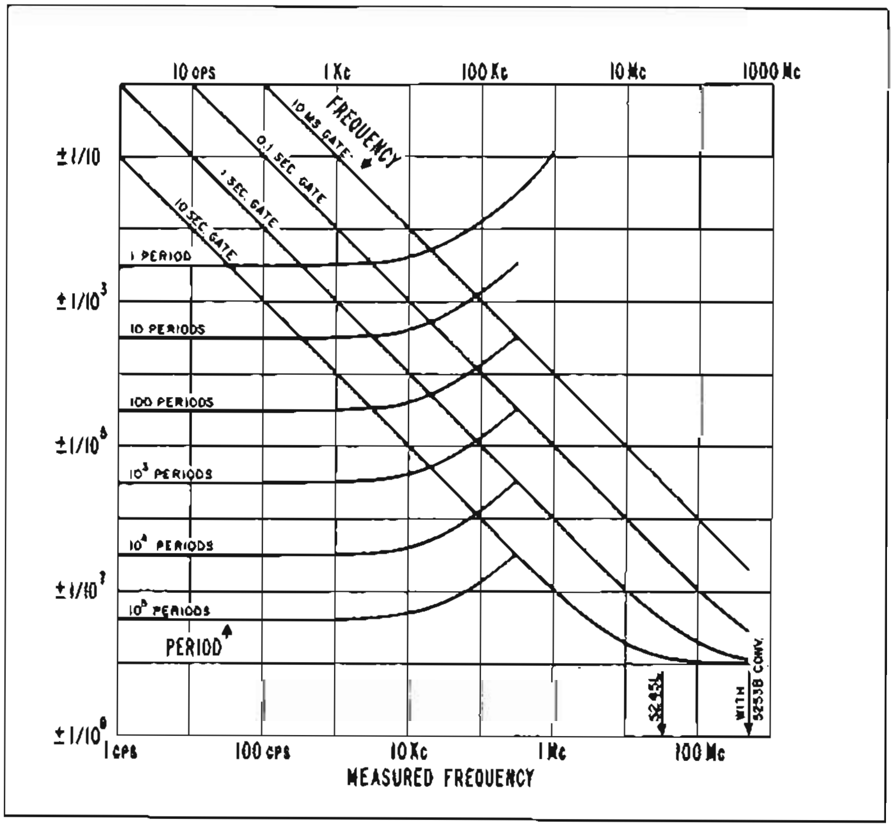


Figure 8. Attainable accuracy of 5245L Counter. Period measurement accuracy based on 10 mc counted frequency. Time base accuracy is 1 part in 10^8.

[1] "Measuring Frequency from VHF up to and above 18 gc with Transfer Oscillator/Counter Techniques," Hewlett-Packard Application Note No. 2.

5245L ELECTRONIC COUNTER

Compact 50 mc counter with 3 parts in 10^9 time base stability

Advantages:

- Time base stability of 3 parts in 10^9 per day
- Measure directly to 3 gc with frequency converter plug-in
- Display storage
- More accurate low-frequency measurements with multiple period averaging
- Low-level 0.1 volt sensitivity without accessories
- Higher sampling rates; time between samples independent of gate time

The Hewlett-Packard Model 5245L Electronic Counter accurately makes frequency, period, multiple period average, ratio and multiple ratio measurements. In addition, the 5245L can be used to scale a signal by decades up to 10^9. Plug-ins are directly installed in the 5¼ inch high front panel and extend frequency measurements to 3 gc, permit time interval measurements, preset operation, dc voltage measurements and several other functions (see pages 48-51). The basic counter (without plug-ins) provides a counting rate of 50 mc with 8-digit resolution, presented on an in-line readout with easy-to-read rectangular digital display tubes. Designed with solid-state components throughout, power consumption is only 80 watts, and net weight is 32 pounds.

Unprecedented stability is attained with a new proportionally controlled oven for the quartz crystal. Careful design minimizes the effects of temperature and line voltage variations and contributes to greater realizable accuracy. The high time base stability, ±3 parts in 10^9 per day or better, means the time base output may be useful as a frequency standard.

Basic counter operation

The hp 5245L (without plug-ins) measures frequencies and repetition rates of periodic or random pulses from 0 to 50 million pps. Gate times from 1 μsec to 10 seconds are selected with a front-panel switch. Multiple period average to 10^5 periods is obtained without need for a separate plug-in. This capability also applies for ratio measurements, since the decade divider assemblies are usable at any frequency, and makes possible accurate measurements at low and intermediate frequencies. The increase in accuracy over that possible in single period or ratio is a result of division of the trigger error by the averaging factor, as well as the result of increased resolution.

Ratio measurements also may be made with high accuracy, using the multiple period average function to obtain multiples of ratio. Thus, small differences may be accurately resolved, since the trigger error is reduced by the averaging factor. Also, since the reading is displayed as the multiplication factor times the ratio, more counts are obtained. The inherent ±1 count ambiguity, which is the most significant error in ratio measurements near unity, becomes less significant and 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 mc in decade steps by factors up to 10^9. For example, a 14 mc signal can be divided to 0.014 cps. A rear-panel BNC connector and switch provide your choice of nine decade output frequencies.

Display storage, sample rate

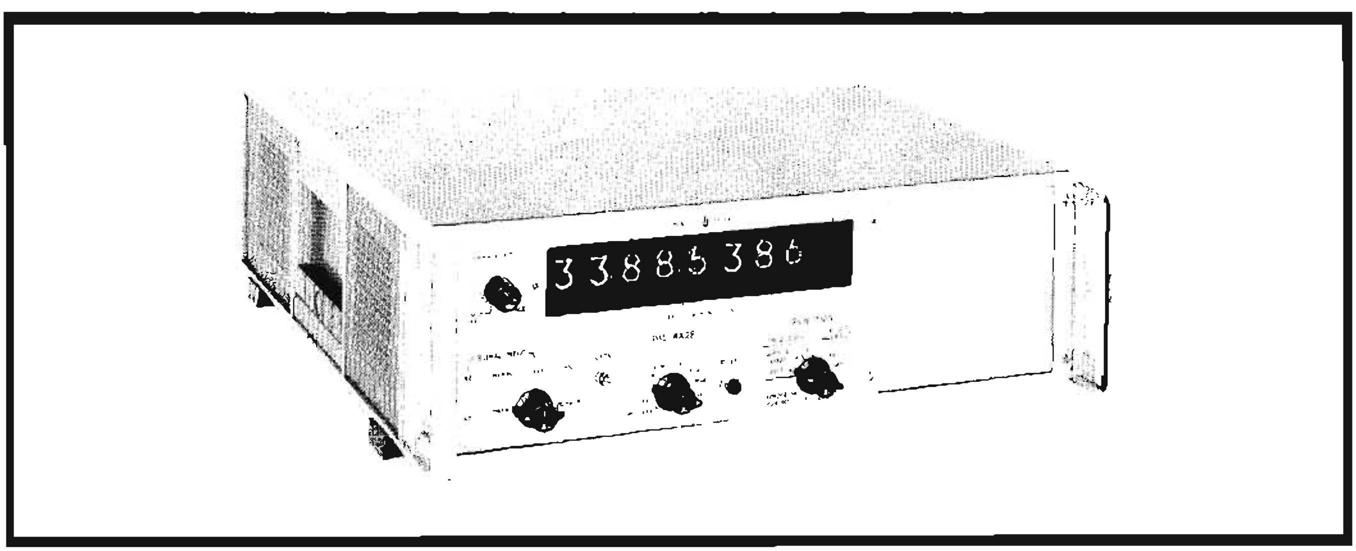
The 5245L is designed with display storage, which provides a continuous display of the most recent measurement. This display is held even while the instrument is gated for a new count. If the new count differs from the stored count, the display will shift to the new reading directly. The storage feature can be disabled with a switch on the rear panel.

The Sample Rate control determines the time interval following gate closure, during which the gate may not be reopened. When the Function switch is set to Frequency, the Sample Rate control adjusts the time between gates from less than 0.2 second to at least 5 seconds and is independent of gate time. The control also may be set to hold a display indefinitely.

Remote programming, BCD output

All functions normally controlled at the counter front panel may be remotely programmed except for Sample Rate and Sensitivity. The counter provides voltages necessary for remote control through connectors on the rear panel. (Remote programming available on special order only.)

Four-line BCD code output is provided, with assigned weights of 1-2-2-4 ("1" state positive with respect to "0" state) as standard. This output is suitable for systems use or for output devices, such as hp Model 562A Digital Recorder (page 76), hp Model 580A or 581A Digital-to-Analog Converter (page 79); 1-2-4-8 BCD code output is optional at nominal extra cost.



Specifications

Frequency measurements

Range: 0 to 50 mc (dc input); 50 cps to 50 mc (ac input, maximum sensitivity).

Gate time: 1 μsec to 10 seconds in decade steps.

Accuracy: ±1 count ± time base accuracy.

Reads in: kc or mc with positioned decimal point; units annunciator in line with digital display.

Self check: counts 10 mc for the gate time selected.

Scaling

Frequency range: 0 to 50 mc.

Factor: by decades up to 10^9 with rear-panel switch.

Input: front panel, Signal Input.

Output: in place of time base output frequencies.

Period average measurements

Range: single period, 0 to 1 mc; multiple period, 0 to 300 kc.

Periods averaged: 1 period to 10^5 periods in decade steps.

Accuracy: ±1 count ± time base accuracy ± trigger error.*

Frequency counted: 1 and 10 period, 1 cps to 10 mc in decade steps; 100 period, 10 cps to 10 mc; 1000 period, 100 cps to 10 mc; 10,000 period, 1 kc to 10 mc; 100,000 period, 10 kc to 10 mc.

Reads in: sec, msec, μsec, with positioned decimal point; units annunciator in line with digital display.

Self check: gate time is 10 μsec to 1 sec (periods averaged of 100 kc); counts 100 kc from the time base.

Ratio measurements

Displays: (f_1/f_2) times period multiplier.

Range: f_1 - 0 to 50 mc; f_2 - 0 to 1 mc in single period; 0 to 300 kc in multiple period; periods averaged 1 to 10^5.

Sensitivity: 0.1 v rms, each input.

Accuracy: ±1 count of f_1 ± trigger error* of f_2; f_1 is frequency applied to the decimal counters (enters Time Base Ext. jack on front panel); f_2 is frequency applied to decade dividers (enters Signal Input jack).

Reads in: dimensionless; positioned decimal point for number of periods averaged.

Self check: period average self check applies.

Time base

Frequency (internal): 1 mc.

Stability: aging rate, less than 3 parts in 10^9 per 24 hours;** as a function of temperature, less than ±2 parts in 10^{10} per °C from −20°C to +55°C; as a function of line voltage, less than ±5 parts in 10^{10} for ±10% change in line voltage from 115 v or 230 v rms; short-term, less than 2 parts in 10^{10} rms with averaging time of one second under constant environmental and line voltage conditions.

Adjustments: fine frequency with range approximately 4 parts in 10^8 and medium frequency with range approximately 1 part in 10^6 available from front through plug-in compartment; coarse frequency with range approximately 1 part in 10^5 available at instrument rear panel.

Output frequencies

Rear panel: 0.1 cps to 10 mc in decade steps; switch selected on rear panel; all frequencies available in manual function without interruption at reset; 10 kc to 10 mc available continuously in all functions; 1 kc available continuously for all functions except 100 K period average; stability same as internal time base; 5 volt p-p rectangular wave with 1000-ohm source impedance at 1 mc and lower; 1 volt rms sine wave with 1000-ohm source impedance only at 10 mc.

Front panel: 0.1 cps to 1 mc in decade steps; selected by Time Base switch; availability as defined under "rear panel" above; stability same as internal time base; 1 volt peak to peak.

External standard frequency: 1 mc, 1 volt rms into 1000 ohms required at rear-panel BNC connector.

General

Registration: 8 digits in line with digital display tubes and display storage; 99,999,999 maximum display; total width of 8-digit display, including illuminated units annunciator and auto-positioned decimal point indication, does not exceed 7 inches.

Display storage: display held between samples; 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 sec to 5 sec in frequency mode, independent of gate time; display can be held indefinitely.

Operating temperature range: −20°C to +65°C.

Connectors: BNC type except for remote programming and BCD output.

Signal input

Maximum sensitivity: 100 mv rms.

Coupling: ac or dc, separate BNC connectors.

Attenuation: attenuator provides ranges of 0.1, 1, and 10 v.

Impedance: 100 K ohms/v (10 K ohms at 100 mv); approx. 40 pf on 0.1 v range, 15 pf on 1 and 10 v ranges.

Overload: diodes protect input circuit to 50 v rms signal on 0.1 v range; 150 v rms on 1 v range; 500 v rms on 10 v range; ac coupling capacitance, 1 μf, 600 v.

Time base external input (front panel)

Maximum sensitivity: 100 mv rms.

Impedance: 10 K ohms, approx. 40 pf.

Overload: diodes protect input circuit to 50 v, rms.

Output

4-line BCD: 1-2-2-4, "1" state positive; 4-line BCD 1-2-4-8 available as Option 02. ("1" state positive) and Option 03. ("1" state negative); "0" State Level: −8 v; "1" State Level: +18 v.

Impedance: 100 K ohms each line.

BCD reference voltage levels: approximately +17 v, 350-ohm source; approximately −6.5 v, 1000-ohm source.

Print command: +13 v to 0 v step, dc-coupled.

Cable connector: Amphenol 50-pin 57-30500, 1 required

Hold-off requirement: +15 v min., +25 v max. from chassis ground (1000-ohm source).

Dimensions: 5¼" high, 16¾" wide, 16⅜" deep (132 x 425 x 416 mm).

Weight: net 32 lbs (14,5 kg) with blank plug-in; shipping 40 lbs (18,2 kg).

Power: 115 or 230 volts ±10%, 50 to 60 cps; 95 watts (50 to 1000 cps operation, price on request).

Accessories furnished: 10503A Cable, 4 feet long, male BNC connectors; detachable power cord, 7½ feet long (2040 mm), NEMA plug; circuit board extender.

Optional and special features

Option 02. 4-line BCD 1-2-4-8, "1" state positive in lieu of 1-2-2-4 (identical in other respects to above "output" data), add $80.

Option 03. 4-line BCD 1-2-4-8, "1" state negative in lieu of 1-2-2-4 (identical in other respects to above "output" data), add $80.

Remote operation (special order): programming voltages for Time Base and Function control are −15 volts dc at 5 ma per gate; decimal point position and measurements units may be controlled with internal +170 volts or an external supply; order H65-5245L, price on request.

Cable connector: Amphenol 36-pin 57-30360, 2 required for remote operation.

Price: hp 5245L, $2950.

* Trigger error is less than ±0.3% of one period ÷ periods averaged for signals with 40 db or better signal-to-noise ratio.

** After 72 hours of continuous operation.

5264A PRESET UNIT

Read directly in engineering units with normalized measurements

The hp Model 5264A Preset Unit extends the versatility of the hp 5245L Electronic Counter's time base, and the counter retains its basic functions and measurement range. The 5264A makes possible:

1. Frequency measurements for N units of time (N x Freq).
2. Measurement of time for N events to occur (N x Period).
3. Ratio and normalized ratio measurements (N x Ratio).
4. Counting N events (Preset).
5. Division of input frequency by N $\left(\frac{f}{N}\right)$

In these modes N may be any integer between 1 and 100,000. Decade dividers in the preset unit control the counter gate.

N x frequency measurements

In N x frequency measurements, gate time is controlled by the preset decades (N) and the counter's Time Base switch (10 μsec to 10 sec). The gate is held open for N periods (N = 1 to N = 100,000) 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 (up to 10^6 seconds) permit measurement of low frequencies with high accuracy.

Ratio, N x ratio measurements

Model 5264A permits ratio measurements over a range of frequencies with a choice of normalizing factors from 1 to 100,000 in one-digit steps. The counter displays $Nf_1 \div f_2$ and f_1 is counted for N periods of f_2.

Dividing by N (f/N)

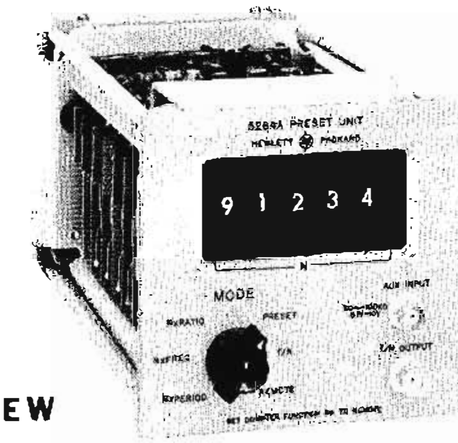
Another operation provided by the 5264A is division of any input frequency up to 100 kc by N. Higher division ratios are possible using the counter to prescale the input signal in decade steps. With this technique, frequencies as high as the maximum rate of the counter can be divided by a five-digit number so long as the frequency supplied the preset unit does not exceed 100 kc.

N x period measurements

In the N x period mode of the 5264A, the 5245L measures the time for N events to occur. The measurement may be made in increments of 0.1 μsec to 10 seconds, depending on the setting of the counter's Time Base switch. Period and multiple period measurements also are easily made with the mode switch in the N x period position. Period average is determined by dividing the time reading by N.

Preset counting

When the mode switch of the 5264A is set to Preset, N events are counted. The first event opens the gate; the Nth closes the gate. This feature is useful in batching and the gate signal (positive at count start and negative at count end) can be used to control external circuitry or relays.



NEW

Specifications, 5264A*

N x frequency (counter signal input)

- **Range:** 5245L, 0 to 50 mc.
- **Gate time:** (set by counter Time Base and "N" switches)
  - 10 μsec to 1 sec in 10 μsec steps
  - 100 μsec to 10 sec in 100 μsec steps
  - 1 msec to 100 sec in 1 msec steps
  - 10 msec to 10^3 sec in 10 msec steps
  - 0.1 sec to 10^4 sec in 0.1 sec steps
  - 1 sec to 10^5 sec in 1 sec steps
  - 10 sec to 10^6 sec in 10 sec steps
- **Accuracy:** ±1 count ± time base accuracy.
- **Maximum sensitivity:** 0.1 v rms.
- **Input impedance:** 100 K/v; 40 pf on 0.1 range, 15 pf on 1 and 10 v ranges.

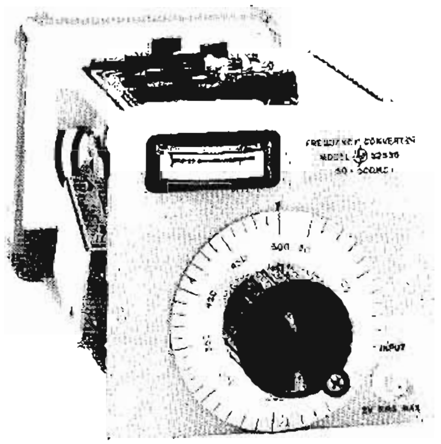
N x ratio

- **f_1 (counter Ext. Time Base Input)**
  - Frequency range: 5245L, 0 to 50 mc.
  - Sensitivity: 0.1 v rms.
  - Input impedance: 10 K; 40 pf shunt.
- **f_2 (counter signal input)**
  - Frequency range: 0 cps to 100 kc.
  - Maximum sensitivity: 0.1 volt.
  - Input impedance: 100 K/v; 40 pf on 0.1 range, 15 pf on 1 and 10 v ranges.
- **Reads:** $N \times f_1/f_2$.
- **Accuracy:** ±1 count of f_1.

Divide by N (5264A Auxiliary Input, f/N mode)

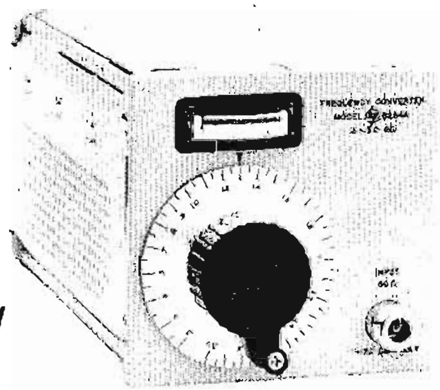
- **Frequency range:** 20 cps to 100 kc (sinusoidal).
- **Sensitivity:** 0.1 v rms.
- **Overload:** signals in excess of 10 v rms may damage the instrument.
- **Prescaling:** in decade steps to 10^9 to maximum rate of counter; (scaled output frequency $\leq$100 kc).
- **Output:** 0.2 v peak to peak centered at 0 volts, into high-impedance load; rise time $<$1 μsec, duration approximately 5 μsec.

* When used with hp 5245L Electronic Counter.



5253B

NEW



5254A

5253B AND 5254A FREQUENCY CONVERTERS

Measure to 3000 mc with counter accuracy

Model 5253B extends the range of the 5245L Electronic Counter to 500 mc, and Model 5254A extends the range to 3000 mc. The stability and accuracy of the basic counter are retained, since the plug-in converters use a multiple of the 10 mc signal from the electronic counter time base to beat with the signal to be measured. The level-indicating meter and positive, smooth tuning permit quick and accurate frequency measurements by non-technical personnel.

The basic functions and measurement range of the 5245L are retained when a frequency converter plug-in is installed. Simply move the counter Sensitivity switch off the "Plug-In" position and connect the input signal directly to the counter input.

The hp 5253B subtracts multiples of 10 megacycles, and the hp 5254A subtracts multiples of 50 megacycles from the input frequency. The difference frequency is then supplied to the counter for measurement. Thus, the measured frequency is the sum of the counter display in megacycles and the value in megacycles indicated by the frequency converter dial. The same stable internal crystal oscillator used for the counter's time base is used to obtain the harmonics subtracted from the measured frequency. Therefore, the additional frequencies generated by the converter introduce no error, and the counter accuracy is maintained over the range of the frequency converter used.

Specifications, 5264A, continued.

Input impedance: 1 megohm, 50 pf shunt.

N x period (counter signal input)

Input frequency range: 0 cps to 100 kc.

Maximum sensitivity: 0.1 v rms.

Input impedance: 100 K/v; 40 pf on 0.1 v range, 15 pf on 1 v and 10 v ranges.

Time units: 0.1 μsec to 10 sec in decade steps.

Accuracy: ±1 count ± time base accuracy ± trigger error.**

Preset (5264A Auxiliary input)

Input frequency range: 20 cps to 100 kc.

Maximum sensitivity: 0.1 v rms.

Overload: signals in excess of 10 v rms may damage the instrument.

Input impedance: 1 megohm, 50 pf shunt.

Preset range: 1 to 99,999 in steps of one.

Weight: net 3 lbs (1,4 kg); shipping 9 lbs (4,1 kg).

Accessory furnished: 10503A cable, 4 ft (1220 mm) long, male BNC connectors.

Price: hp 5264A, $650.

** 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.

Specifications, 5253B, 5254A*

Range (as converters for 5245L): 5253B, 50 to 500 mc; 5254A, 300 to 3000 mc.

Accuracy: retains accuracy of 5245L.

Input voltage range: 50 mv rms to 1 v rms (−13 dbm to +13 dbm).

Maximum input: 5253B, 2 v rms or 100 v dc; 5254A, input power in excess of 100 mw (+20 dbm or 2.2 v rms) may damage the converter.

Input impedance: approximately 50 ohms.

Level indicator: meter aids frequency selection; indicates output voltage to counter.

Input connector: 5253B, BNC female; 5254A, Type N female.

Registration: counter display in megacycles is added to frequency converter dial readings.

Weight: net 5 lbs (2,3 kg); shipping 10 lbs (4,5 kg).

Accessory furnished: 5253B, 10503A cable, 4 ft (1220 mm) long, male BNC connectors.

Accessory available: 5251A Frequency Converter for 5245L, 20 mc to 100 mc range; other specifications same as 5253B; hp 5251A, $300.

Price: hp 5253B, $500; hp 5254A, $825.

* When used with hp 5245L Electronic Counter.

5261A VIDEO AMPLIFIER, 5262A TIME INTERVAL UNIT

1 mv sensitivity for 5245L; time interval measurements with 0.1 μsec resolution

5261A Video Amplifier

The hp 5261A plug-in increases the hp 5245L sensitivity to 1 mv rms over the range of 10 cps to 50 mc and increases input impedance to 1 megohm. The output level meter indicates when the signal level to the counter is acceptable for a 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 cps to 50 mc with 5245L.

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 5245L 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 lbs (0,90 kg); shipping 8 lbs (3,8 kg).

Price: hp 5261A, $325.

5262A Time Interval Unit

The hp 5262A greatly increases the versatility of a 5245L by making possible accurate time interval measurements with 0.1 μsec 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 5262A measures from 1 μsec to 10^8 sec, measures pulse length, pulse spacing and delays. It triggers from separate or common signals. The 5262A may be used as an amplitude discriminator for the 5245L, which permits counting only signals meeting requirements set by trigger level controls.

Specifications, 5262A*

Range: 1 μsec to 10^8 sec.

Standard frequency counted: 10^7 to 1 cps in decade steps from 5245L or external frequency.

Accuracy (pulse): ± 1 period of standard frequency counted $\pm$ time base accuracy.

Registration: on 5245L 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: Resistance	Input Impedance: Capacitance	Max. input
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 meg 3 meg 10 meg	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 mc when used as input signal discriminator.

Markers: 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.

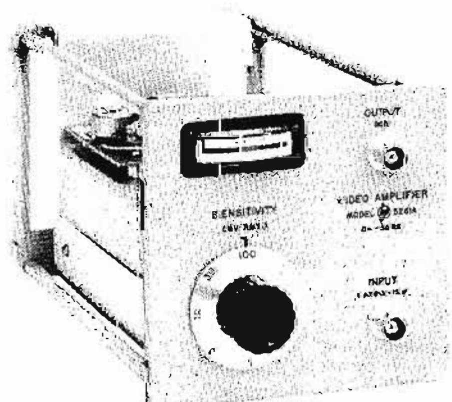
Reads in: μsec, msec, sec with measurements unit indicated and decimal point positioned.

Accessories furnished: 10503A Cable Assembly, male BNC to male BNC, 4 feet (1220 mm) long.

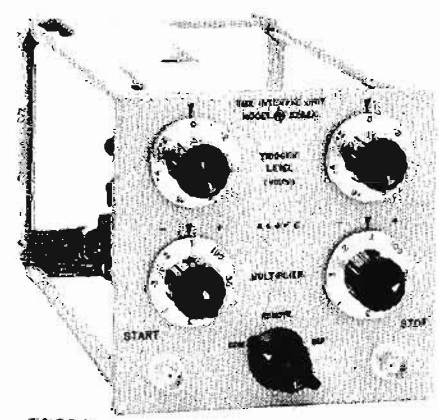
Weight: net 2.5 lbs (1,1 kg); shipping, 7 lbs (3,2 kg).

Price: hp 5262A, $300.

* When used with hp 5245L Electronic Counter.



5261A



5262A

5252A PRESCALER, 5265A DIGITAL VOLTMETER

Increase capability of 5245L

5252A Prescaler

The direct-counting frequency of the hp 5245L Electronic Counter is extended to 350 mc using the Model 5252A Prescaler Plug-in. Prescaling is accomplished with transistor binary dividers which operate over the frequency range dc to 350 mc. No tuning is required. A trigger level adjustment is provided to permit counting of either positive or negative random pulses.

Prescaling is accomplished by scaling the input frequency by a factor of 2, 4 or 8, while at the same time adjusting the counter's time base to provide a direct reading in frequency. A front-panel selector switch allows the operator to easily choose the correct scale factor. In the dc to 100 mc position, the scale factor is two; in the dc to 200 mc position, the scale factor is four, and in the dc to 350 mc position, the scale factor is eight.

Tentative specifications, 5252A*

Operating frequency range: dc to 350 mc.
Accuracy: same as the basic counter.
Input sensitivity: 100 mv rms.
Maximum input: 2 volts or +20 dbm.
Input impedance: 50 ohms (nominal).
Operating temperature range: —20°C to +65°C.
Trigger level control: ±1 volt.
Scaled output: >100 mv rms into 50 ohms is available at the auxiliary output BNC connector of the basic counter.

5265A Digital Voltmeter

The hp 5265A Digital Voltmeter Plug-in quickly converts your 5245L Electronic Counter to an accurate dc digital voltmeter. It can be operated easily by non-technical personnel for production-type voltage measurements. Operation is straightforward—simply set range switch, connect the voltage to be measured and read. Decimal points are properly positioned, and polarity is automatically indicated.

Fundamentally, the 5265A is a voltage-to-time-interval converter which uses a linear voltage ramp and voltage coincidence circuits to define the time interval. Since the ramp is linear with time, the time interval is directly proportional to input voltage, and is measured by counting a 10 mc signal from the counter's time base.

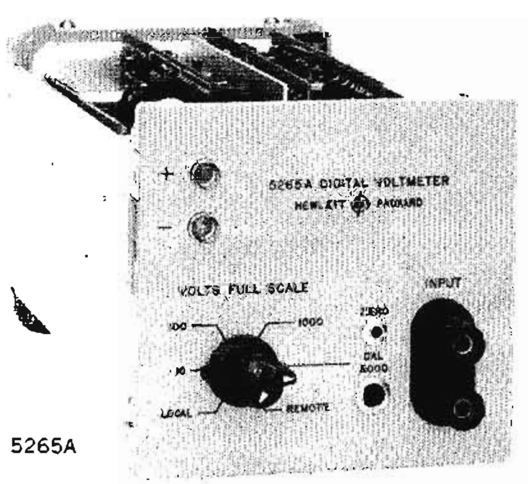
A Local-Remote switch permits remote selection of the DVM mode or the regular electronic counter functions when used with an H65-5245L Counter.

Specifications, 5265A*

Voltage range: 6-digit presentation of 10.0000, 100.000, and 1000.00 v full scale with 5% overrange capability.
Registration: on 5245L.
Reads in: dc volts with decimal point positioned by range switch; automatic polarity indicator.
Accuracy (0° to +50°): 0.1% of reading (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.
Input resistance: 10.2 megohms to dc on all ranges.
Input filter
  AC rejection: 30 db at 60 cps, increasing at 12 db per octave.
  Response time: less than 450 msec to a step function to within 0.05% of final value.
Accessory furnished: 5060-0630 22-pin extender board.
Weight: net 2½ lbs (1,1 kg); shipping 7 lbs (3,2 kg).
Price: hp 5265A, $575.

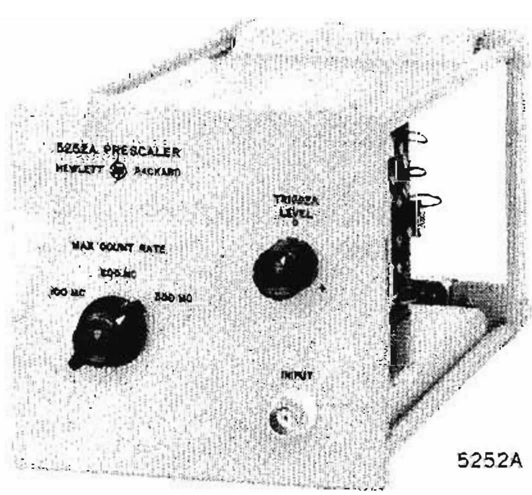
* When used with hp 5245L Electronic Counter

NEW



5265A

AVAILABLE MID-1965



5252A

5244L ELECTRONIC COUNTER

50 mc counting rate with 0.1 v rms sensitivity

The hp 5244L Electronic Counter measures frequency, period, multiple period average, ratio and multiples of ratio with a maximum counting rate of 50 mc. 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 mc, dc input; 50 cps to 50 mc, ac input.

Gate time: 1 μsec to 10 seconds in decade steps.

Accuracy: ±1 count ± time base accuracy.

Reads in: kc or mc with positioned decimal point; units annunciator in-line with digital display.

Self check: counts 1 mc for the gate time selected by time base switch.

Period average measurements

Range: single period, 0 to 1 mc; multiple period, 0 to 300 kc.

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 cps in decade steps; multiple period, 10^6, 10^5 or 10^4 cps.

Reads in: sec, msec, μsec with positioned decimal point; units annunciator in-line with digital display.

Self check: gate time is 10 μsec to 1 sec; counts 100 kc.

Ratio measurements

Displays: f_1/f_2 times period multiplier.

Range: f_1: 50 cps to maximum rate of counter; f_2: 0 to 1 mc in single period, 0 to 300 kc in multiple period; periods averaged 1 to 10^5 in decade steps.

Sensitivity: f_1: 1 v rms from 100 cps to maximum rate of counter, 2 v rms from 50 to 100 cps; 2500-ohm input impedance; f_2: 0.1 v rms, 100 K/v 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).

Reads in: dimensionless units with positioned decimal.

Self check: gate time is 10 μsec to 1 sec; counts 100 kc.

Time base

Frequency: 1 mc.

Stability:** aging rate: less than ±2 parts in 10^7 per month; as a function of 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 −20° to +65°C; as a function of line voltage: less than ±1 part in 10^7 for ±10% line voltage change.

Output frequencies: 0.1 cps to 1 mc in decade steps selected by Time Base switch.

General

Registration: 7 digits in-line with rectangular digital display 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 0.2 second to 5 seconds, independent of gate time; display can be held indefinitely.

Input

Maximum sensitivity: 100 mv rms.

Coupling: ac or dc.

Attenuation: step attenuator provides ranges of 0.1, 1 and 10 volts.

Impedance: 100 K/v (10 K at 100 mv), approximately 40 pf on 0.1 v range, 15 pf on 1 and 10 v ranges.

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: −20°C to +65°C.

Connectors: BNC type except for BCD output.

Output: 4 line 1-2-2-4 BCD with "1" state positive; 1-2-4-8 optional; "0" state: −8 volts; "1" state: +18 volts; impedance: 100 K ohms 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 36 lbs (16.3 kg).

Power: 115 or 230 volts ±10%, 50 to 60 cps, approximately 80 watts (50 to 1000 cps 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.

Price: hp 5244L, $2225.

Options

01. 8-digit registration, add $110.
02. 1-2-4-8 BCD output in lieu of 1-2-2-4 BCD, add $70.
03. same as 02, except "1" state negative, add $70.
04. 8-digit registration and 1-2-4-8 ("1" state positive). BCD output in lieu of 1-2-2-4 BCD, add $190.
05. same as 04, except "1" state negative, add $190.

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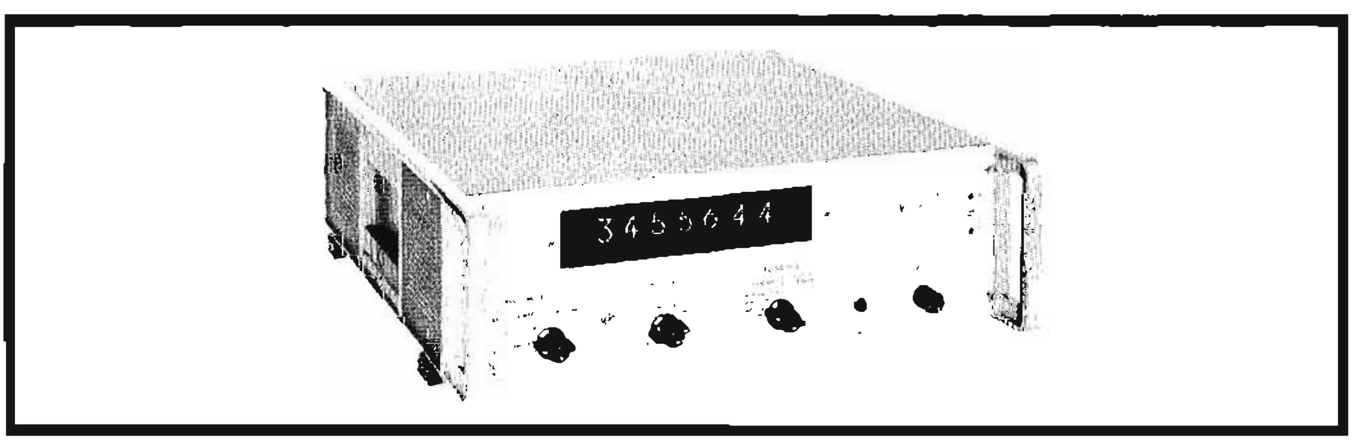
*Trigger error for sine wave input is $\frac{<\pm 0.3\% \text{ of one period}}{\text{periods averaged}}$ for signals with 40 db or more signal-to noise-ratio.

**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.



2590A MICROWAVE FREQUENCY CONVERTER

Measure frequency to 15 gc with counter accuracy

Model 2590A, in a single compact all-solid-state instrument, performs the functions of a transfer oscillator and a transfer oscillator synchronizer. (hp 540B, page 63, is a transfer oscillator only.)

By phase-locking an internal transfer oscillator to the signal frequency, Model 2590A makes cw frequency measurements inherently equal to the accuracy of the external time base used, even on rapidly drifting signals. With the hp Model 5245L/5253B combination (pages 46, 47, 49) complete coverage is provided from dc to 15 gc, with attainable accuracy as high as 5 parts in 10^{10}. Permanently phase-locked, the signal frequency's drift may be tracked continuously over long periods.

The 2590A 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 10^6 using the 2590A with an auxiliary oscilloscope. FM on the pulse also can be observed.

The 2590A is available as an individual instrument to be coupled by the user with a counter, or as part of a complete frequency measuring and recording system, Dymec Model DY-2040A. The system includes the 2590A, hp 5245L Counter with hp 5253B Frequency Converter, and hp 562AR Printer (page 76).

Specifications

Frequency range: 0.5 to 15 gc.

Signal input: minimum level, typically −20 to −30 dbm from 0 5 to 10 gc, increasing to −7 dbm at 15 gc; maximum level, +20 dbm (100 mw); Type N connector.

Lock-on range: approx. ±0.25% of signal frequency in normal APC mode; track mode increases lock-on range to ±0.45% (approx.) at lower end of transfer oscillator range, decreasing to 0.25% at upper end.

Accuracy: ± stability ± resolution of measurement of transfer oscillator fundamental: stability, same as 10 mc 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.

External reference: 10 mc, 0.1 v min. into 90 ohms; BNC connector.

FM measurements: discriminator characteristics when in FM mode: linearity (max. deviation from straight line through origin), better than ±1% over bandwidth of ±500 kc, better than ±5% over bandwidth of ±2 mc; video frequency response, 30 cps to 1 mc (3 db points); center frequency, 30 mc (nominal); sensitivity, 5 v/mc (±10%); output impedance, 1 K; front-panel BNC connector.

AM measurement: sensitivity, 100 mv rms (nominal) for 100% modulation at 1 kc; frequency response, 30 cps to 1 mc; load impedance, 1 megohm shunted by 12 pf max.; front-panel BNC connector.

APC monitor: FM on signal may be monitored when in FM operating mode; sensitivity, ±3 v minimum for frequency deviation of ±0.25%; deviation limits, APC mode can follow frequency deviations up to ±0.005% of signal frequency at rates from 100 cps to 50 kc (min.); at rates below 100 cps, deviation limit increases at 6 db/octave to a max. of 0.25%; impedance, measuring device should have min. input impedance of 1 megohm, shunt capacitance not greater than 20 pf; rear-panel BNC connector.

Transfer oscillator: fundamental frequency range, 240 to 390 mc; drift, less than $1/10^5$ per hour immediately after turn-on, less than $1/10^5$ per hour after 2 to 3 hours' operation (oscillator automatically corrected for drift in APC mode); residual FM, less than 10 cps rms; dial, 2¼" dia. calibrated in 5 mc increments.

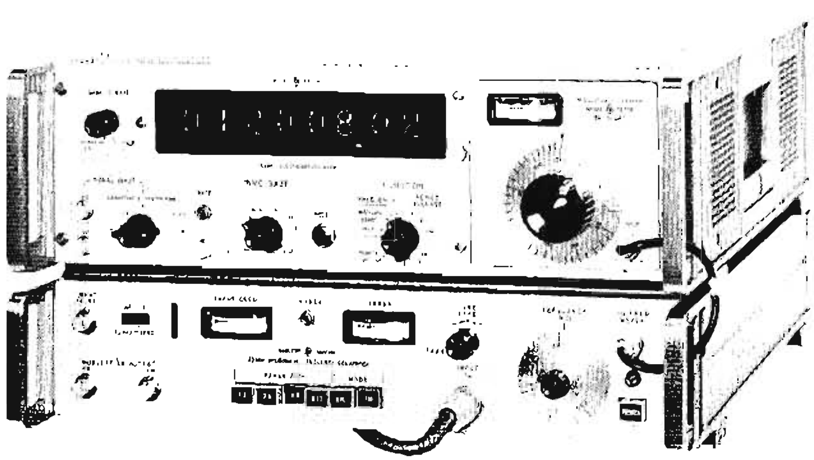
Power: 115/230 v ±10%, 50 to 1000 cps, approx. 35 w.

Operating conditions: ambient temperatures 10 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 2590A, $1900.



2590A shown with 5245L Counter, 5253B Plug-In

5223L, 5233L ELECTRONIC COUNTERS

Versatile universal counters, to 2 mc counting rate

Advantages:

- Superior trigger level controls usable in all functions
- Improved readability with rectangular digital tubes
- Minimum bench or rack space, 3½" panel height
- Reliable, rugged and completely solid state
- Versatile, yet easy to operate
- More accurate low-frequency measurements with multiple period averages
- Low-level measurements without accessories; 0.1 volt sensitivity
- High sampling rates; times between samples independent of gate time
- 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

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 kc and 5-digit resolution, and the 5233L provides a maximum counting rate of more than 2 megacycles with 6-digit resolution. Both instrument readouts are in-line displays of rectangular digital tubes.

DC coupling

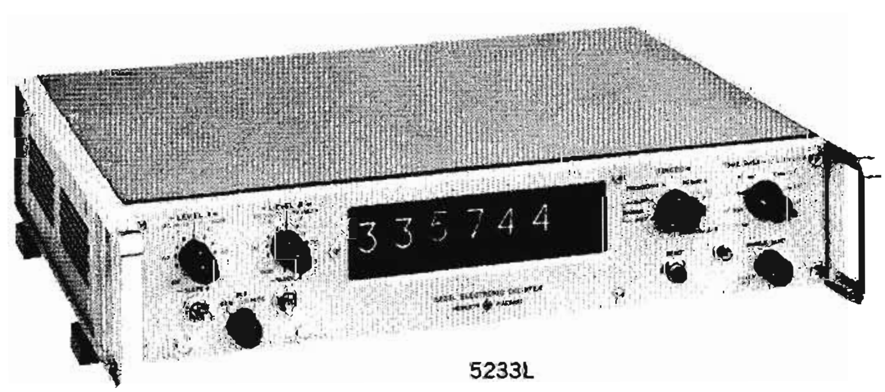
With the 5223L and 5233L, dc coupling allows accurate trigger point definition with low input amplifier noise and low trigger drift. A trigger preceded by an ac-coupled input will respond to an average dc level. The trigger point will change with wave shape and repetition rate. This situation is not of great significance in frequency measurements since it is only desired to maintain the number of zero crossings. 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. The variability of trigger point with repetition rate and wave shape (produced with ac coupling) is a serious source of error in time interval measurements — some doubt always exists as to where the actual trigger point is. It may be a point of low slope near the top of a pulse where noise can cause appreciable error.

Optimum trigger point definition

The 5223L and 5233L each provide two identical input channels for optimum trigger point definition. 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 with a choice of ac or dc coupling. 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 increases. Consequently, for precise measurement capabilities, 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.

Particular design care was necessary to insure that these input amplifiers would possess an extremely wide dynamic range. This insures that the input signal peaks can exceed the highest level control adjustment for the next higher attenuator range 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

	NEW 5223L Electronic Counter	**5233L Electronic Counter**
Input channels (A and B)	**Range:** dc coupled: 0 to more than 300 kc; ac coupled: 10 cps to more than 300 kc. **Impedance:** approx. 1 megohm, 80 pf shunt. **Sensitivity:** 0.1 v rms sine wave; 1 v pulse, 1 μsec min. width. **Trigger level:** −100 to +100 volts, 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 μsec duration and −15 volts peak.	**Range:** dc coupled: 0 to more than 2 mc; ac coupled: 10 cps to more than 2 mc. **Impedance:** approx. 1 megohm, 80 pf shunt. **Sensitivity:** 0.1 v rms sine wave; 1 v pulse, 0.2 μsec min. width. **Trigger level:** −100 to +100 volts, 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 μsec duration and −15 volts peak.
Time interval	**Range:** 10 μsec to 10^6 sec. **Input:** Channels A and B. **Accuracy:** ±1 count ± time base accuracy ± trigger error.* **Reads in:** msec or sec 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 μsec to 10^7 sec. **Input:** Channels A and B. **Standard frequency counted:** 1 mc to 0.1 cps in decade steps or external frequency/100 cps to 1 mc. **Accuracy:** ±1 count ± time base accuracy ± trigger error.* **Reads in:** msec or sec with positioned decimal. **Measurement:** time from A to B.
Frequency	**Range:** 0 to >300 kc. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy. **Reads in:** kc or mc with positioned decimal. **Gate time:** 10 μsec to 10 sec in decades. **Self check:** counts 100 kc for the gate time chosen by time base selector.	**Range:** 0 to >2 mc. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy. **Reads in:** kc or mc with positioned decimal. **Gate time:** 10 μsec to 10 sec in decades **Self check:** counts 1 mc for the gate time chosen by time base selector.
Period	**Range:** 0 to 100 kc. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μsec or msec with positioned decimal. **Frequency counted:** 100 kc to 0.1 cps in decade steps. **Self check:** gate time is 1 sec; frequency counted is 0.1 cps to 100 kc as selected by time base switch.	**Range:** 0 to 100 kc. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** msec or sec with positioned decimal. **Frequency counted:** 1 mc to 0.1 cps in decade steps. **Self check:** gate time is 1 sec; frequency counted is 0.1 cps to 1 mc as selected by time base switch.
Period average	**Range:** 0 to 300 kc. **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μsec or msec with positioned decimal. **Frequency counted:** 100 kc. **Periods averaged:** 10 to 10^6 in decade steps. **Self check:** gate time is 10 μsec to 10 sec (1 to 10^6 periods of 100 kc); counts 100 kc.	**Range:** 0 to 2 mc (multiple period), 0 to 1 mc (X10), 0 to 100 kc (X1). **Input:** Channel A. **Accuracy:** ±1 count ± time base accuracy ± trigger error.** **Reads in:** μsec or nsec with positioned decimal. **Periods averaged:** 10 to 10^7 in decade steps. **Frequency counted:** 1 mc. **Self check:** gate time is 10 μsec to 10 sec (10 to 10^7 periods of 1 mc); counts 1 mc.
Ratio	**Range:** Channel A (F_A): 0 to above 300 kc; Channel B (F_B): 0 to 300 kc. **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 kc for 10 μsec to 10 sec, depending on multiplier setting.	**Range:** Channel A (F_A): 0 to more than 2 mc; Channel B (F_B): 0 to 2 mc (multiple period), 0 to 1 mc (X10), 0 to 100 kc (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 mc for 10 μsec to 10 sec, 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 × 10^6/sec; random events with pulse spacing of 3.3 μsec 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/sec; random events with pulse spacing to 0.5 μsec or less.
Time base	**Frequency (internal):** 100 kc. **Stability:** aging rate: <±2 parts in 10^6/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 cps to 300 kc, sine wave. **Outputs, rear panel** **Oscillator:** 100 kc, 1 v peak to peak, open circuit; time base (separate BNC connector): 0.1 cps to 100 kc in decade steps, 5 v peak open circuit, 1 μsec width, 1000-ohm source; available in Period, Time Interval, and Manual without reset interruptions.	**Frequency:** (internal): 1 mc. **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 (−20° to +65°C) **External input:** sensitivity: 1 v rms into 500 ohms, sine wave; range: 100 cps to 1 mc, sine wave. **Outputs, rear panel** **Oscillator:** 1 mc, 3 v peak to peak; time base (separate BNC connector): 0.1 cps to 1 mc in decade steps, 5 v peak to peak, 600-ohm source, available in Period, Time Interval, and Manual without reset interruptions.
Scaling	**Range:** 0 to 300 kc. **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 mc. **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 1-2-2-4 BCD, 100 K each line; "0" state level: approx. −28 volts; "1" state level: −2 volts. **Reference levels:** approx. −2.4 volts, 350-ohm source impedance, and −26.9 volts, 1000-ohm source. **Print command:** +28 volt step from 2700-ohm source in series with 1000 pf. **Hold-off requirements:** chassis ground to +12 volts 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 sec to 5 sec, 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 volts ±10%, 50 to 60 cps***; 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 26 lbs (11.7 kg). **Price:** hp 5223L, $1325. **Option 02.:** 1-2-4-8 BCD output ("1" state positive), in lieu of 1-2-2-4 BCD output, add $50.	**Printer output** **Output:** 4-line 1-2-2-4 BCD; 100 K each line; "0" state level: approx. −8 volts; "1" state level: approx. +18 volts. **Reference levels:** approx. +17 volts, 350-ohm source impedance, and approx. −6 volts, 1000-ohm source impedance. **Print command:** +28 volt step, 2700-ohm source impedance; 1000 pf in series. **Hold-off requirements:** from +2 volts to −20 volts. **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 sec to 5 sec; 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 volts ±10%, 50 to 60 cps,***; 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 22 lbs (10 kg). **Price:** hp 5233L, $1750. **Option 02.:** 1-2-4-8 BCD output in lieu of 1-2-2-4 BCD, add $60.†

* For any wave shape, trigger error is less than $\pm\frac{0.0025}{\text{signal slope (v/μsec)}}$ μsec; below 0.1 cps 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 $60.

5211A,B, 5212A, 5512A, 5232A, 5532A ELECTRONIC COUNTERS

Compact counters with measurement versatility to 1.2 mc

Advantages:

Reliable, rugged and compact
Stable internal frequency standard
Low power consumption with solid-state components
Modular cabinet permits bench or rack operation

Uses:

Accurate low frequency measurements with multiple period averaging
Low-level measurements without accessories
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 kc to 1.2 mc. 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, 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 volt rms, input impedance, 1 megohm.

5211A,B Counters

Models 5211A and 5211B have a maximum counting rate of 300 kc 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. 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 μsec 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.

5212A, 5512A, 5232A, 5532A Counters

With this group of solid-state instruments, two basic counters give maximum counting rates of 300 kc and 1.2 mc, 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 kc, 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 mc 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 60°C (−20°C to +50°C for 5211A,B).

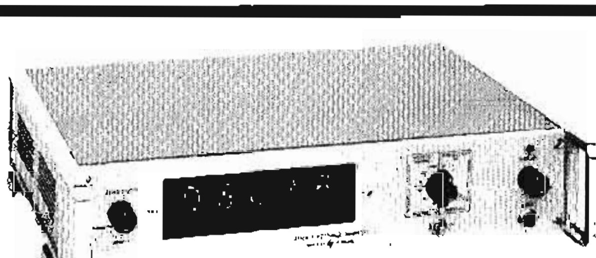
Weight: all models, net less than 15 lbs (6,8 kg).

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.

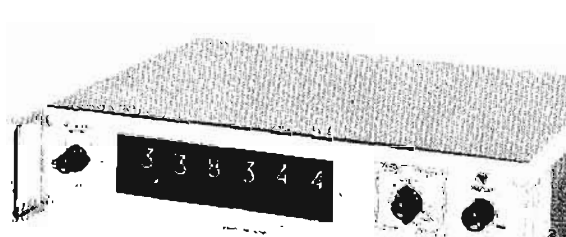
Power: 115 or 230 v ±10%, 50 to 60 cps*, less than 40 w.

Accessories furnished: 10503A Cable, 4 feet long, BNC connectors; detachable power cord; circuit board extender.

* hp 5211A,B require 50 or 60 cps operation (specify Option 01, for 50 cps operation); 5212A, 5512A, 5232A and 5532A operate between 50 and 60 cps line frequency with limit imposed by fan.

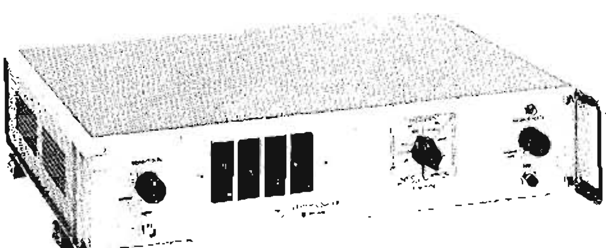


5512A

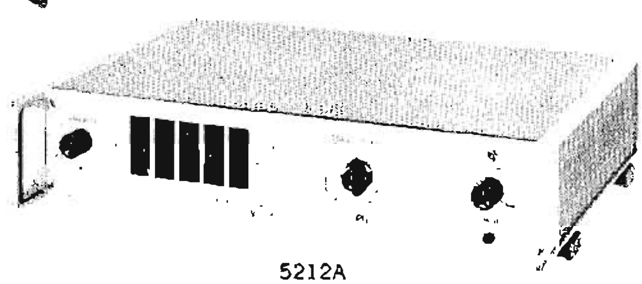


5532A

hp Counter		5211A,B	5212A	5512A	5232A	5532A
Max. counting rate		300 kc	300 kc	300 kc	1.2 mc	1.2 mc
Registration		4 digits columnar	5 digits columnar	5 digital display indicators	6 digits columnar	6 digital display indicators
Time base		power line; accuracy typically ±0.1% or better	100 kc crystal oscillator; aging rate, ±2/10⁶/week		1 mc crystal oscillator; aging rate, ±2/10⁷/month	
Period and multiple period average measurement	Range	2 cps to 300 kc			2 cps to 1.2 mc	
	Accuracy	± one count, ± time base accuracy, ± trigger error				
	Reads in	msec or μsec with positioned decimal				
	Periods averaged	1, 10, 10^2, 10^3, 10^4, 10^5				
Frequency measurement	Range	2 cps to 300 kc			2 cps to 1.2 mc	
	Accuracy	±1 count, ± time base accuracy				
	Reads in	kc, cps with positioned decimal	kc with positioned decimal			
	Gate time	1, 0.01 sec; 5211B, additional 10 sec	10, 1, 0.1, 0.01 sec			
Ratio measurement	Reads	f_1/f_2	f_1/f_2 x periods averaged			
	Range	f_1: 2 cps to 300 kc (0.1 v rms); f_2: 100 cps to 300 kc (1 v rms into 1000 ohms)	f_1: 100 cps to 300 kc (1 v rms into 1000 ohms); f_2: 2 cps to 300 kc		f_1: 100 cps to 1.2 mc (1 v rms into 500 ohms); f_2: 2 cps to 300 kc	
	Accuracy	+1 count of f_1, ± trigger error of f_2				
Recorder output		4-line BCD (1-2-2-4); 4-line BCD (1-2-4-8) available as Option 02. (Extra cost special on 5211A)				
	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				
		(output optional at extra cost in 5211A)				
Price		hp 5211A, $600 hp 5211B, $725	hp 5212A, $925	hp 5512A, $1050	hp 5232A, $1300	hp 5532A, $1450



5211A,B



5212A

5232A

5214L PRESET COUNTER

Presetable time base decades provide new measurement versatility

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 is one of the most versatile electronic counters ever produced. It 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.

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 kc), 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 kc time base is connected directly to the preset decades (M at X1), the gate time is set in 10 μsec 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 μsec or 1 msec 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 msec (0.01 sec) and measure rps directly or you can set the gate for 600.00 msec (0.6 sec) 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 msec 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 msec, 0.1 msec, or 1 msec 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 1-2-2-4 ("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 (pages 76 and 79). 1-2-4-8 BCD code output is also available at extra cost.

Specifications

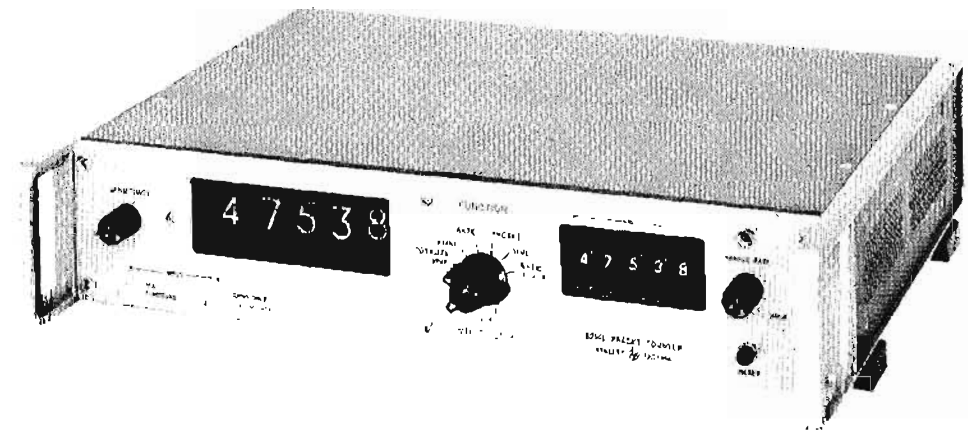
Functions

Totalize (Input A)

Range: 2 cps to 300 kc.
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 cps to 300 kc.
Sensitivity: *0.1 volt rms sine wave.
Gate time: 10 μsec to 1 sec in 10 μsec steps; 100 μsec to 10 sec in 100 μsec steps; 1 msec to 100 sec in 1 msec steps.
Accuracy: $\pm$1 count $\pm$ time base accuracy.
Input impedance: 1 megohm, 50 pf shunt.



Preset (Input A)

Input frequency range: 2 cps to 100 kc.

Sensitivity*: 0.1 volt rms sine wave.

Reads: time for N events in msec.

Time units: 10 μsec, 0.1 msec or 1 msec.

Input impedance: 1 megohm, 50 pf shunt.

Accuracy: ±1 count ± time base accuracy ± trigger error.†

Ratio

Input A: frequency range 2 cps to 300 kc; sensitivity, *0.1 volt rms sine wave; input impedance, 1 megohm, 50 pf shunt.

Input B: frequency range, 2 cps to 100 kc on X1 (2 cps to 300 kc on X10 and X100); sensitivity, 0.1 v to 10 v rms; input impedance, 1 megohm, 50 pf shunt.

Reads: N x A/B x Multiplier.

Accuracy: ±1 count.

Internal time base

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.

Printer output

Output: 4-line 1-2-2-4 BCD; 1-2-4-8 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.

General

Registration: 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 sec min. to at least 5 sec 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.

Operating temperature: −20 to +65°C.

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).

Weight: net 15 lbs (6,75 kg); shipping 25 lbs (11 kg).

Power: 115 or 230 v ±10%, 50 to 60 cps, 35 w (line frequency limit imposed by fan motor).

Accessories provided: two 10503A cables, 4 feet long, BNC connectors, circuit board extender, detachable power cord.

Price: hp 5214L, $1475.

Options

02. 1-2-4-8 BCD ("1" state positive) in lieu of 1-2-2-4, add $50.

03. Same as Option 02, except "1" state negative, add $50.

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† Trigger error (sine wave) $< \frac{0.3\% \text{ of one period}}{N}$ for ≥40 db signal-to-noise ratio on input signal; trigger error decreases with increased signal amplitude and slope.

* Internal control allows trigger adjustment for negative or positive pulses.

COMPLEMENTARY EQUIPMENT FOR HEWLETT-PACKARD SOLID-STATE COUNTERS

Increase versatility of basic instruments

The versatility of Hewlett-Packard counters is enhanced in four ways by complementary Hewlett-Packard equipment. First, the DY-2590A Microwave Frequency Converter manufactured by the Dymec Division of Hewlett-Packard extends the frequency measuring capability of the 5245L 50 MC Counter, 5253B 500 MC Frequency Converter Plug-in combination to 15 gc. Second, the DY-2539A Digital Comparator and DY-2514A Digital Scanner increase the number of systems applications by providing data handling for making Go/No-Go decisions on counter measurements and scanning the BCD outputs of up to six counters. Third, Dymec 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. Fourth, Moseley x-y and strip-chart recorders, in conjunction with the Hewlett-Packard 580A, 581A Digital-to-Analog Converters provide the user with a selection of analog recording equipment. In each case, the equipment provides convenient, permanent records of counter measurements in analog form.

Figure 1 demonstrates the capability of the DY-2539A Digital Comparator to compare readings made with the 5245L 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 562A Digital Printer or 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 562A or converted to analog form by the Hewlett-Packard 580A, 581A Digital-to-Analog Converters and plotted on a Moseley 680 Strip-Chart Recorder, providing a permanent, visual record of the comparison.

The system in Figure 2 demonstrates the use of the DY-2514A Digital Scanner to scan up to six 5245L 50 MC Counters with 5253B 500 MC Frequency Converter Plug-ins, using the DY-2590A Microwave Frequency Converter to measure microwave frequencies. Frequency measurements made by the counters are sequentially or randomly (depending on the mode of operation) scanned by the DY-2514A, and the data, in BCD form, is made directly available to one of four different types of output equipment. The scanner couples directly to the hp 562A,AR Digital Recorders and modified versions of the DY-2545 Tape Punch Coupler, DY-2546 Magnetic Tape Recorder Coupler and DY-2526 Card Punch Coupler. Both the magnetic tape records and the punched cards are IBM-compatible.

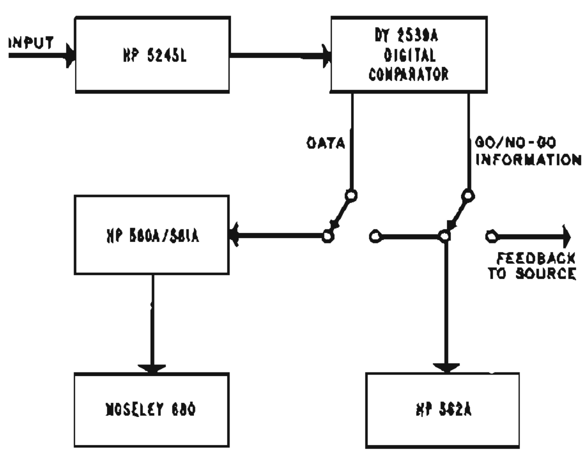


Figure 1

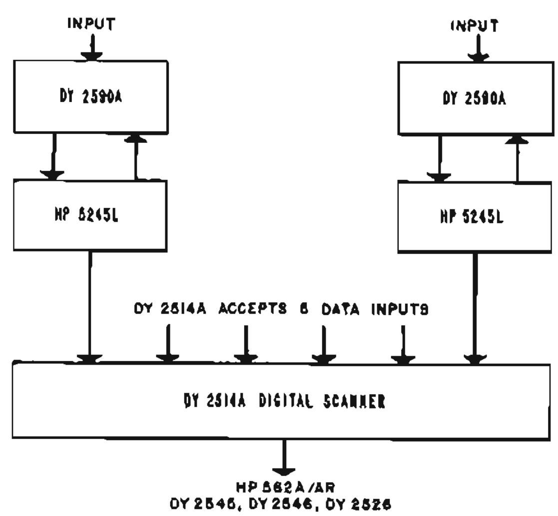
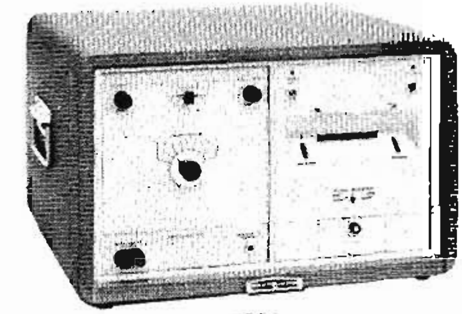
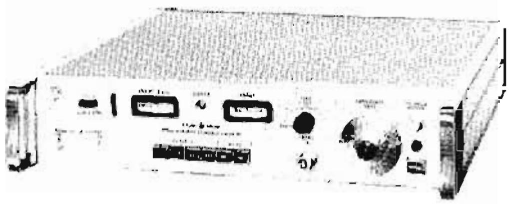


Figure 2



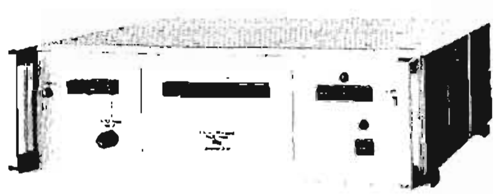
562A

The hp 562A Digital Recorder is a solid-state recorder featuring parallel entry that provides a permanent printed record of counter measurements. Low-inertia moving parts allow printing rates as high as 5 lines/sec. Standard capacity is 11 digits per line (12 on special order). A data storage feature allows the driving source to transfer data in 2 msec. Available for operation from BCD or 10-line sources. Price: hp 562A, $1600 (approximate, depending on options). See page 76 for more complete information.



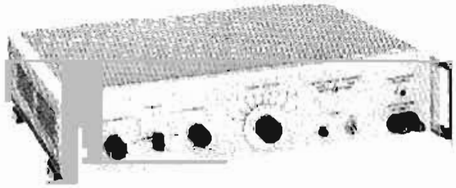
DY-2590A

The DY-2590A Microwave Frequency Converter, page 53, is an all solid-state instrument with its chassis cast in one piece to completely eliminate troublesome RFI. The DY-2590A measures frequency to 15 gc by phase-locking an internal transfer oscillator to the signal source. Measurement accuracy is equal to the counter time base. A search oscillator is provided to simplify phase locking. Price: Dymec DY-2590A, $1900.



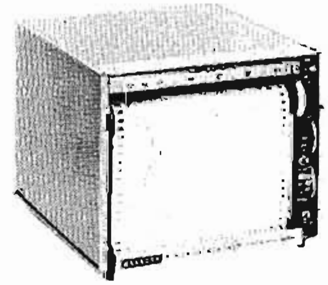
DY-2514A

The DY-2514A Digital Scanner, page 78, 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. The 2514A can operate in either sequential or random scanning modes with continuous scan, single scan or manual steps. Price: Dymec DY-2514A, $2500 (for 3 sources, 8 digits per source).



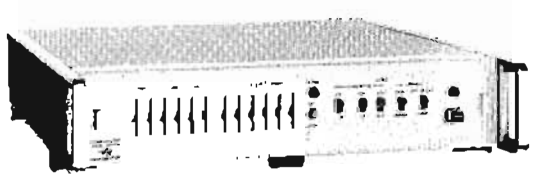
580A

The hp 580A, 581A Digital-to-Analog Converter accepts the 4-line BCD output from all hp solid-state counters The analog output is available for galvanometer or potentiometer recorders. The two models, described on page 79, vary only in physical dimension. Price: hp 580A, hp 581A, $525 each.



Moseley 680A

The Moseley 680A Strip-Chart Recorder is a solid-state device with eight chart speeds, continuous zero set, and a zener reference. The 680A uses 6-inch chart paper up to 100 feet long. The recorder may be used with a digital-to-analog converter to obtain permanent, visual records of counter measurements versus time. The Moseley 680A, described on pages 360, 361, is priced at $750.



DY-2539A

The DY-2539A Digital Comparator, pages 82, 83, compares BCD information against single or dual preset limits providing Go/No-Go lamp indications and electrical output. Comparisons take less than 2 msec. The DY-2539A provides all possible comparison conditions—combinations of relative sign and magnitude—encountered in measurement situations with counters. Price: Dymec DY-2539A, $1850 for 4-digit comparison, $1950 for 5-digit and $2050 for 6-digit.

5275A 100 MC TIME INTERVAL COUNTER

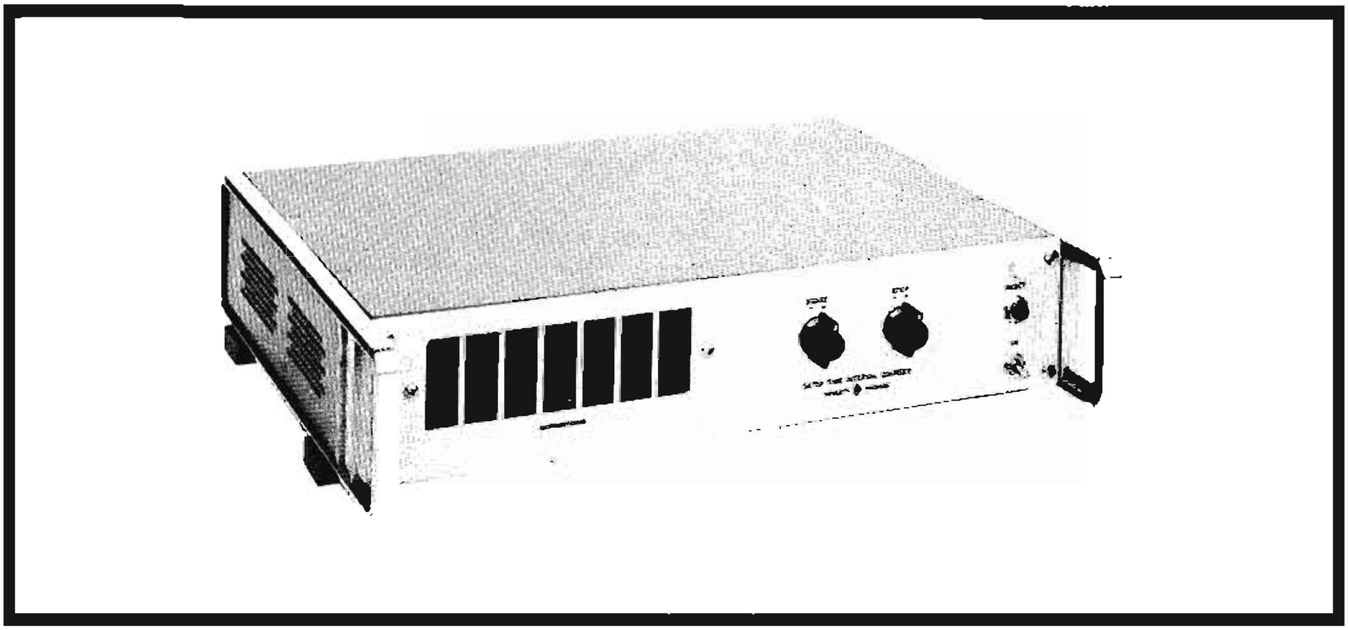
Time interval measurements with 10 nanosecond resolution

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 mc, obtained from an external 1 megacycle standard by a multiplying circuit within the counter. Applications for this instrument include the measurement of explosive burning rates, speed and acceleration timing of test vehicles in the free-flight wind tunnels, and nuclear measurements of various kinds.

Rugged, modular construction and solid-state components contribute to the typical hp quality and reliability of this remarkable 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. The time interval counter is housed in the hp cabinet configuration which allows easy convertibility from bench use to rack mount.

For system installation hp 101A 1 MC Oscillator (pages 100, 101) 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.



Specifications

Range: 10 nanoseconds to 0.1 second.

Resolution: 10 nanoseconds.

Accuracy: ±10 nanoseconds ± time base accuracy.

Time base input: (hp 101A Oscillator recommended)
- Frequency: 1 mc.
- Amplitude: 1 v rms into 1000 ohms.
- Signal-to-noise ratio: 60 db.
- Phase and amplitude modulation: less than 0.1%.
- Stability: compatible with measurement needs.

Registration: 7 places, digital, in neon columns.

Reads in: microseconds, with decimal point.

Start and stop trigger input: separate channels.

Input impedance: 50 ohms.

Minimum trigger pulse requirements: 3 v peak, 0.5 v/nsec rise time, 5 nsec width.

Trigger polarity: selectable, positive or negative.

Reset: automatic, manual, or remote, using rear terminals.

Standard frequency counted: 100 mc.

Output: 4-line BCD 1-2-2-4, "1" state positive; 4-line BCD 1-2-4-8, "1" state positive available as Option 02.; "1" state negative available on special order; "0" state: −8 volts, "1" state: +18 volts.

Impedance: 100 K, each line.

Print command: step from −6 to +13 volts, dc coupled, 2000-ohm source.

Hold-off requirements: any voltage from 0 to +12 volts, inclusive.

External reset: −13-volt pulse, 30 μsec minimum duration.

Accessories furnished: two 10503A Cables, 4 ft. long, male BNC connectors.

Operating temperature range: −20°C to +65°C.

Dimensions: 16¾" wide, 3-15/32" high, 19" deep (425 x 88 x 483 mm).

Weight: net, 15 lbs (7 kg); shipping 18 lbs (8 kg).

Price: hp 5275A, $2500.

Option 02.: 4-line BDC output, 1-2-4-8, "1" state positive in lieu of 1-2-2-4 (identical in all other respects), add $70.

External standard: 100 kc or 1 mc signal from external primary standard can be applied to unit for highest accuracy; 2 volts rms required; input impedance, nominal: 56 K, 40 pf shunt.

Connectors: BNC type.

Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 600 w.

Accessories furnished: 10503A Cable Assembly, 48" RG-58/U cable, terminated each end with UG-88/U BNC male connectors.

Dimensions: cabinet: 20" wide, 21¼" high, 23½" deep (508 x 540 x 597 mm); rack mount: 19" wide, 19¼" high, 20¼" deep (483 x 489 x 514 mm).

Weight: net 118 lbs (53 kg), shipping 153 lbs (69 kg) (cabinet); net 108 lbs (49 kg), shipping 153 lbs (69 kg) (rack mount)

Price: hp 524C, $2600 (cabinet); hp 524CR, $2600 (rack mount); hp 524D, $2350 (cabinet); hp 524DR, $2350 (rack mount); with 4-line (1-2-2-4 "1" state positive); BCD output and reference voltage for driving 562A Digital Recorder, price on request.

Options

01. Single-line voltage coded decimal output (staircase) for operating 560A Digital Recorder; 524D-95A installed, add $75 (MS 3102A-22-14S output connector).

02. 10-line decimal code output and 562A-16C Cable for operating 561B Digital Recorder or remote indicator; 524C-95B installed (524C,CR only), add $150 (Amphenol 57-20500 output connector).

525A Frequency Converter Unit

(plugged into 524 Electronic Counter)

Range: as amplifier, 10 cps to 10.1 mc; as converter, 10.1 mc to 100 mc.

Accuracy: retains accuracy of counter.

Resolution: 0.1 cycle to 1000 cycles, depending on gate time.

Input voltage: 0.1 volt to 10 volts rms, 10 cps to 10 mc; 10 mv to 1 volt rms, 10 mc to 100 mc.

Input impedance: approximately 1 megohm shunted by 40 pf, 10 cps to 10 mc; approximately 50 ohms, 10 mc to 100 mc.

Tuning indicator: tuning eye aids frequency selection, indicates correct voltage level adjustment.

Weight: net 5 lbs (2 kg); shipping 8 lbs (4 kg).

Price: hp 525A, $300.

525B Frequency Converter Unit

(plugged into 524 Electronic Counter)

Range: 100 mc to 220 mc.

Accuracy: retains accuracy of counter.

Resolution: 0.1 cycle to 1000 cycles, depending on gate time.

Input voltage: 0.2 volt rms minimum.

Input impedance: approximately 50 ohms.

Tuning indicator: tuning eye aids frequency selection, indicates correct input voltage.

Weight: net 5 lbs (2 kg); shipping 8 lbs (4 kg).

Price: hp 525B, $300.

525C Frequency Converter Unit

(plugged into 524 Electronic Counter)

Range: as converter for counter, 100 mc to 510 mc; as amplifier for counter, 50 kc to 10.1 mc; direct connection for 0 to 10.1 mc.

Accuracy: retains accuracy of counter.

Resolution: 0.1 cycle to 1000 cycles, depending on gate time.

Input voltage: 20 mv rms minimum, 50 kc to 10.1 mc; 100 mv rms minimum 100 to 510 mc.

Maximum input: 2 v rms from 50 kc to 10.1 mc and 100 to 510 mc.

Input impedance: approximately 700 ohms, 50 kc to 10.1 mc; approximately 50 ohms, 100 mc to 510 mc.

Level indicator: meter aids frequency selection, indicates usable voltage level.

Weight: net 6½ lbs (3 kg); shipping 10 lbs (5 kg).

Price: hp 525C, $475.

526A Video Amplifier Unit

(plugged into 524 Electronic Counter)

Range: 10 cps to 10.1 mc.

Accuracy: retains accuracy of counter.

Minimum input voltage: approximately 10 mv rms.

Level control: meter indicates input signal level, correct voltage adjustment.

Output terminal: BNC connector provides 10 times input voltage from 93-ohm source on the most sensitive range; allows oscilloscope monitoring of input signal without loading circuit.

Reads in: same as basic 524 Counter.

Accessories furnished: supplied with 10505A Probe Assembly, which increases input impedance to 10 megohms shunted by 15 pf; maximum sensitivity using probe is 0.1 volt rms.

Weight: net 5 lbs (2 kg); shipping 7 lbs (3 kg).

Price: hp 526A, $200.

526B Time Interval Unit

(plugged into 524 Electronic Counter)

Range: 1 µsec to 10^7 seconds.

Accuracy: ±1 period of standard frequency counted, ± time base accuracy.

Registration: on 524 Counter.

Input voltage: 1 volt peak minimum, direct-coupled input.

Input impedance: approximately 1 megohm, 40 pf shunt.

Start-stop: independent or common channels.

Trigger slope: positive or negative on start and/or stop channels.

Trigger amplitude: both channels continuously adjustable from −192 to +192 volts.

Standard frequency counted: 10 cps, 1 or 100 kc, 10 mc from 524 counter; or externally applied frequency.

Reads in: sec, msec or µsec; decimal point automatically positioned.

Accessory furnished: 10503A Cable Assembly, 48" RG-58C/U cable terminated with UG-88/U BNC connectors.

Weight: net 5 lbs (2 kg); shipping 7 lbs (3 kg).

Price: hp 526B, $200.

526C Period Multiplier Unit

(plugged into 524 Electronic Counter)

Range: 0 to 100 kc.

Gate time: 1, 10, 100, 1000, and 10,000 cycles of the unknown frequency.

Accuracy: ±1 count ± time base accuracy ± trigger error.

Standard frequency counted: 10 cps, 1 kc, 100 kc, 10 mc or externally applied frequency.

Reads in: seconds, milliseconds, microseconds.

Input voltage: 1 volt rms minimum.

Input impedance: 1 megohm, 40 pf shunt.

Weight: net 5 lbs (2 kg); shipping 7 lbs (3 kg).

Price: hp 526C, $225.

526D Phase Unit

(plugged into 524 Electronic Counter)

Range: phase angle, 0 to 360° lead or lag.

Frequency range: 1 cps to 20 kc.

Reads in: time units with maximum resolution of 0.1 µsec for full frequency range; for frequencies 396 to 404 cps, a frequency multiplier (3600X) provides readings direct in tenths of degrees.

Accuracy: $\pm 0.1° \pm (F_p/F_c) \times 360°$ where F_p is frequency of phase measured signal, and F_c is counted frequency ... assuming noise 65 db below signal and negligible counted frequency error; S/N ratio influences accuracy; accuracy diminishes somewhat below 350 cps when ac coupled; for highest accuracy both inputs should be coupled in the same mode, ac or dc.

Input voltage: 5 to 120 volts rms; usable to 240 v rms.

Input impedance: approximately 1 megohm, 80 pf shunt.

Weight: net 5 lbs (2 kg); shipping 10 lbs (5 kg).

Price: hp 526D, $750; for direct measurement in 0.01° of 800 cps systems, specify H01-526D, price on request.

522B, 523C,D ELECTRONIC COUNTERS

Measure period, time or frequency, 10 cps to 1.2 mc

Advantages:

- Increased sensitivity
- Superior trigger level controls
- Versatility
- Compact, rugged design
- High accuracy
- Easy to operate and maintain

Uses:

- Measure frequency
- Count periodic or random pulses
- Measure period, time interval
- High-accuracy phase measurements
- Totalize events, measure ratios
- Ballistic measurements

523C,D Electronic Counters

High sensitivity and sophisticated trigger level circuitry make the hp 523C and 523D Electronic Counters useful for a broad range of applications. The instruments measure frequency, period, time interval, phase delay, random events and ratios. They also totalize electrical events, periodic or random. The 523C has an in-line display, while the 523D has a neon columnar display. Digital recorder output is optionally available on both instruments.

Specifications, 523C,D

Frequency measurement

Range: 10 cps to 1.2 mc.

Accuracy: ±1 count ± time base accuracy.

Input sensitivity: 0.1 v rms, adjustable to 150 v rms maximum input.

Input trigger levels: stop channel may be used so that only signals meeting conditions set by trigger level controls are counted; slope may be + or −, level −300 to +300 volts.

Input impedance: approximately 1 megohm, 50 pf shunt.

Gate time: 0.001, 0.01, 0.1, 1, 10 seconds.

Reads in: kilocycles, positioned decimal point.

Period measurement

Range: 0.00001 cps to 100 kc.

Accuracy measuring sine waves: ±1 count ± time base accuracy ± trigger error.

Input requirements: 0.1 v rms minimum, direct-coupled.

Input impedance: approx. 1 megohm shunted by 50 pf.

Measurement period: 1 or 10 cycles of unknown.

Standard frequency counted: 1 cps to 1 mc in decade steps or externally applied signal, 10 cps to 1.2 mc, 0.1 v rms minimum.

Reads in: seconds, msec or µsec, positioned decimal point.

Time interval measurement

Range: 1 µsec to 10^6 sec.

Accuracy (pulse input): ±1 count ± time base accuracy.

Input impedance: approximately 1 megohm, 50 pf shunt.

Input requirements: 0.1 v rms minimum; direct- or ac-coupled input.

Start and stop input: separate channels with independent controls; separate or common input.

Start and stop marker output: separate output pulses, each approximately 5 µsec duration and −20 v peak, available at rear of instrument for oscilloscope intensity modulation to mark start and stop points on input waveform; may be combined with Sep-Com switch on rear of instrument.

Trigger slope: pos. or neg. on start and stop channels.

Trigger amplitude: continuously adjustable on both input channels from −300 to +300 v.

Standard frequency counted: 1 cps, 10 cps, 100 cps, 1 kc, 10 kc, 100 kc, 1 mc; external.

Reads in: seconds, msec or µsec; positioned decimal point.

Phase measurement

Range: 1 cps to 20 kc, dc coupled; 50 cps to 20 kc, ac coupled.

Input voltage: 5 to 10 v rms, pure sinusoidal signal.

Accuracy: $\pm 0.1^\circ \pm \left(\frac{f_p}{f_c}\right) \times 360^\circ$ where f_c is the counted frequency and f_p the measured frequency.

Ratio measurement: displays f_1/f_2, or 10 f_1/f_2, with accuracy of ±1 count; f_1, 10 cps to 1.2 mc; f_2, 0.00001 cps to 100 kc ($f_1 > f_2$).

Totalize: electrical events, periodic or random to 999999 at rates to 1,200,000/sec.

General

Registration: 523C, six in-line digital tubes, single line; 523D, six decimal places each indicated by lighted numbers.

Stability: 2 x 10^{-6} per week.

Display time: variable from approximately 0.1 to 10 seconds; display can be held until manually reset.

Self-check: counts of 100 kc or 1 mc.

Output frequencies: available at front panel; 1 cps, 10 cps, 100 cps, 1 kc, 10 kc rectangular; 100 kc and 1 mc sine wave, 0.5 v p-p; stability 2/10^6 per week.

External standard: 100 kc from external primary standard can be applied to unit for highest accuracy; minimum input, 1 v rms.

Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 350 w.

Dimensions: cabinet: 20½" wide, 11¼" high, 18¾" deep (521 x 286 x 476 mm); rack mount: 19" wide, 8¾" high, 16¼" deep (483 x 222 x 413 mm).

Weight: net 48 lbs (22 kg), shipping 78 lbs (35 kg) (cabinet); net 48 lbs (22 kg), shipping 61 lbs (28 kg) (rack mount).

Accessories furnished: two 10503A Cable Assemblies.

Accessories available: remote indicator for 523C, 523CR and interconnecting cable (100' maximum), prices on request.

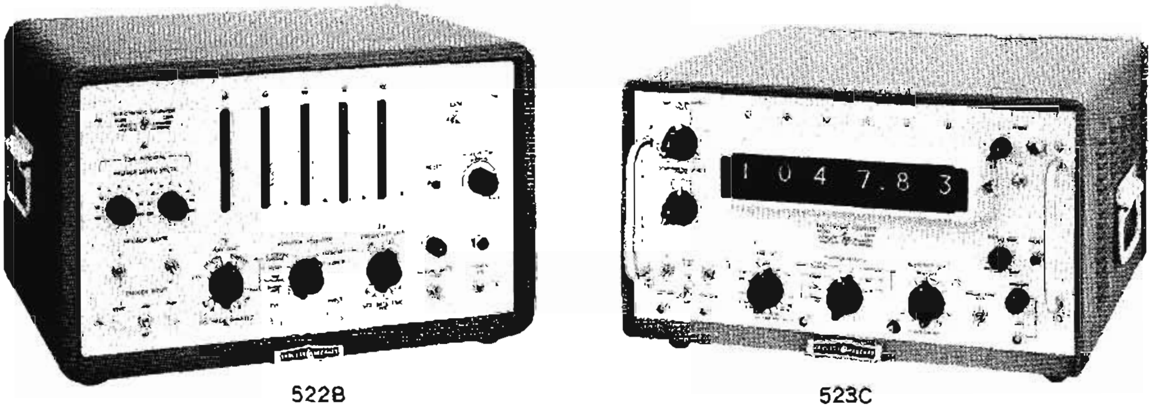
Digital recorder kits for field installation: 523D-95A Adapter Kit for operating 560A Digital Recorder from 523C or 523D, $45; 523C-95B Adapter Kit for operating 561B Digital Recorder from 523C, $45.

Price: hp 523C, $1750 (cabinet); hp 523CR, $1750 (rack mount); hp 523D, $1500 (cabinet); hp 523DR, $1500 (rack mount).

Options

01. Single-line decimal code (staircase) for operating 560A Digital Recorder, add $45.

02. 10-line decimal code output for operating 561B Digital Recorder or remote indicator, 523C only, add $45.



522B 523C

Special output

Four-line BCD output (1-2-2-4, "1" state positive) available for driving 562A Digital Recorder; 580A, 581A Digital-to-Analog Converters; Dymec instruments, or data processing equipment, prices on request.

522B Electronic Counter

Versatile, low-cost precision counter covers 10 cps to 120 kc — The all-purpose hp 522B Counter measures frequency, period and time interval. Results are displayed automatically in direct-reading form—cps, kc, seconds or milliseconds. Reliable and accurate readings make measurement quick and convenient, even for unskilled personnel. The counter can be supplied with digital recorder output for a small additional charge.

Specifications, 522B

Frequency measurement

Range: 10 cps to 120 kc (220 kc optional).

Accuracy: ±1 count ± time base accuracy.

Stability: $1/10^5$/week or better.

Input requirements: 0.2 volt rms minimum; input is direct-coupled (0.5 v rms above 120 kc with 220 kc option).

Input impedance: approximately 1 megohm, 50 pf shunt.

Gate time: 0.001, 0.01, 0.1, 1, 10 sec; manual control extends to any multiple of 1 or 10 sec.

Display time: variable 0.1 to 10 sec in steps of gate time selected or until manually reset.

Reads in: cps or kc, decimal point indicated.

Period measurement

Range: 0.00001 cps to 10 kc; output pulse available to actuate trigger circuit for mechanical register.

Accuracy: ±1 count ± time base accuracy ± trigger error.

Input requirements: 0.2 v rms min.; direct-coupled input.

Input impedance: approximately 1 megohm, 50 pf shunt.

Gate time: one or ten cycles of unknown frequency; may be extended to any number of cycles of unknown frequency lower than 50 cps by manual control.

Standard frequency counted: 1, 10, 100 cps; 1, 10, 100 kc; external.

Display time: variable from 0.1 to 10 seconds in steps of period being measured or until manually reset.

Reads in: seconds or msec, decimal point indicated.

Time interval measurement

Range: 10 μsec to 100,000 seconds (27.8 hrs.).

Accuracy: ±1 count ± time base accuracy.

Input requirements: 1 v peak min.; direct-coupled input.

Input impedance: approx. 250,000 ohms, 50 pf shunt.

Start and stop: independent or common channels.

Trigger slope: + or − on start and/or stop channels.

Trigger amplitude: continuously adjustable on both channels from −100 to +100 volts.

Standard frequency counted: same as for period measurement.

Display time: same as for period measurement.

Reads in: seconds or msec, decimal point indicated.

General

Power: 115 or 230 v ±10%, 50 to 60 cps, 260 w.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14¼" deep (527 x 324 x 362 mm); rack mount: 19" wide, 10½" high, 13⅝" deep (483 x 267 x 346 mm).

Weight: net 50 lbs (22 kg), shipping 60 lbs (26 kg) (cabinet); net 43 lbs (19 kg), shipping 57 lbs (25 kg) (rack mount).

Price: hp 522B, $950 (cabinet); hp 522BR, $950 (rack mount); with staircase output (for 560A operation) specify Option 01., add $45. For 220 kc operation, specify Option 02., add $35; BCD output (1-2-2-4) available, price on request.

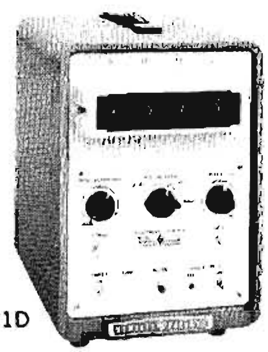
521 SERIES INDUSTRIAL COUNTERS

Low cost, flexible, easy to use; 1 cps to 1.2 mc

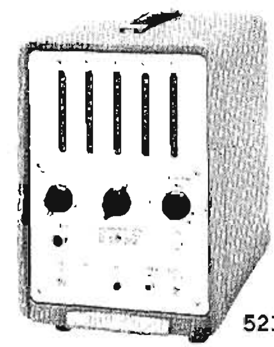
Frequency, speed and random events, such as nuclear phenomena, occurring over a preselected time, are measured quickly and accurately by any one of the five low-cost electronic counters in the Hewlett-Packard 521 Series.

When connected to a suitable transducer that converts mechanical events into electrical pulses, the electronic counters measure weight, pressure, temperature, rps, rpm and other quantities that can be related to frequency.

Adapting the 521 Electronic Counters for recorder operation is conveniently done by the use of an adapter kit, installed by either the factory or the customer. It allows a permanent record of information to be acquired through some appropriate Hewlett-Packard digital recorder — 560A (staircase) or 561B (10-line) (page 77), or 562A (BCD) (page 76)— for analysis or future reference. Additionally, the kit provides compatibility between the counters and the 580A and 581A Digital-to-Analog Converters (page 79), so that chart recorders may be used for analog recordings of frequency drift or other type of signal source variation.



521D



521C

hp Model	521A	521C	521D	521E	521G
Maximum frequency	120 kc (220 kc with Option 03.)	120 kc (220 kc with Option 03.)	120 kc (220 kc with Option 03.)	120 kc (220 kc with Option 03.)	1.2 mc
Accuracy	±1 count, ± line accuracy, approx. 0.1% (0.01% with Option 04.)	±1 count, ±0.01%	±1 count, ± line accuracy, approx. 0.1% (0.01% with Option 04.)	±1 count, ±0.01%	±1 count, ± line accuracy, approx. 0.1% (0.01% with Option 04.)
Registration	4 places, neon display capacity: 9,999	5 places, neon display capacity: 99,999	4 places, digital display capacity: 9,999	5 places, digital display capacity: 99,999	5 places, neon display capacity: 99,999
Gate time	0.1, 1 second, manual, ext.	0.1, 1, 10 seconds, manual, ext.	0.1, 1 second, manual, ext.	0.1, 1, 10 seconds, manual, ext.	0.1, 1 second, manual, ext.
Power	115 or 230 v, 50 to 60 cps, approx. 160 w on 115-volt line (add 10 w for crystal time base unit)				
Size (cabinet)	9¾" wide, 15¼" high, 14¼" deep (248 x 387 x 362 mm)		9¾" wide, 15¼" high, 15½" deep (248 x 387 x 394 mm)		9¾" wide, 15¼" high, 14¼" deep (248 x 387 x 362 mm)
Price: cabinet or rack mount	$600	$715	$850	$1050	$700

Input: 0.2 volt, rms, minimum, or output from 1P41 Phototube (or equal); 0.5 volt rms required at frequencies above 120 kc with 220 kc (Option 03.); continuously adjustable control for reducing sensitivity to overcome noise.

Input impedance: approximately 1 megohm, 50 pf shunt (500 K for "Phototube Jack").

Display time: variable from gate time to approximately 15 seconds, or until manually reset.

Reads in: cps and rps or rpm with 506A or 508A Tachometer accessories (page 69).

Weight: net 28 lbs (13 kg), shipping 37½ lbs (17 kg) (cabinet); net 26 lbs (12 kg), shipping 41½ lbs (19 kg) (rack mount).

Accessory provided: 10501A Cable Assembly, 44" (RG/58C/U terminated on one end only with UG-88/U type BNC connector).

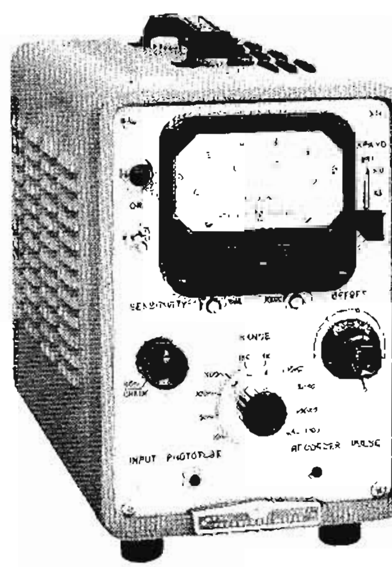
Options: (factory installed or kit form)

01. Adapter for 560A Digital Recorder operation (staircase), all models, add $45; for field installation order Kit No. 521D-95A, $45.
02. Adapter for 561B Digital Recorder operation (10-line) for 521D and 521E, add $45; for field installation order Kit No. 521D-95B, $45.
03. For 220 kc operation for 521A,C,D,E, add $35 (installed).
04. Crystal time base (100 kc) plug-in for 521A,D,G, add $100; for field installation order Kit No. 521C-59B, $100.

Modifications: BCD output (1-2-2-4) for use with 562A Digital Recorder, 580A, 581A Digital-to-Analog Converters; price on request.

500B,C FREQUENCY METERS; 506A, 508A,B,C,D TRANSDUCERS

Measure frequency, 3 cps to 100 kc



500B

The hp Model 500B directly measures the frequency of an alternating voltage from 3 cps to 100 kc. 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 cps to 100 kc, 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 cps 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 megohm 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 kc 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 ±100 ohms.
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 volts ±10%, 50 to 1000 cps, 110 watts.
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, $150; 508A, B,C,D Tachometer Generators, $125 each; 500B-95A Accessory Meter for remote indication (operates from recorder jack), $55.
Price: hp 500B, $335 (cabinet); hp 500BR, $335 (rack mount).

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: hp 500C, $345 (cabinet); hp 500CR, $345 (rack mount).

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 megohm or more impedance) with reflecting and absorbing surfaces ¾" square.
Light source: 21 candlepower, 6 volts automotive bulb.
Phototube: Type 1P41.
Phototube bias: +70 to +90 v dc (supplied by 500B,C, 521).
Power: 115 or 230 volts ±10%, 50 to 1000 cps, 25 watts.
Dimensions: 22" high, 11" wide maximum (559 x 279 mm).
Weight: net 10 lbs (5 kg); shipping 17 lbs (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 hp 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 frequency: 508A, 60 cycles/rev.; 508B, 100 cycles/rev.; 508C, 120 cycles/rev; 508D, 360 cycles/rev.
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" high, 3½" wide, 3¾" deep (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.

NUCLEAR INSTRUMENTATION

Nuclear instruments detect, count and display the occurrence of nuclear events —alpha and beta particles, neutrons and gamma or x-rays. These different radiations occur in the transition of elements from one state to another.

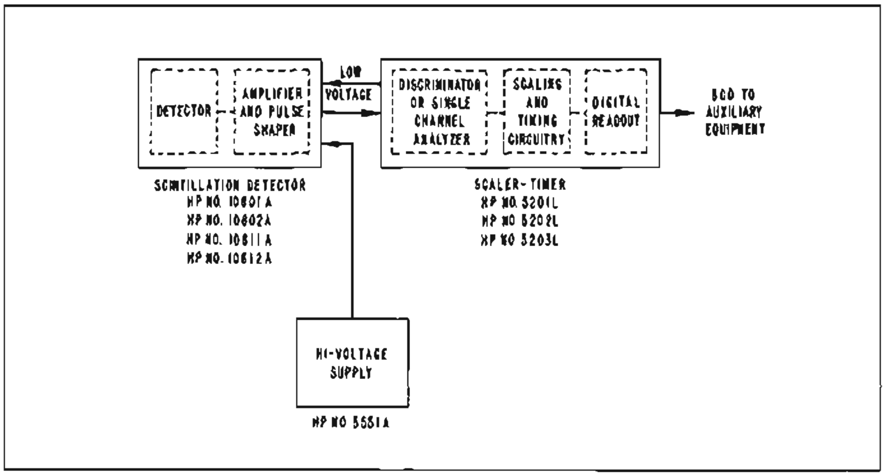


Figure 1. Hewlett-Packard nuclear instrumentation system.

The basic nuclear instrumentation system Hewlett-Packard uses for counting nuclear events 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 the most versatile usage over a wide range of applications. In addition, this format is compatible with instruments in existing gamma spectrometers.

By packaging the NaI(TI) crystal and photomultiplier tube (the integral assembly) and the preamplifier into a detector assembly, by packaging the high-voltage supply separately, and by combining the single-channel analyzer and the scaler-timer in one module, Hewlett-Packard offers instruments grouped so they may be used to count almost every type of nuclear event if the proper detector is used.

There are many types of detectors available, each with an application (type of event counted) for which it is best suited. For example, crystals of sodium iodide activated with thallium, NaI(TI), are particularly suited for detection of gamma radiation. Hewlett-Packard uses this crystal in the integral assemblies in the Models 10601A, 10602A, 10611A and 10612A Scintillation Detectors.

Spectrometer systems

By operating the 5201L Single-Channel Analyzer in the "narrow window—ΔE mode," the system may be used for single-channel pulse height analysis. The precision calibration of the 5201L window enables counting of pulses with peaks falling within a window having a width calibrated between zero and 0.5 volt. The ability to quickly establish a very narrow and calibrated window, with high repeatability, has wide application. With the narrow window the user is able to easily analyze the photo peak(s) of radiation samples.

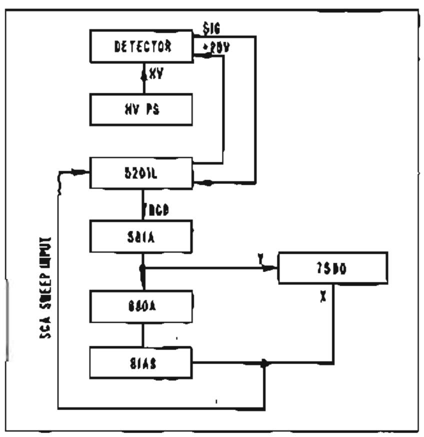


Figure 2. Scanning gamma spectrometer.

If the window of the single-channel analyzer in the 5201L is swept across the full energy spectrum of a sample, providing total energy spectrum information, the system is a scanning gamma spectrometer. Figure 2 shows how the chart drive of a Moseley 680 Strip-Chart Recorder can be used to simultaneously sweep the single-channel analyzer over the energy spectrum and drive the x axis of a Moseley 7590B Nuclear Plotting System, providing both strip-chart and point plot recordings of the energy spectrum of a sample. The Moseley 680 spectrum recording of C_s^{137} is shown in Figure 3.

Substituting the Model 5202L Scaler-Timer for the Model 5201L Single-Channel Analyzer in the spectrometer of Figure 1 provides a simple integral discriminator in place of the single-channel analyzer. This spectrometer is capable of providing gross gamma count information. Connecting a number of scaler-timers with a Dymec DY-2514A Digital Scanner to an hp 562A Digital Recorder and/or recording devices such as the DY-2595 Tape Punch Coupler, DY-2526 Card Punch Coupler or the DY-2546 Magnetic Tape Coupler, provides a means for collecting data from many nuclear sources and in numerous forms. Such a system could be used to monitor the radiation of different types of particles from one source, in one case, or, in another, the strength of gamma radiation at various distances from a source or at different positions about a source.

Applications for gamma spectrometry

The gamma spectrometer configurations described above indicate the far-ranging capability of Hewlett-Packard's nuclear instruments in all areas where gamma (or other nuclear event) spectrometry is of value.

Activation analysis and natural radiation detection are important tools of scientists in both pure and applied scientific research. Radioisotopes are used in medical research, diagnosis and therapy. Industry uses neutron activation analysis in testing for impurity concentrations in products of all forms. For example, the semiconductor industry uses the ability of gamma spectrometers to detect minute quantities of impurities in semiconductor crystals. Law enforcement agencies use spectrometers to detect small quantities of gunpowder, poisons, etc., that have been activated by neutron bombardment, as a tool in crime detection.

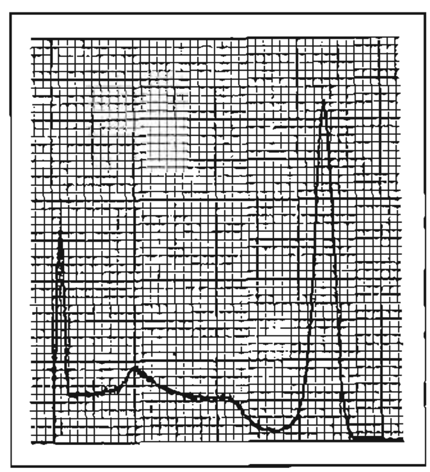


Figure 3. Strip-chart recording of C_s^{137} spectra.

5201L, 5202L, 5203L SCALER-TIMERS

Three models offer broad flexibility

Advantages:

Solid state
Preset time and count
Output for hp printers
6-digit in-line readout
200 nsec pulse resolution

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 nsec. 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" rack mounting configuration (all conversion hardware included at no extra cost).

Specifications, 5201L

General

Resolving time: 200 nsec, Preset Time; 10 μsec, Preset Count.

Maximum count rate: 5×10^6 counts/sec, Preset Time; 1×10^5 counts/sec, Preset Count.

Count time: 0.1 sec x preset number or 0.1 min. x preset number.

Sample time: 200 msec + Gate Time, or Hold.

Sampling mode: "Auto" position allows repeat of function at maximum sampling rate; "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).

Gate in: +5 v to +20 v to count; 0 v for non-count.

Gate out: +20 v when gate open, 0 v when gate closed.

Reset: (a) front-panel pushbutton or (b) automatic internal reset.

Preset range: N number selectable: 0 to 99,999.

Power: 115 or 230 volts ±10%, 60 cps, 35 watts (50 cps available upon request).

+20 v power supply: output through rear TNC.

Pulse height analyzer

Modes of operation: *(a) integral (E_{min} only), (b) differential with narrow window (E_{min} and $\triangle E$), (c) differential with wide window (E_{min} and E_{max}).

Discriminator range: 0.05 v to 5 v (E_{min} and E_{max} adjustable).

External E_{min} control: 4.95 v to scan complete range.

$\triangle E$ range: 0 to 0.5 v, adjustable.

Polarity: positive or negative (selectable).

Input impedance: 500 ohms, ac-coupled, 1 msec input time constant.

Input pulse length range: 15 to 80 nsec for 200 nsec multiple pulse resolution.

Maximum count rate: 5×10^6 counts/sec.

Input discriminator stability: <0.01%/°C full scale (over specified temperature range and line voltage variations).

Integral linearity: ±0.25% of full scale, with pulse rise time-constant of 0.25 μsec and decay time-constant of 1 μsec.

Functions

Preset time: displays number of counts during preset time interval of 0.1 sec or 0.1 min. x preset number N.

Preset count: displays number of 0.1 second or 0.1 minute intervals required for N counts to occur.

Manual: discriminator pulses are totalized (a) pushbutton Start-Stop or (b) +5 to +20 volts applied at rear connector.

Check: counts internal source approx. 80 kc and reads preset N.

Specifications, 5202L

(Same as 5201L except as follows)

Discriminator

Discriminator range: 0.1 to 5 volts (max. peak pulse amplitude).

Polarity: positive or negative (selectable).

Input impedance: 1000 ohms, ac-coupled, 1 msec input time constant.

Input pulse rise time: 7 to 660 nsec.

Input pulse length range: 15 to 80 nsec for 200 nsec multiple pulse resolution.

Maximum count rate: 5×10^6 counts/sec.

Specifications, 5203L

General

Resolving time: 200 nsec.

Maximum count rate: 5×10^6 counts/sec.

Gate In: +5 v to +20 v to count, 0 v for non-count.

Gate out: +20 v when gate is open, 0 v when gate is closed.

*$\triangle E$ 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)

Reset: (a) front-panel pushbutton or (b) automatic internal reset.

Power: 115 or 230 volts ±10%, 60 cps, 35 watts (50 cps available upon request).

+20 v power supply: output at rear TNC.

Discriminators: same as 5202L

Functions

Check: totalize internal source of approx. 80 kc 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 volts.

Negative state level: −8 volts.

Reference levels: +17.6 v, 350-ohm source impedance, −6.9 v, 1000-ohm source impedance.

Print command: +28 volt step, from 2700 ohms in series with 1000 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 x 3-3/16" high x 11¼" deep (426 x 97 x 286 mm).

Weight: net 15 lbs (6,8 kg); shipping 24 lbs (11 kg).

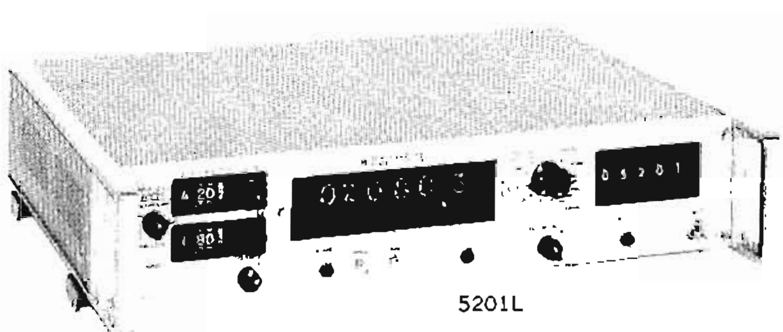
Accessories furnished (5201L, 5202L and 5203L): two 10503A Cables, 4' long, BNC connectors; circuit board extenders; detachable power cord.

Prices: on request.

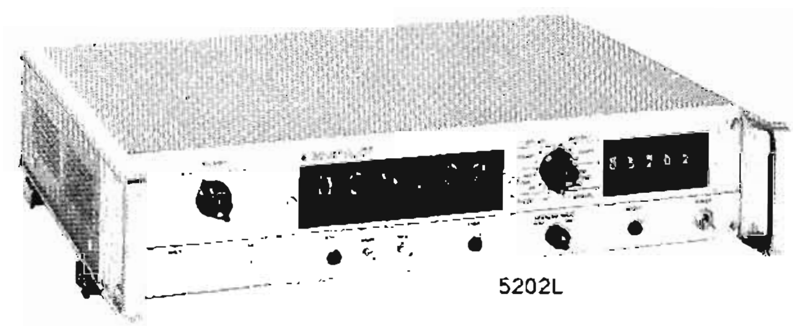
Miscellaneous

Remote operation for (5201L and 5202L): as an optional extra, N can be preset remotely by appropriate closure at rear-panel connector.

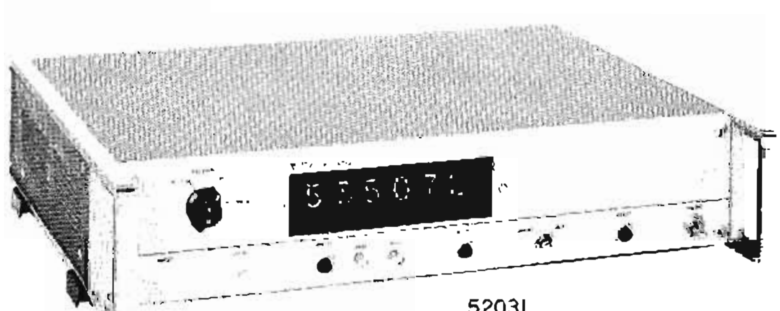
NEW



5201L



5202L



5203L

10601A, 10602A, 10611A, 10612A SCINTILLATION DETECTORS; 5551A POWER SUPPLY

For gamma ray detection

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 solid-state amplifier, with sufficient gain and pulse shaping characteristics to directly drive a single channel analyzer without a linear amplifier, completes the scintillation detector.

The hp scintillation detectors are available in both solid and well configurations, with 2 x 2 and 3 x 3 NaI (Tl) crystals. A magnetic shield is utilized in all detectors, which 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.

Specifications, 10601A

Crystal: 2" x 2" solid.
Resolution: <8% FWHM*.
Stability: <2%**.
Overall dimensions: 2¾" diameter x 11¾" long (70 x 298 mm), nominal.
Weight: net 4 lbs (1,8 kg).

Specifications, 10602A

Crystal: 3" x 3" solid.
Resolution: <8% FWHM*.
Stability: <1%**.
Overall dimensions: 3½" diameter x 13¼" long (82 x 336 mm), nominal.
Weight: net 7½ lbs (3,4 kg).

Specifications, 10611A

Crystal: 2" x 2" well.
Resolution: <10% FWHM*.
Stability: <2%**.
Overall dimensions: 2¾" diameter x 12¼" long (70 x 311 mm), nominal.
Well dimensions: 1" diameter x 1-35/64" deep (25 x 39 mm).
Weight: net 4 lbs (1,8 kg).

Specifications, 10612A

Crystal: 3" x 3" well.
Resolution: <10% FWHM*.
Stability: <1%**.
Overall dimensions: 3½" diameter x 13¼" long (82 x 336 mm), nominal.
Well dimensions: 21/32" diameter x 2" deep (17 x 51 mm).
Weight: net 7½ lbs (3,4 kg).

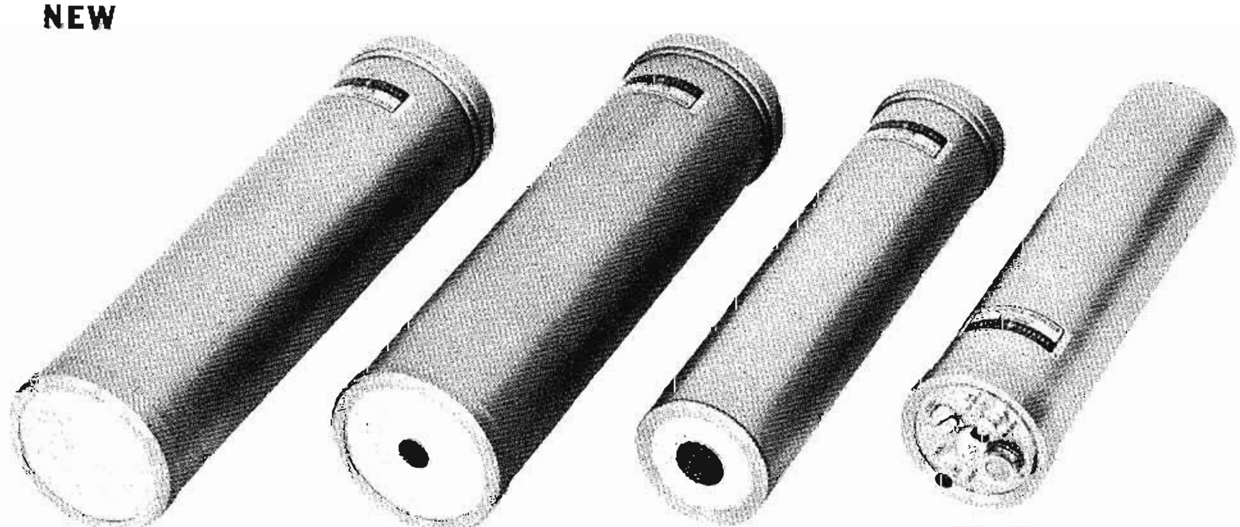
Specifications, all models

(integral assembly)

Crystal: NaI (Tl)

*FWHM = full width at half maximum of Cs^{137} photo-peak.
**pulse height change at 25°C over 24 hours or 1000 cpm/10,000 cpm count rate shift at 25°C, using a Cs^{137} source, 0.662 mev.

NEW



10602A 10612A 10611A 10601A

Typical output: LTC (Long Time Constant): 0.3 v/mev; X1 gain (Short Time Constant): 1.8 v/mev; X10 gain (Short Time Constant): 18 v/mev.

Magnetic field effects: ac: $< \pm 0.1\%$ change in resolution (4 gauss rms, 60 cps field; dc: $< \pm 0.5\%$ change in pulse height (± 2 gauss field).

Amplifier

High-voltage input: 1500 volts (max.), 7.35 megohms (approx.).

Low-voltage input: +20 volts at 21 ma (+24 volts maximum input).

Output pulse shape: LTC: 0.25 μsec rise time-constant, 12.5 μsec fall time-constant, 30 μsec fall time, peak to 0 volts; X1: 0.25 μsec rise time-constant, 1 μsec fall time-constant, 3 μsec fall time, peak to 0 volts; X10: 0.25 μsec rise time-constant, 1 μsec fall time-constant, 3 μsec fall time, peak to 0 volts.

Maximum output: LTC: +4 volts; X1: +10 volts; X10: +10 volts.

Output impedance: 50 ohms nominal (with 100 μf in series).

Focus control: to adjust photomultiplier tube for maximum gain and resolution.

Gain switch: 3-position slide switch: LTC, X1 and X10.

Accessory furnished: one 10517A Cable 4′ long, TNC connectors.

Price: on request.

5551A Power Supply

The Hewlett-Packard Model 5551A High-Voltage Power Supply is designed to supply the high voltage (170 v to 1615 v) requirements of the photomultiplier in a gamma scintillation detector assembly. High stability and broad voltage range (voltage ranges are overlapped with an accurate vernier adjustment) make this instrument valuable in numerous other experimental and laboratory applications.

The 5551A utilizes standard components operating well within their design range. This, coupled with conservative overall design means long, trouble-free operation, plus ease of maintenance. As a safety feature, microswitches break the ac power when either the top or bottom cover is removed, and pushbuttons are provided to remove residual charges from the instrument's capacitors.

This instrument is packaged in Hewlett-Packard's modular cabinet, allowing quick and easy conversion from bench to 19″ rack configuration.

Specifications, 5551A

Electrical

Output voltage: 170 v to 1615 v.

Polarity: positive or negative (selectable).

Output current: 1 ma max.

Output impedance: 20 K.

Line regulation: $\pm 0.01\%$ for $\pm 10\%$ line change.

Ripple: $< 0.005\%$ rms.

Power: 115 or 230 volts $\pm 10\%$, 60 cps, 30 watts (50 cps version available upon request).

Physical

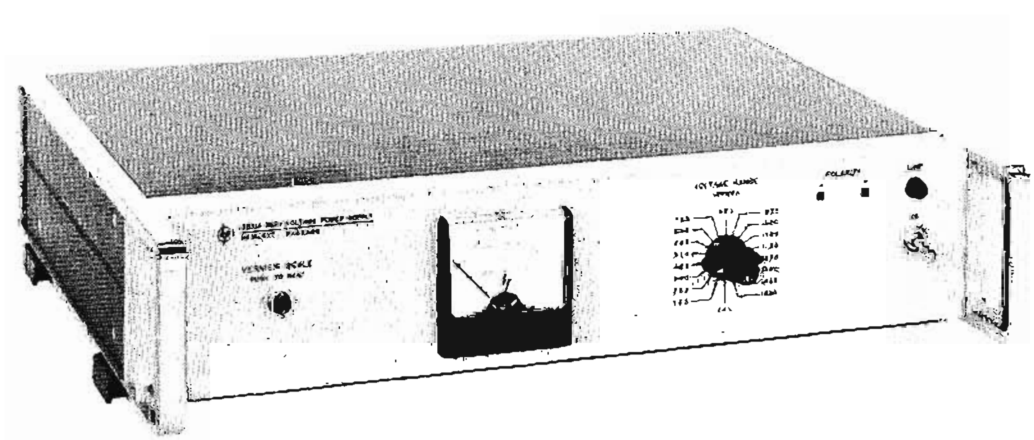
Weight: net 20 lbs (9,1 kg).

Dimensions: 16¾″ wide, 3-3/16″ high, 11¼″ deep (426 x 97 x 286 mm).

Connectors: 2 high-voltage BNC (female) connectors on rear.

Accessories furnished: one 10516A high-voltage cable, 4′ long, high-voltage BNC connectors; detachable power cable.

Price: on request.



5551A

DIGITAL RECORDERS AND ACCESSORIES

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.

Digital recorders

Hewlett-Packard digital recorders are electro-mechanical devices which provide printed records of digital information from electronic counters, digital voltmeters, scaler-timers, etc.

The form of the digital information determines which hp recorder is to be used. The hp Model 560A accepts "single-line" or staircase information for each digit position from the data source, i.e., each position (0 through 9, blank and —) of each print wheel) is determined by a specific voltage level on a single-line connection to that column (digit position). The hp Model 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.

562A Digital Recorder

The hp Model 562A requires a parallel-entry, 4-line binary-coded-decimal input (or 10-line; see options on page 76). 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 unique storage feature in the 562A permits the driving source to transfer its data into the 562A binaries in 2 milliseconds, thus freeing the source to initiate a new measurement. The hp Model 565A is the basic printer mechanism used in the preceding hp 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.

Operator convenience

These digital recorders provide a printed record on 3" fan-folded paper tape (or standard 3" roll). A convenient storage drawer is provided to collect the printed paper tape. The recorder paper is quickly and easily changed.

All hp recorders feature a manual paper advance control to aid observation of the recorder's last printout. A space selector also is provided which permits single- or double-spaced records. A three-position "Record" switch selects standby, momentary or print-on-command operation.

Hold-off signals from the digital recorders (except 565A) prevent external equipment from changing input data while print wheels are being positioned. A print command pulse is required from the data source to initiate a recorder print cycle.

Accuracy

Recorder accuracy is the same as the accuracy of the digital source providing the input. Parallel data entry and low-inertia moving parts allow printing rates as high as 5 lines per second with 11-digit information per line (12 on special order). The high printing rate makes the recorders ideal for recording rapidly changing data such as frequency, period, time, flow rate, pressure, voltage, current or other data available in a digital form. The recorders are designed for continuous, unattended operation. Printing mechanisms are simple, durable and trouble-free, with little maintenance required.

An analog output, suitable for driving either potentiometer or galvanometer recorders is standard on the 560A and optional on the 562A (for those 562A's with either 1-2-2-4 or 1-2-4-8 BCD column boards installed). See pages 76 and 77 for details.

Digital clocks

For providing time-of-day reference to recorded data, all hp recorders (except the 565A) may have a digital clock installed. The hp Model 570A Digital Clock is used with the 560A Digital Recorder, the 571B Digital Clock with the 561B Digital Recorder, and a special clock, the HO3-571B, is used with the 562A Digital Recorder. These hp clocks indicate time to 23 hours, 59 minutes and 59 seconds in an in-line display. 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.

Accessories

Hewlett-Packard digital recorders are supplied with an inked ribbon, packet of printer paper, input cable (omitted in 565A), and a maintenance service kit. Extra inked ribbons (hp Stock No. 9283-0002, $3.50 each) and a 24-packet carton of paper (Stock No. 560A-131A, $20) are available from Hewlett-Packard. A wide range of optional and complementary equipment for the various recorders is listed on pages 76 and 77.

For the 560A, digital recorder adapter kits for field installation in hp counters are available as follows:

hp Counter model	Kit number	Price
521 Series	521D-95A	$45
522B	522B-95A	$45
523B	523B-95A	$45
523C,D	523D-95A	$45
524B	524B-95C	$200
524C,D	524D-95A	$60

Also available for the 560A:

hp 405A-95C Adapter, connects 560A to 405CR Digital Voltmeter, $85.
hp 560A-16H Cable, $80.
hp 560A-16P Extension Cable, 6', 20-conductor, $65.
hp 560A-16Q Extension, 6', 26-conductor, $85.

Additional comparators increase printout of 560A from 6 columns to 11 columns. Comparators plug into sockets in the 560A. hp 560A-58 Plug-In Comparator Unit, $25 each.

561B accessories available include: Digital recorder kits for field installation: hp 521D-95B, $45, for 521D and 521E Counters; hp 523C-95B, $65, for 523C; hp 524C-95B, $165, for 524C; hp 561B-16A Cable, $100; hp 561B-95D Connector, $8.50.

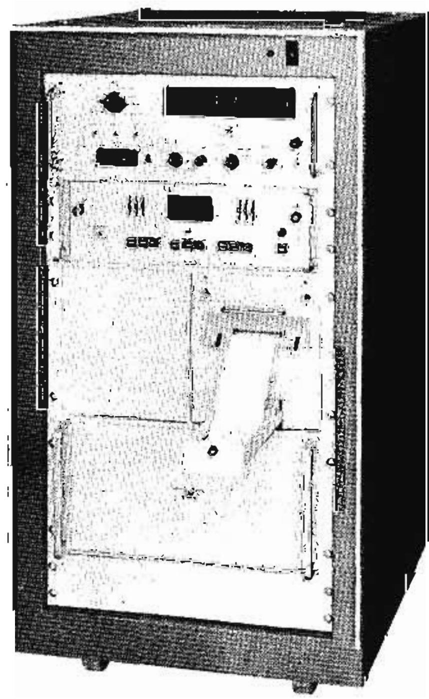


Figure 1. Typical Dymec DY-2010 System incorporating hp 562A Digital Recorder.

562A DIGITAL RECORDER

Flexible data input with information storage

Hewlett-Packard Model 562A Digital Recorder is a solid-state electro-mechanical 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 1-2-2-4 BCD, other 4-line codes or 10-line code by substituting plug-in column boards.

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 (1-2-2-4, 1-2-4-8 or 1-2-4-2) 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, 6 to 20 volts amplitude, 1 v/μsec minimum rise time, 20 μsec or greater in width, ac coupled.

Analog output (optional): (from 1-2-2-4 or 1-2-4-8 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 msec 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.

Line spacing: single or double.

Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 130 w. (4 prints/sec at 50 cps; 50 cps model with 5 prints/sec 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, $1085 (cabinet); hp 562AR, $1060 (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 1-2-2-4 "1" state positive code, add $540

Option 12. For 9-column operation from 1-2-2-4 "1" state positive code, add $765.

Option 13. For 11-column operation from 1-2-2-4 "1" state positive code, add $993.

Option 14. For operation with 5245L; 10-column operation; prints measurement unit and indicates decimal position—e.g., 16942.496 kc would be printed as 3 kc 16942496; the first digit shows how far to move the decimal to the left; add $865.

Options, Group 2, column boards

Option 21. 1-2-2-4 "1" state positive, $75 each.
Option 22. 1-2-4-8 "1" state positive, $75 each.
Option 23. 1-2-4-8 "1" state negative, $75 each.
Option 24. 1-2-2-4 "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. 1-2-4-2 "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.

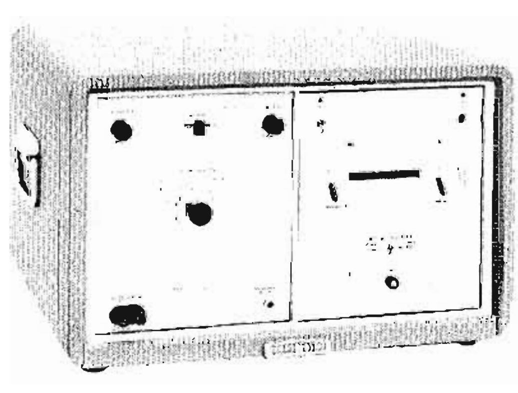
Option 32. Input cable, for up to 9 BCD columns or three 10-line columns, $35.

Option 33. 10-line input connector assembly for up to 3 columns, $35.

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 1-2-2-4 boards), $175.
Option 42. Analog output (from 1-2-4-8 boards), $175.



560A, 561B, 565A DIGITAL RECORDERS

Print 11-digit information at rates of 5 lines per second

Similar in operation to the hp 562A, the 560A Digital Recorder accepts parallel entry staircase inputs, and the hp 561B Digital Recorder accepts 10-line decimal code inputs. The hp 565A Printer Mechanism is mechanically similar to the mechanism employed in the 560A, 561B and 562A Recorders. It is designed specifically for use in custom systems.

Specifications, 560A, 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: 560A: parallel entry staircase voltages, staircase descends from +135 v at count of zero to +55 v at count of nine; 561B: decimal code, 10 lines, plus 2 lines for blank and minus sign for each column.

Driving sources: 560A: hp electronic counters which have staircase output recorder kits installed, 405A-95C Adapter, or other sources providing appropriate input voltages; 561B: hp electronic counters (521D, 521E, 523C, 524C; pages 64-68) with recorder kits and 405CR Digital Voltmeter (page 153), 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 μsec or greater in width, 1 v/μsec 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 watts, (250 watts for 560A) 50 to 60 cps (4 prints/sec maximum at 50 cps); 50 cps model available which retains 5 print/sec capability.

Dimensions: cabinet: 20¾" wide, 12½" high, 18½" deep (527 x 324 x 470 mm); rack mount: 19" wide, 10-15/32" high, 16½" deep (483 x 266 x 419 mm).

Weight: 560A: net 60 lbs (28,5 kg), shipping 82 lbs (38 kg) (cabinet); net 55 lbs (25 kg), shipping 79 lbs (35,5 kg) (rack mount). 561B: net 42 lbs (19 kg), shipping 61 lbs (28 kg) (cabinet); net 30 lbs (18 kg), shipping 62 lbs (28 kg) (rack mount).

Accessories available: 560A-131A folded paper tape, 24-packet carton, $20; 560A: 9283-0602 inked ribbon, $3.50, 560A-16P Extension Cable, 6 ft. (1830 mm) long, 20-conductor, $65, 560A-16Q Extension Cable, 6 ft. (1830 mm) long, 26-conductor, $85; 561B: 561B-16A Cable, $100, 561B-95D Connectors (mates with J101 or J102), $8.50.

Accessories furnished: 560A and 561B: 9281-0018 folded paper tape, one packet, 9283-0002 inked ribbon, 560A-95N Digital Recorder Service Kit; 560A: 560A-16H Cable, accommodates 8 columns, connects to Option 01.-equipped hp vacuum tube counters and 405CR Digital Voltmeter; 561B; 561B-16A Cable, accommodates 6 columns, connects to Option 02.-equipped vacuum tube counters.

Price: hp 560A, $1400 (cabinet); hp 560AR, $1385 (rack mount); additional 560A-58 Plug-in Comparators (one required per column; 6 furnished), $125 each; hp 561B, $1150 (cabinet); hp 561BR, $1135 (rack mount).

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 cps (50 cps provides 4 prints/sec max.).

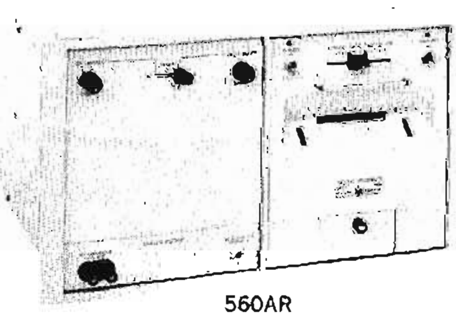
Clutch solenoid: 240 to 260 v dc, 75 ma (operates for approx. 15 msec to start printing cycle); coil designed for vacuum tube switching networks; lower voltage coils are available on special order for transistor switching.

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 available on special order for transistor switching.

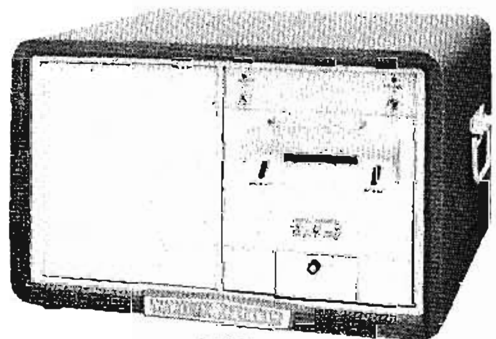
Dimensions: 9¾" high, 8⅜" wide, 9¾" deep (248 x 213 x 248 mm).

Weight: net 15 lbs (7 kg); shipping 20 lbs (9 kg).

Price: hp 565A (with high-voltage clutch and pawl coils for vacuum tube drive), $750; for 115 v, 50 cps operation with 5 prints/sec capability specify H27-565A, $763; for 230 v, 50 cps operation with 5 prints/sec capability specify H24-565A, $765.



560AR



561B

DY-2514A DIGITAL SCANNER

Transmit digital data from multiple sources to one recording device

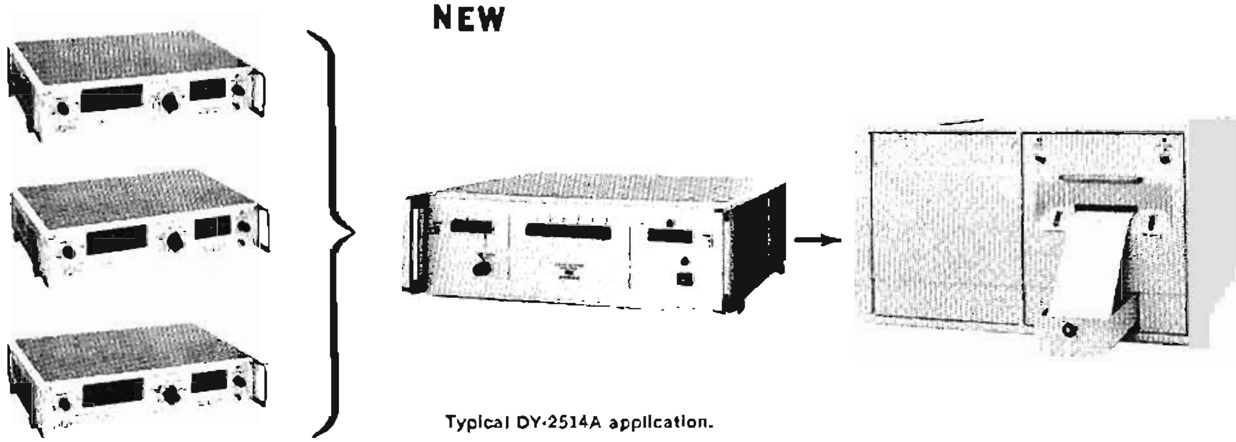
The Dymec DY-2514A Digital Scanner provides for sequential scanning of multiple digital measuring instruments, such as electronic counters, nuclear scalers, digital voltmeters or digital clocks, and couples their outputs into a single set of recording equipment such as a digital recorder, card or tape punch or magnetic tape recorder.

The basic DY-2514A accepts up to 8 digits of BCD data from up to 3 sources. Easily added modifications expand this to 6 sources and 10 digits per source. By cascading scanners, data from up to 36 sources can be transferred to a single recorder. In all cases, the output recorder is provided source identification. It sequentially interrogates all selected data sources and transmits these data directly to the recorder by means of contact closures, necessitating only that source outputs be compatible with recorder input.

Sources to be recorded are selected by depressing pushbuttons on the 2514A front panel. (All sources not selected can be operated as independent instruments.) Upon command, the 2514A scans all selected sources in sequence. This command can be provided by manual depression of a front-panel pushbutton, by remote contact closure or at timed intervals determined by a clock. Three operating modes permit: (1) manual advance one channel at a time through all selected channels each time a front-panel pushbutton is depressed; (2) single scan of all selected channels; (3) continuous scanning of all selected channels.

Sources can be scanned in either of two modes: In Sequential mode, the 2514A interrogates selected sources in sequence, passing from one source to the next when data from the previous source have been recorded. Hold-off signals to all selected sources are removed simultaneously at end of scan. In Random mode, the DY-2514A interrogates all selected sources sequentially, but passes to the next source if data are not available for recording. Hold-off signals are removed individually as data are recorded. If, in a given scan, a source does not have data available, it will be passed over and recorded on a subsequent scan when data become available.

NEW



Typical DY-2514A application.

Specifications

Source-scanner Interface

Number of sources: 3 standard; options expand up to 6.

Digit capacity: 8 digits/source, standard; options expand to 10.

Accuracy: identical to data source.

Data Input: parallel-entry 4-line BCD, any code; binary swing must meet recorder requirements; source-scanner record command and hold-off signals, compatible with all hp solid-state counters.

Scanner-recorder Interface

Digital recorders compatible with DY-2514A: hp M45-562AR Digital Recorder; DY-2526-M19 Card Punch Set; DY-2545-M61 Tape Punch Set; DY-2546-M15 Magnetic Tape Recorder Set.

Source Identification: positive-true 4-2'-2-1 standard; 8-4-2-1 positive-true and negative-true optionally available; "1" state (—0.5 to 0)v at 2.5 ma; "0" state (—10 to −8)v, 1 K impedance, 1 ma max.

Scanner-recorder record command and hold-off signals: compatible with hp digital recorders and Dymec output couplers.

Transfer rate: to 20 sources/sec (depends on recorder).

External select signals: Reset/Start/Stop Commands: dc shift from (−12 to −6)v to (−0.5 to +15)v; input impedance 4.3 K; min. duration 20 μsec; accepts equivalent command from ac-coupled source; requirements for external source select signals same as above.

Power: 115 or 230 v ±10%, 50 to 60 cps, 30 w approx.

Dimensions: 16¾" wide, 5¼" high, 16⅜" deep behind panel (426 x 133 x 416 mm); adapter kit furnished for 19" rack mounting.

Weight: net 30 lbs (13,6 kg); shipping 45 lbs (20,4 kg).

Options: 3 sources, 10 digits/source, add $45 to basic instrument price; 4 sources, 8 digits/source, add $125; 4 sources, 10 digits, add $185; 5 sources, 8 digits, add $170; 5 sources, 10 digits, add $245; 6 sources, 8 digits, add $215; 6 sources, 10 digits, add $305; negative-true 4-2-2-1 source identification, positive- or negative-true 8-4-2-1 identification, add $25 for each; external source selection, add $200; mode to permit cascading 6 slave scanners, add $300; manual data entry of 18 digits, add $350.

Price: DY-2514A for 3 sources, 8 digits/source, $2500.

580A, 581A D/A CONVERTERS; 570A, 571B DIGITAL CLOCKS

High resolution with conventional strip-chart recorders; clocks for timing data

The hp 580 Series 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 all Hewlett-Packard and Dymec solid-state counters, and 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, including nuclear scalers.

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.

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.

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, 1-2-2-4 (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 μsec or greater in width, 6 to 20 volts amplitude.

Transfer time: 1 millisecond.

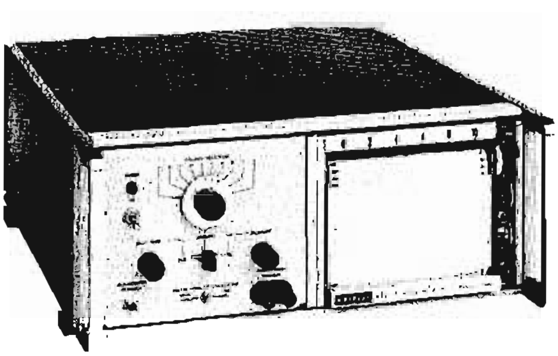
Power: 115 or 230 volts ±10%, 50 to 1000 cps, 11 watts.

Dimensions: 580A: 16¾" wide, 3-15/32" high, 11¼" deep (425 x 9 x 285 mm); 581A: 7-25/32" wide, 6-3/32" high, 8" deep (198 x 155 x 203 mm).

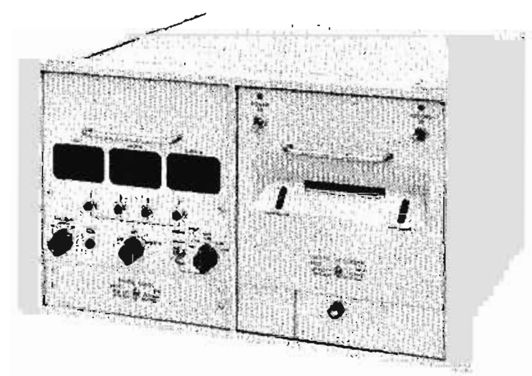
Weight: 580A: net 13 lbs (6 kg), shipping 20 lbs (9 kg); 581A: net 8 lbs (3,5 kg), shipping 13 lbs (6 kg).

Accessory furnished: 562A-16C Cable, 6' (1830 mm) long with an Amphenol 57-30500 connector at each end.

Price: hp 580A, $525; hp 581A, $525.



581A, Moseley 680 Recorder



571B with 561BR Recorder

The 570A, 571B Digital Clocks, which mount in the left side of the hp 560A and 561B Digital Recorders (page 77), provide time-of-day information and control the rates at which measurements are made. They indicate time in hours, minutes and seconds (24-hour basis) in an in-line display. All time digits displayed are available for printing. Clocks may be ordered installed in the respective recorders. In addition, a modified 571B (H03-571B) is available for use with the hp 562A Digital Recorder (page 76).

Specifications, 570A, 571B

Indication: 6 in-line digital display tubes indicate to 23 hours, 59 min, 59 sec; 12-hour format available on special order.

Time base: front-panel time-base switch selects: (1) 60 cps (50 cps available on special order), (2) counter (1 pps from hp counters), (3) external (5 v positive pulses, 200 μsec long, 1 pps; input impedance approximately 500 ohms).

Time print format

570A: program plug at rear of 560A serves all 11 columns of digital recorder; time format determined by wiring of program plug; normally wired to print six time digits on left side of 560A paper; blank also can be programmed in any single column by program plug.

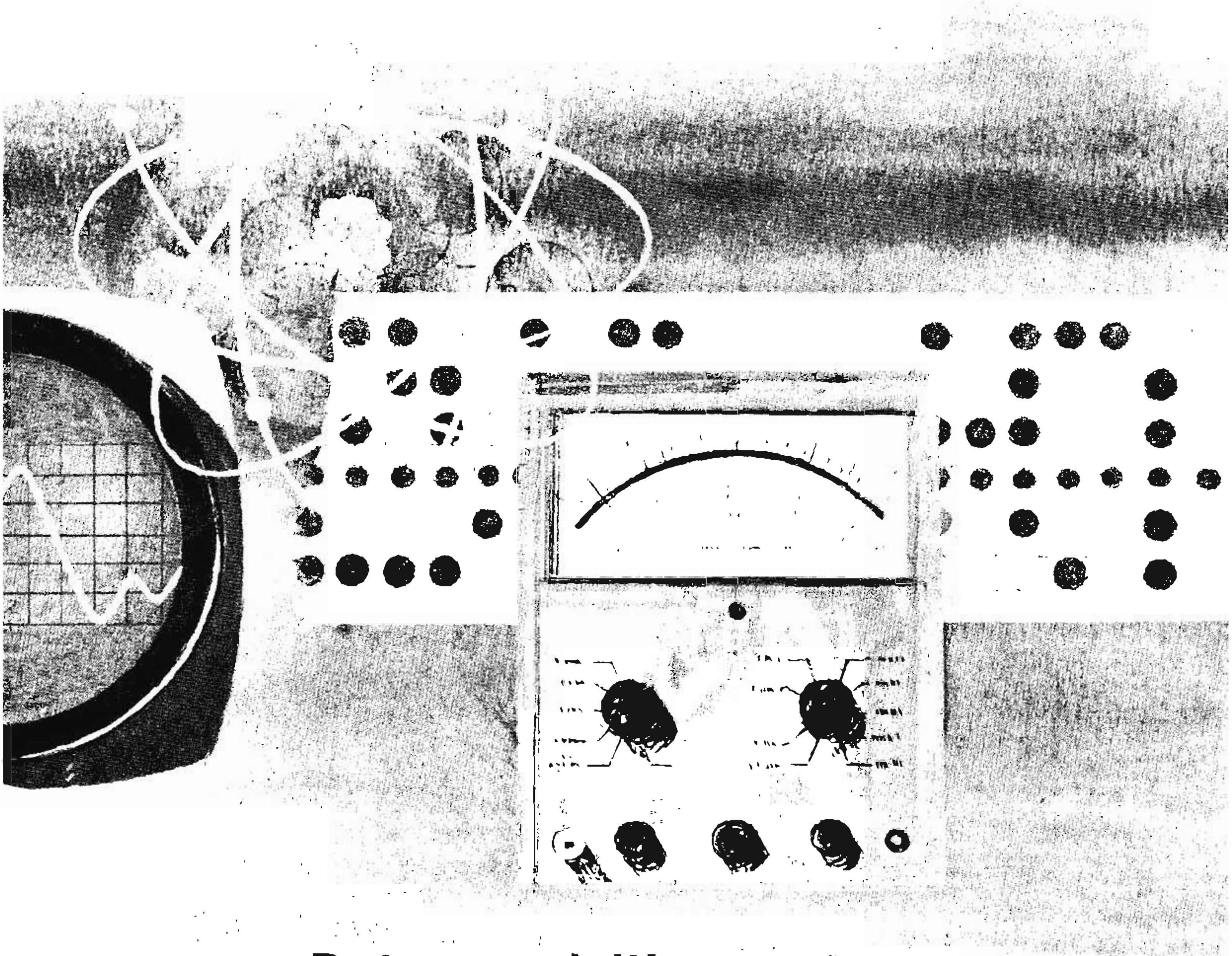
571B: six time digits may be recorded in right-hand six columns of 561B with clock connected to J101 on 561B; with clock cable connected to J102, time digits will be recorded in the five left-hand columns of the 561B, without the tens-of-hours digit.

Weight: net 20 lbs (9 kg); shipping 28 lbs (13 kg).

Power: ac and dc supplied by digital recorder, approximately 15 watts (normally wired to operate on 60 cps).

Price: hp 570A, $1050; hp 571B, $1000.

Because of the many option arrangements for the 570A and 571B, please contact your nearest hp sales office for assistance when ordering or requesting quotations.



Data acquisition systems

DATA ACQUISITION SYSTEMS

Instrumentation systems can be categorized into two basic classes: digital and analog. An analog system usually consists of a set of signal conditioning, measuring and recording equipment for each transducer. In a digital instrumentation system, the measuring and recording equipment are sequentially used by the transducers; and for a given type of measurement, signal conditioning equipment may be shared. Depending on measurement specifications, scanning equipment also may be shared.

Analog data systems are used when wide bandwidth is required or when less accuracy can be tolerated. Digital data acquisition systems are used when the physical process being monitored is slowly varying (narrow bandwidth) and high accuracy and low per-channel cost are required.

Digital systems range in complexity from economical single-channel dc voltage measuring and recording systems to sophisticated, totally automatic multiple-channel systems that measure all electrical parameters, compare against preset limits and even perform limited computation. Systems are available with a wide range of speed and accuracy. Applications span individual data logging to high-speed automatic checkout of space vehicle, missile and aircraft systems.

Since measurement requirements can change rapidly, data acquisition systems must have the flexibility needed for frequent change to cope with new problems. Data systems produced by Hewlett-Packard's Dymec Division employ standard system-oriented instruments, permitting system modification or expansion to be made simply by changing instruments or adding appropriate new instruments.

Where and why data systems are used

Data acquisition systems, in general, are applied in many of the same situations as digital voltmeters. Systems are generally used to measure analog signals originating in two different ways:

1) Direct measurement of electrical quantities. This includes dc and ac voltages, frequency and resistance, and applies typically to areas of electronic component and subassembly testing, environmental and QA testing.

2) Signal inputs from transducers which are in common use, i.e., strain gage, pressure transducer and thermocouples, and including tachometry and flow metering.

Digital systems are generally found wherever multiple installations of transducers or electrical pickups are employed and are frequently referred to as data logging systems, whether measured data is prepared for computer entry or logged for manual study.

There are several reasons why data systems are widely used; however, most can be reduced to economic considerations. Data acquisition systems, such as the Dymec DY-2010 and DY-2013 Series, perform functions which otherwise would be done manually. When the total number of measurements to be made is small and records simple and routine, operating personnel can manually perform the measurement and recording. As the number of measurements increases and arithmetic operations for converting the measurements to usable form become necessary, manual techniques are subject to human error and are time-consuming. Automated data systems used in conjunction with or employing digital computers are the solution for these situations.

They accomplish the measuring, scaling and recording operations in a fraction of the time. Systems are available ranging in capability from simple data gathering to the most complex tasks, at prices from as low as $3000 to several hundred thousand dollars.

Dymec data acquisition systems include four basic series of standard packages engineered for a variety of input and output situations. Specific advantages resulting from standard system design include:

Quick delivery: Since systems are composed of standard instruments and cables, standard production techniques can be employed.

Better specifications: In that each system is a thoroughly engineered and completely tested package, Dymec can guarantee top system specifications. Systems are completely specified on a data sheet. Moreover, ease of system expansion is assured with a wide variety of options.

Greater reliability — through the use of production techniques as applied to standard Hewlett-Packard and Dymec instruments. These techniques have obvious advantages over the "one shot" system that has to be custom engineered and produced.

Low price: Systems are composed exclusively of standard, systems-oriented instruments. Special system engineering prices are not required.

The DY-2010 Series of systems (pages 82-85) measure dc voltage and frequency with both visual readout and permanent output recorded on printed strip, punched card or tape or magnetic tape. Optional equipment permits measurement of ac voltage, resistance, plus dc measurements of ± 10 mv full scale. Programmable high-low limit comparison can be accomplished on any of the above parameters. System operation can be controlled by either pin-board or punched-tape programming. In this series the measuring element (analog-to-digital converter) is the floated and guarded DY-2401C Integrating Digital Voltmeter, which permits accurate low-level measurement even in the presence of severe common mode noise and noise superimposed on the measured signal.

The DY-2013 Series (pages 86, 87), which incorporate the hp 3440A Digital Voltmeter as the measuring device, provide multiple-point scanning capability with output on printed strip, typewritten record or punched card or tape—at an economical price.

The DY-2015 Series incorporate the hp 3460A Digital Voltmeter (pages 146, 147) as the analog to digital converter The systems employ the input scanners and output devices common to the DY-2010 Series, and feature high system speed and new clean-signal accuracy.

DY-2017 Series systems parallel the DY-2010 Series (pages 84, 85) in regard to input and output devices and system auxiliary equipment. All systems incorporate the DY-2417A Data Linearizer (page 83) to permit direct readout in familiar measurement units. These systems apply primarily to areas of transducer measurement where, for example, display of thermocouple outputs in degrees rather than millivolt is needed. The systems eliminate the need for conversion tables and computer conversion.

Dymec data plotting systems

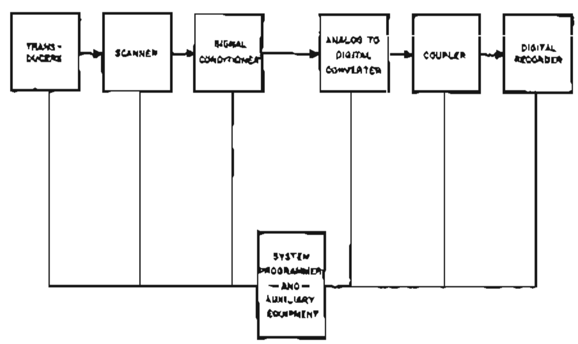
Data plotting instrumentation systems produce graphical plots from digital information stored in punched cards, perforated tape or magnetic tape as produced by a Dymec DY-2010, 2013 or similar data acquisition system. The DY-2031 (page 88) accepts data directly from magnetic or perforated tape, or operates from a punched card reader. Data also can be entered manually on a keyboard.

When digital data is more meaningful in graphical form a paper tape editor, DY-2734B (page 88) is available to provide direct x-y graphical output of data recorded on punched tape. With any of the DY-2010 and 2013 Systems providing a recorded output on punched paper tape, you can measure data—then the data can be played back immediately on a DY-2031 Plotting System. No computer or other equipment or intermediate steps are required.

DY-2010 SERIES DATA ACQUISITION SYSTEMS

Digital data system elements

Elements making up a Dymec digital system may include all or part of those listed and illustrated. 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:



Basic system block diagram

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.

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 ac or dc voltage, resistance, frequency, period, time interval or events occurring in a specified time interval.

Signal conditioner: Translates the analog signal to a form acceptable by the analog-to-digital converter. An example is amplification of low-level signals from thermocouples or strain gage bridges.

Analog-to-digital converter (or digitizer): Converts the analog signal to its equivalent digital form. Output is a visual display and voltage outputs for further processing or recording on a digital recorder.

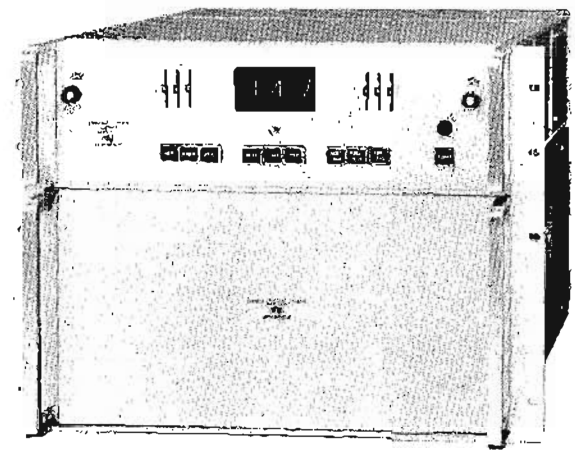
Auxiliary equipment, programmer: Performs subordinate system programming and digital data processing functions within a system. Typical functions include hi-lo limit comparison, linearizing, manual data entry, time.

Coupler: Receives digital information from the analog-to-digital converter and translates it to the proper form for entry into a digital recorder.

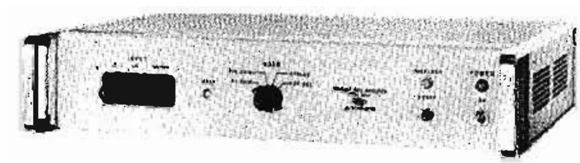
Digital recorder: Records digital information on punched cards, perforated paper tape, magnetic tape, continuous printed paper strips or typewritten pages.

Input scanners

DY-2901A scans 25 3-wire inputs, programs all system functions. May be expanded to 100 channels with DY-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 with pinboard inside scanner. Max. scanning rate 15 channels/second. Visual channel indication and BCD output. Panel height 7" (177 mm). Prices: Dymec DY-2901A Master, $2175; Dymec DY-2902 Slaves (25 channels each), $1975.

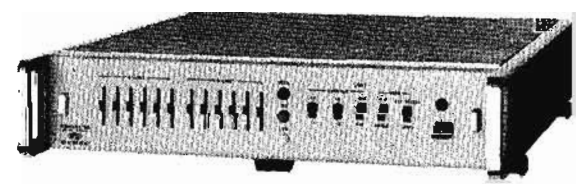


DY-2911

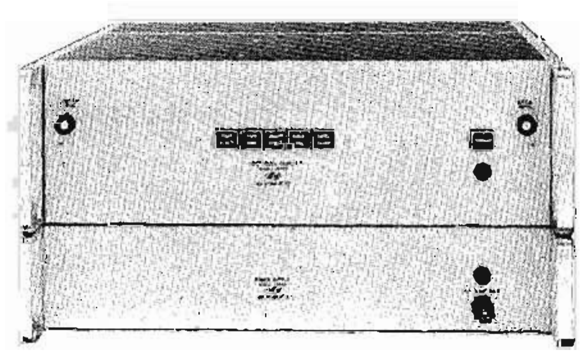


DY-2411A

NEW DY-2401C



NEW DY-2539A



DY-2545

DY-2911 Guarded Crossbar Scanner for rejection of common mode noise. User may select 600 1-wire, 300 2-wire, 200 3-wire or 100 6-wire inputs. Lower and upper scan limits selectable, random access to any channel. Channel being monitored indicated by in-line digital display tubes and BCD output. Roller-mounted switch withdraws from rear for easy cabling. Max. scanning rate 25 channels/second. Panel height 14" (355 mm). Price: Dymec DY-2911, $4650.

Signal conditioners

DY-2410B AC/Ohms Converter (pages 148, 149) used in conjunction with DY-2401C Digital Voltmeter for measurement of ac voltages and resistances. Converter features floated, guarded input similar to voltmeter. Combined common mode rejection is 110 db at 60 cps. DY-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: Dymec DY-2410B, $2250.

DY-2411A Guarded Data Amplifier (pages 148, 149). This floated and guarded amplifier provides the DY-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 DY-2401C is 134 db. DY-2411A features very low noise and zero drift, short settling time for fast data sampling. Panel height 3½" (88 mm). Price: Dymec DY-2411A, $1150.

Analog-to-digital converters

DY-2401C Integrating Digital Voltmeter (pages 148, 149). Features floated and guarded input and is average-reading, leading to an effective common mode noise rejection better than 140 db at all frequencies, including dc. Noise problems with grounded low-level transducers are eliminated with the DY-2401C. 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 applications. BCD outputs provided for digital recording or comparison. Panel height 7" (177 mm). Price: Dymec DY-2401C, $3950.

Auxiliary equipment, programmers

DY-2539A Digital Comparator compares BCD information against single or dual preset limits, providing (respectively) Hi/Go/Lo lamp indications and electrical outputs. Comparisons take less than 3 msec. Instrument can be operated either manually or by external signals. The DY-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: Dymec DY-2539A, $1850 for 4-digit comparison, $1950 for 5-digit, $2050 for 6-digit.

DY-2417A Data Linearizer. Arithmetic conversion of electrical values produced by transducers into familiar units such as rpm, psi, degrees C or F, is usually accomplished after the measurement either with a computer or manually using charts or tables. The DY-2417A permits direct display and recording of transducer outputs in engineering units *at the time of measurement*. Corrections provided are scale factoring, transducer zero offset and linearization. Readout is annunciated at the DY-2401C Digital Voltmeter. Digital techniques are employed, and the capability introduces no significant error into the system accuracy. Panel height 5¼" (133 mm). Price: Dymec DY-2417A, $2750.

DY-2509A Digital Clock is a precision time source used to supply time information to the data system and initiate measurements at predetermined intervals. Time-of-day is available visually and as an electrical output for connection to a recorder. It supplies time information on demand, without ambiguities due to time changes, permitting associated system to operate independently of clock. The instrument is all solid state, features pushbutton selection of timing outputs at intervals from 1 second to 1 hour. Time reference derived internally from line frequency or from external 1 pps signal. Provision for 100 kc external reference optional. Easy manual or remote time set. 4-2'-2-1 BCD output. Panel height 5¼" (133 mm). Price: Dymec DY-2509A, $2685.

DY-2911C Programmer is designed to operate with the DY-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 input 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. DY-2911C is all solid state. Panel height 5¼" (133 mm). Price: Dymec DY-2911C, $3250.

DY-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. Optional tape-search capability allows programmer to search for different instructions on tape in response to comparison results and/or time information supplied by a digital clock. Operation of the entire system can be changed simply by changing programming tape. DY-2560A is all solid state. Panel height 5¼" (133 mm). Price: Dymec DY-2650A, $3425 to $5125, depending on options. Price includes tape reader.

Output couplers, recorders

DY-2545 Coupler operates with Teletype BRPE 11 Tape Punch (Tally 420 Punch optional). Recording speed 110 characters/second. Data storage feature permits new reading during recording cycle, for faster data sampling. Standard model accepts 10 input characters, produces IBM 8-level code. Up to 16 input characters and other 5 to 8-level output codes optional. Simultaneous printer operation optional. All solid state. Panel height 8¾" (222 mm). Price (including punch): Dymec DY-2545, $3900.

Tape punch and spooler available in rack-mount form (DY-2545C). Panel slides up for access. Assembly rolls forward for easy tape loading and unloading. Panel height 12¼" (310 mm). Add $800 to price of DY-2545 set.

DY-2526 Coupler operates with IBM 526 Summary Punch. Standard model accepts 10 input characters, stores data to allow new reading during recording cycle for faster system operation. Format flexibility through IBM patchboard. Optional simultaneous operation of printer. All solid state. Panel height (incl. junction panel) 10½" (266 mm). Price: Dymec DY-2526, $3100.

DY-2546 Coupler operates with a Cook Model 150 Incremental Magnetic Tape Recorder. Records in standard IBM 7-channel NRZ code, with tape format completely flexible as controlled by a diode pinboard. Accepts up to 12 BCD characters and records at 150 characters/second, asynchronous. Data storage permits fast data sampling. Simultaneous printer operation optional. All solid state. Panel height 5¼" (133 mm) for coupler, 24½" (621 mm) for tape deck. Price: Dymec DY-2546, $8465.

DY-2010 SERIES DATA ACQUISITION SYSTEMS

Rapid, accurate measurement of analog signals

Dymec DY-2010 Data Acquisition Systems measure analog data derived from a number of sources and display and record this information in digital form. The series comprises 8 basically different systems numbered from 2010A through 2010J. All incorporate the noise-rejecting DY-2401C Integrating Digital Voltmeter (pages 148, 149) as the analog-to-digital converter, but differ in input and output capabilities.

To present the recorded information in its most useful form, systems are available with a choice of output recording devices. For direct reading by the operator, a print-out on paper tape is provided. If the data is to be entered into a computer, it may be recorded on punched paper tape, punched cards or digital magnetic tape, as appropriate.

Typical inputs are dc and ac voltage, frequencies and resistances. Dymec data systems may be employed to measure any combination of physical parameters that are convertible by transducers to these analog forms.

Digital techniques obtain high measurement resolution and accuracy, high sampling speeds and the ability to transfer the measured information easily to a wide variety of digital recorders. In particular, the DY-2401C Integrating Digital Voltmeter used as the digitizer in the DY-2010 Series features a floated and guarded input, permitting accurate low-level measurements in the presence of severe common mode noise — a common problem with grounded transducers.

All DY-2010 Systems are capable of scanning and logging data from a number of sources either continuously or upon demand. A digital clock can be added for data logging at predetermined time intervals. By virtue of a large choice of standard optional features, the DY-2010 Systems can be tailored to suit a wide range of measurement applications, and it is likely that your requirements can be met by a fully specified standard system. Meeting your needs with standard equipment means modest cost, fast delivery, high reliability derived from standard design and construction, and proved performance. If a standard DY-2010 System does not exactly match your requirements, Dymec will supply modified versions, or advise you about other systems in the Dymec Line that may be closer to your needs. (See pages 86, 87 for information on the modestly priced DY-2013 Series.)

Systems provide direct readout

Special requirements for direct readout of transducers in familiar units (such as psi, rpm, °C) is accomplished by systems including the DY-2417A Data Linearizer. This series of systems, numbered the DY-2017, is specifically designed for application to transducer measurement, and provides the maximum in readout convenience.

Instruments common to all DY-2017 Systems are the DY-2417A Data Linearizer, the guarded crossbar scanner and DY-2401C Integrating Digital Voltmeter. Systems offer a choice of outputs as follows: DY-2017A, printed paper tape; DY-2017B, perforated paper tape; DY-2017C, punched card; DY-2017D, digital magnetic tape.

Standard programming and signal conditioning equipment is available; measurement accuracy is unaffected.

Specifications, DY-2010 Series

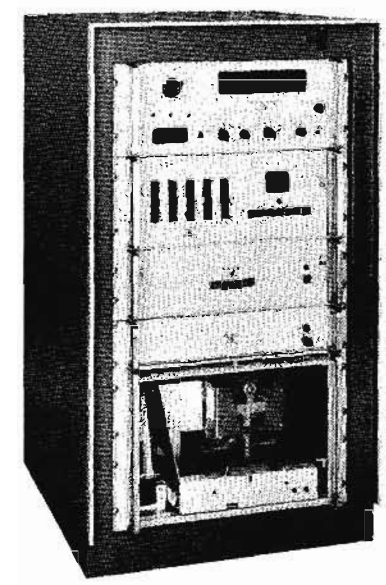
DC voltage measurements

Noise rejection

Overall effective common mode rejection (ratio of common mode signal to its effect on digital display): 2010A, B, E, H: 105 db at all frequencies, 100 db at dc; 2010C, D, F, J: 130 db at all frequencies, including 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): 2010A, B, E, H: 85 db at 60 cps, 100 db at dc; 2010C, D, F, J: 110 db at 60 cps, 130 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 digital display): on 0.1 sec sample period, noise rejection is infinite to 60, 120, 400 cps and all common noise frequencies.



DY-2010B

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%; reset automatically as scanner advances to next channel, or manually.

Input impedance: 10 megohms 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 10 v.

Resolution: three fixed sample periods of 0.01, 0.1 and 1 sec.

Internal calibration source: ±1 v internal standard provided for self-calibration; voltage reference is derived from temperature stabilized zener diode; drift less than ±0.01% in 6 months; internal standard may be compared against external standard; factory adjusted to better than ±0.005% absolute accuracy at 25°C; temperature effect ±0.002%/°C.

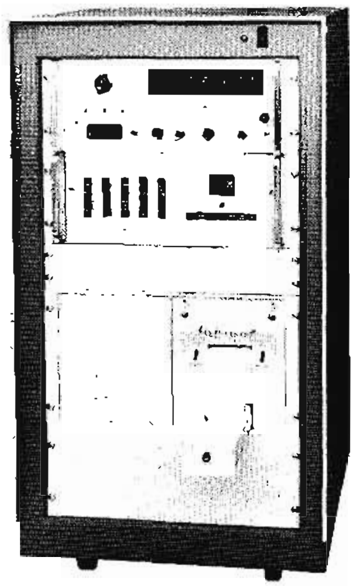
Overall dc accuracy for DY-2010 Systems: (specifications hold for ±10% line voltage change)

Basic accuracy: ±0.01% reading ±0.005% full scale ±1 digit (0 to full scale); ±0.02% reading ±0.005% full scale ±1 digit (at 2X full scale); ±0.025% reading ±0.005% full scale ±1 digit (at 3X full scale); applies to all ranges, 6 months' operation; assumes daily calibration against internal standard, operation at 25°C.

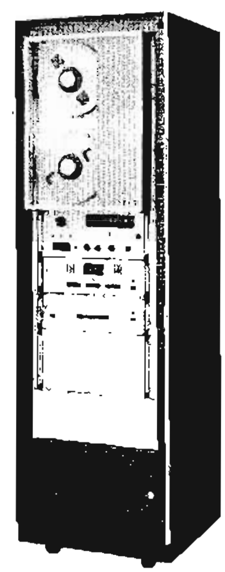
Temperature coefficient: ±0.001% reading per °C, 10 to 40°C; ±0.0015% reading per °C, 40 to 50°C; when calibrated against internal standard at operating temperature: ±0.002% reading ±0.0005% full scale per °C (0.1 v range); ±0.002% reading ±0.0002% full scale per °C (1/10/100/1000 v ranges); when not calibrated at operating temperature, over range 10 to 50°C.

Frequency measurements

Range: 5 cps to 300 kc.



DY-2010A



DY-2010J

Sample period: 0.01, 0.1 or 1 sec.

Accuracy: ±1 digit ± time base accuracy; stability of internal time base, $\pm 2/10^6$ per week over ±5°C temperature range; temperature effect, $\pm 100/10^6$ over 10 to 50°C range; rear BNC and switch provided for external frequency standard; level, 2 v peak to peak into 1.2 K.

Input sensitivity: 0.1 to 100 v rms (front-panel adjustment), or 1 v negative pulses, 2 μsec min. width.

Impedance: 1 megohm shunted by 250 pf.

AC voltage measurements (optional)

Noise rejection

Common mode rejection: 2010A, B, E, H: 85 db at 60 cps; 2010C, D, F, J: 110 db at 60 cps, with 1000 ohms between ground point of source and low side of system input.

Voltage ranges: same as for dc voltage measurements (optional amplifier not applicable); max. input. 750 v peak.

Input impedance: 1 megohm on all ranges, shunted by 400 pf.

Accuracy (steady state): 50 cps to 10 kc, ±0.05% full scale ±0.2% of reading; 10 kc to 30 kc, ±0.06% full scale ±0.4% of reading; 30 to 100 kc, ±0.1% full scale ±0.6% of reading.

Transient error: normal response (frequencies below 400 cps) output settles to ±0.25% of final value in 550 msec; fast response (frequencies above 400 cps): output settles to ±0.25% of final value in 250 nsec.

Resistance measurements (optional)

Noise rejection: resistance measurement circuit is guarded; ac common mode pickup on resistance measurements can be reduced to negligible level by connecting guard to grounded end of test resistance.

Ranges: six ranges from 0.1 K to 10 megohms full scale.

Overranging: to 300% of full scale on all ranges except 10 megohm; input attenuator switched automatically to 10 megohm range if overload exceeds 310%; reset automatically as scanner advances to next channel, or manually.

Resistance measurement accuracy

Range	Measurement current	Accuracy (% of full scale)
0.1 K	10 ma	0.5%
1 K	1 ma	0.05%
10 K	100 μa	0.04%
100 K	10 μa	0.04%
1 M	1 μa	0.15%
10 M	1 μa	0.5%

General

Display: 6-digit in-line readout; polarity, decimal point, measurement units, and overload; storage holds display between readings, switch permits display during count if desired; scanner provides in-line digital indication of channel being monitored

Major specifications, DY-2010 Series

Dymec model	2010A	2010B	2010E	2010H	2010C	2010D	2010F	2010J
Number of input channels	stepping-switch scanner; up to 25 3-wire inputs; to 100 channels with slave scanners				guarded crossbar scanner; up to 200 3-wire inputs; also accepts 100 6-wire, 200 3-wire and 600 1-wire inputs			
Programming	self-programming capability permits measurement of mixed types and levels of signals				punched tape or pinboard programmer may be added to handle mixed types and levels of signals			
Effective common mode rejection		105 db			130 db			
Measurement speed (max. dc volts meas.)	5 channels per sec	10 channels per sec	1 channel per sec	10 channels per sec	5 channels per sec	10 channels per sec	1 channel per sec	10 channels per sec
Output	printed paper tape	perforated paper tape	punched card (on IBM 526)	digital magnetic tape	printed paper tape	perforated paper tape	punched card (on IBM 526)	digital magnetic tape
Price	$8,675	$10,800	$9,885	$15,365	$10,965	$12,850	$12,175	$17,415
Options	time of day; ac voltage, resistance measurements; 10 mv full-scale sensitivity; limit comparison; programmers; cabinet							

DY-2013 SERIES DATA ACQUISITION SYSTEMS

Measure multiple dc or ac voltages automatically, economically

Advantages:

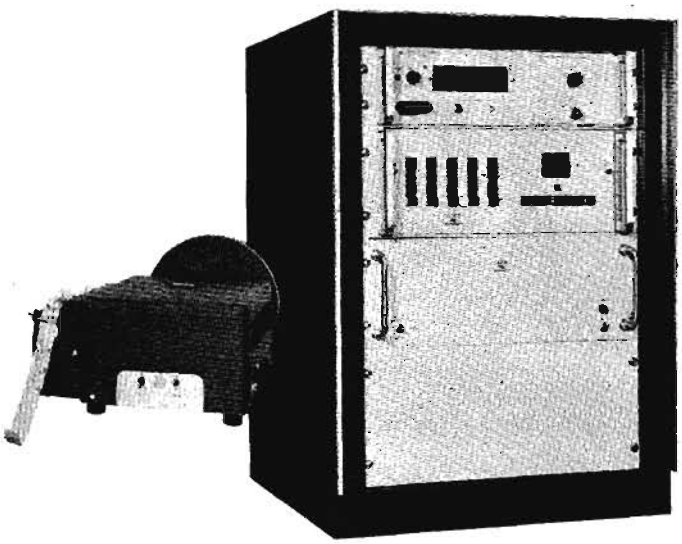
- Constant 10-megohm input impedance
- 30 db rejection of 60 cps noise
- Channel number and measurement data displayed on front-panel digital readout

Uses:

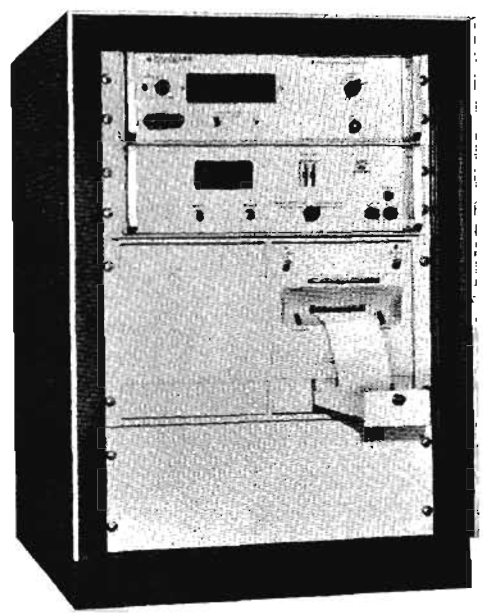
- Digital measurements of dc inputs from millivolts to 750 volts
- Optional ac voltage measurements from 50 cps to 100 kc
- Automatically log measurement function, voltmeter reading, decimal point and channel number for each channel
- Optional 24-hour digital clock for periodic data logging

Dymec DY-2013 Series Data Acquisition Systems seqentially scan many analog sources, convert the data to digital form and measure and record it digitally. Ten different individual systems comprise the series and are numbered 2013A through E and 2013J through N. All DY-2013 Systems use the hp Model 3440A Digital Voltmeter (pages 150-152) as the analog-to-digital converter. (See page 82 for descriptions of basic system functions.) All provide a visual readout and permanent record of the measurement and channel identification.

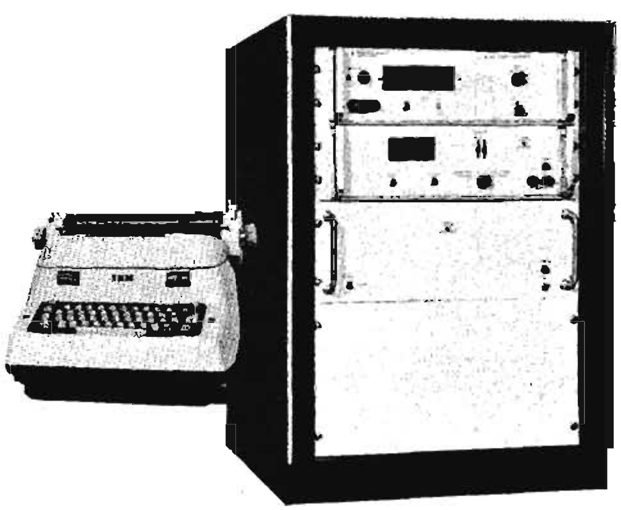
Advantages common to all DY-2013 Systems, arising from use of standard, proved system elements in fully engineered systems: lowest cost, quick delivery, completely specified system performance, high reliability.



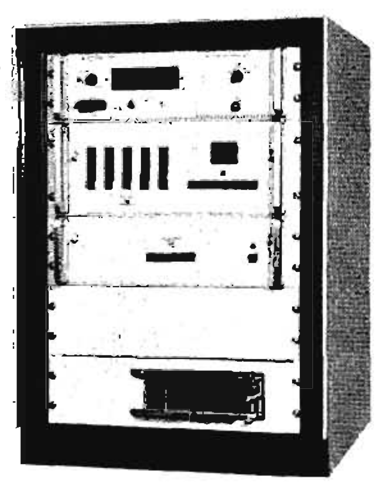
DY-2013K



DY-2013A



DY-2013C



DY-2013N

For maximum usefulness, systems in the series differ in input accommodations and output recording devices. Models DY-2013A,B,C,D,E all use a DY-2900B Scanner with scan upper limit control to confine scanning to occupied channels. Input capacity is 25 2-wire or 50 1-wire channels. DY-2013J,K,L,M,N use a modified version of the DY-2901A Scanner (page 82) with input capacity of 25 3-wire channels (expandable to 100 with slave scanners).

Models DY-2013A and J record on printed paper strip. Each printed line contains the data for one system input channel, including channel identification, data, function (polarity) and indication of decimal point location. DY-2013B and K provide a perforated tape output, using an output coupler (DY-2540-M110) and a Friden SP-2 Tape Punch, to produce tape punched in standard IBM 8-level code. Models DY-2013C and L log typewritten records, using a coupler (DY-2540-M111) and an IBM Model B output writer. Record up to 25 channels per line.

DY-2013D and DY-2013M produce electrical outputs suitable to drive IBM 024 or 026 Card Punch equipment, incorporating a DY-2540-M112 Coupler to serialize the binary-coded decimal output of the digital voltmeter, and present it in a form suitable for the card punch.

DY-2013E and N terminate in a junction panel which is directly suitable for connection to an IBM 526 Card Punch (not supplied with the Dymec system). A DY-2526A-M3 Card Punch Coupler is employed, and a DY-2526B Junction Panel mates directly to the IBM Card Punch input terminal plug.

Many standard options are available. Any DY-2013 System will record 6 digits of time information by adding a 24-hour digital clock. Options also provide input ranges of 100 mv and 1 v, auto-ranging capability, and ac measurement capability.

Specifications

DC voltage measurements

Voltage ranges: 10, 100, 1000 v full scale (max. input 750 v); optionally 0.1, 1, plus above.

Overranging: 5% all ranges except 1000 v, indicated in display window and recorded.

Range selection: manual at front panel standard models; optionally manual or automatic for all or the upper three voltage ranges.

Auto-range change points: upwards at decade, down at 9% full scale.

Input impedance: 10.2 megohms all ranges.

Resolution: 4 digits.

Accuracy (for ±10% line voltage change)

Voltage range	0.1 v*		1 v*		10, 100, 1000 v	
Max. error	±% fs	±% rdg	±% fs	±% rdg	±% fs	±% rdg
Stability (per day, after 1 hour warm-up)	0.03	--	0.03	--	0.03	--
Linearity (referred to straight line through zero and full scale)	0.03	--	0.03	--	0.01	--
Noise (includes scanner offset, ± 1 count ambiguity)	0.015	--	0.015	--	0.01	--
Temperature** (per °C, 10 to 50°C)	0.01	--	0.01	--	0.01	--
Internal calibration source stability (3 months)	--	0.05	--	0.05	--	0.05
Internal calibration source temp. coeff. (per °C)	--	0.002	--	0.002	--	0.002

* With optional hp 3443 DVM Plug-In
** Typical

AC voltage measurements (optional)

Ranges: 1, 10, 100, 1000 v full scale (max. input 300 v rms).

Overranging: 5% all ranges except 1000 v.

Range selection: manual.

Frequency range: 50 cps to 100 kc.

Input impedance: 1 megohm shunted by 500 pf.

Accuracy: (average-reading, calibrated for rms value of sinusoidal input) 50 cps to 50 kc, ±0.3% of reading ±0.001 v ± dc accuracy (above); 50 kc to 100 kc, ±0.75% of reading ±0.001 v ± dc accuracy (above).

General

Input: single-ended (signal low must be connected to ground either at source or voltmeter) all models; DY-2013A through E, 25 switched wire-pairs or 50 single wires, barrier strip; DY-2013J through N, 25 3-wire shielded pairs (Cannon XLR-3-11C-A95 supplied).

Options: 10 to 1000 v auto/manual range selector, add $135; 0.1 to 1000 v auto/manual range selector, add $450; ac voltage measurements (includes 0.1 to 1000 v selector), add $950; time recording once each scan, add $2500; time recording once each channel (2013A and J only), add $1775; output for simultaneous paper tape printer (2013E and N), add $375; rack mount Friden tape punch (2013B and K), add $800.

Accessories: cabinets: 5060-2445 and 5060-2446 include power strip, switch, indicator lamp and cord, caster base, fan assembly, rear door, instrument-mounting rails and blank panels for unoccupied space, 5060-2445, $565; 5060-2446, $735; 5060-2451 same style, but includes only rails and blank panels, $300; 5060-3760 is hp 1117A Testmobile (page 304) modified to accept instrument mounting rails, $200.

Dymec Model	DY-2013A	DY-2013B	DY-2013C	DY-2013D	DY-2013E	DY-2013J	DY-2013K	DY-2013L	DY-2013M	DY-2013N
Scanner input	25 2-wire or 50 1-wire, single-ended inputs; upper limit scan selection					up to 25 3-wire signal sources; to 100 channels with slave scanners, single-ended inputs; channels individually selected				
Display	4 digits of data, range, polarity all included in readout and output recording									
Speed	100 channels/min	60 channels/min	40 channels/min	40 channels/min	100 channels/min	100 channels/min	60 channels/min	40 channels/min	40 channels/min	100 channels/min
Output	printed paper tape	perforated tape	typewritten sheet	punched card (IBM 024, IBM 026)	punched card (IBM 526)	printed paper tape	perforated tape	typewritten sheet	punched card (IBM 024, IBM 026)	punched card (IBM 526)
Price	$4330	$4985	$5390	$4190	$5660	$4960	$5590	$5995	$4795	$6225

DY-2031 SERIES DIGITAL PLOTTING SYSTEMS

X-Y displays of digital information

The Dymec DY-2031 Digital Data Plotting Systems provide easily read graphical presentations of digital data stored on punched card, paper tape or magnetic tape. A DY-2031 System is a valuable accessory to any computer installation, for both quick visual checks of the computer data and the production of accurate finished curves. Systems may also be used to plot data recorded on perforated tape or magnetic tape by a Dymec DY-2010 or DY-2013 Series Data Acquisition System. This allows measurements to be examined immediately after acquisition without waiting for computer analysis.

Six basic systems are available, Models DY-2031A through F, as outlined in the table. The punched card and tape systems can accept the complementary input simply by addition of the appropriate input device.

The heart of the DY-2031 Systems is the DY-2701A Point-Plot X-Y Translator or DY-2702A for line plots. These units convert digital information to analog voltages, and include control circuits to initiate card or tape readout and actuate the functions of the x-y recorder. Instruments are all solid state and feature modular plug-in construction.

Dymec Model	2031A	2031B	2031C	2031D	2031E	2031F
Type of input	punched cards		perforated tape		magnetic tape	
Plotting area: in. (mm)	10 x 15 (254x381)	30 x 30 (762x762)	10 x 15 (254x381)	30 x 30 (762x762)	10 x 15 (254x381)	30 x 30 (762x762)
Price	from approx. $7500 for perforated tape system to $17,000 for magnetic tape systems					
Options	tape editor (2031C thru F), line generation, programmable character printer, cabinet					

Standard DY-2031 Systems plot data as a series of discrete points. The plotter is equipped with a character printer for plotting each point; up to six characters may be selected manually. Line plotting is optionally available, allowing the system to interpolate automatically from coordinate data supplied for successive points, and draw smooth straight lines to connect the points. Lines are drawn at high speed with minimum overshoot. The line segment generator employs digital techniques which contribute no degradation to system accuracy. No adjustments for line length and circuit balancing are required.

Data acquired by Dymec DY-2010 (page 82-85), DY-2013 (page 86, 87) or DY-2017 Series Data Acquisition Systems with punched tape or magnetic tape output can be plotted directly on a DY-2031 Plotting System. To select the desired information from the data tape, a DY-2734B Tape Editor is added to the plotting system. The editor offers these plotting modes: (1) data in any two channels can be plotted against each other in x-y form; (2) data in any channel can be plotted against time-of-day recorded on the tape.

The DY-2031E, F Plotting Systems include a digital magnetic tape reader and are used to plot data from these tapes. Dymec data acquisition systems are available with computer-compatible punched tape or card or digital magnetic tape output. Computer plotting sub-routines also can be furnished to allow tapes to be prepared by most IBM computers for plotting by a DY-2013E,F System. With suitably prepared tapes, a tape editor is not required.

A serial-entry keyboard is supplied with each system for manual plotting of tabular data and for calibrating the x-y plotter. The keyboard is integral with both 10" x 15" and 30" x 30" plotters.

DY-2031C

Specifications

Punched card input (DY-2031A,B): DY-2736A Card Reader reads 80-column punched cards in any format.

Punched tape input (DY-2031C,D): code: IBM 8-level; system can be modified to accept any code in 5- through 8-level at extra cost; tape size: 1" standard; front-panel control allows tape reader to handle 7/8" or 11/16" tape for non-standard codes.

Magnetic tape input (DY-2031E,F): recording standards: IBM compatible; tape width: 1/2"; reel: 10 1/2" diameter, IBM type; code: IBM BCD; format: as prepared by Dymec data acquisition system or standard computer subroutines.

Keyboard input (all systems): manual keyboard for entering 4 digit coordinates into x and y axes; key for sign included.

Resolution: 4 digits (10,000 counts), sign accepted for both axes.

Accuracy: overall system accuracy better than ±0.15% f.s.; repeatability better than ±0.05% f.s.

Point plotting speed: punched cards: 50 pts./minute max.; perforated and magnetic tape: 120 pts./minute max. (1/8" spacing).

Line plotting speed (option): lines between points are drawn at 4 inches per second; speed automatically reduced to 2 inches per second as point is approached, minimizing overshoot.

Digit selection: any 4 consecutive digits from up to 11, supplied for each coordinate.

Scale factor: continuous adjustment up to X20 for each axis (full scale may be varied from ±9999 to 1000 counts).

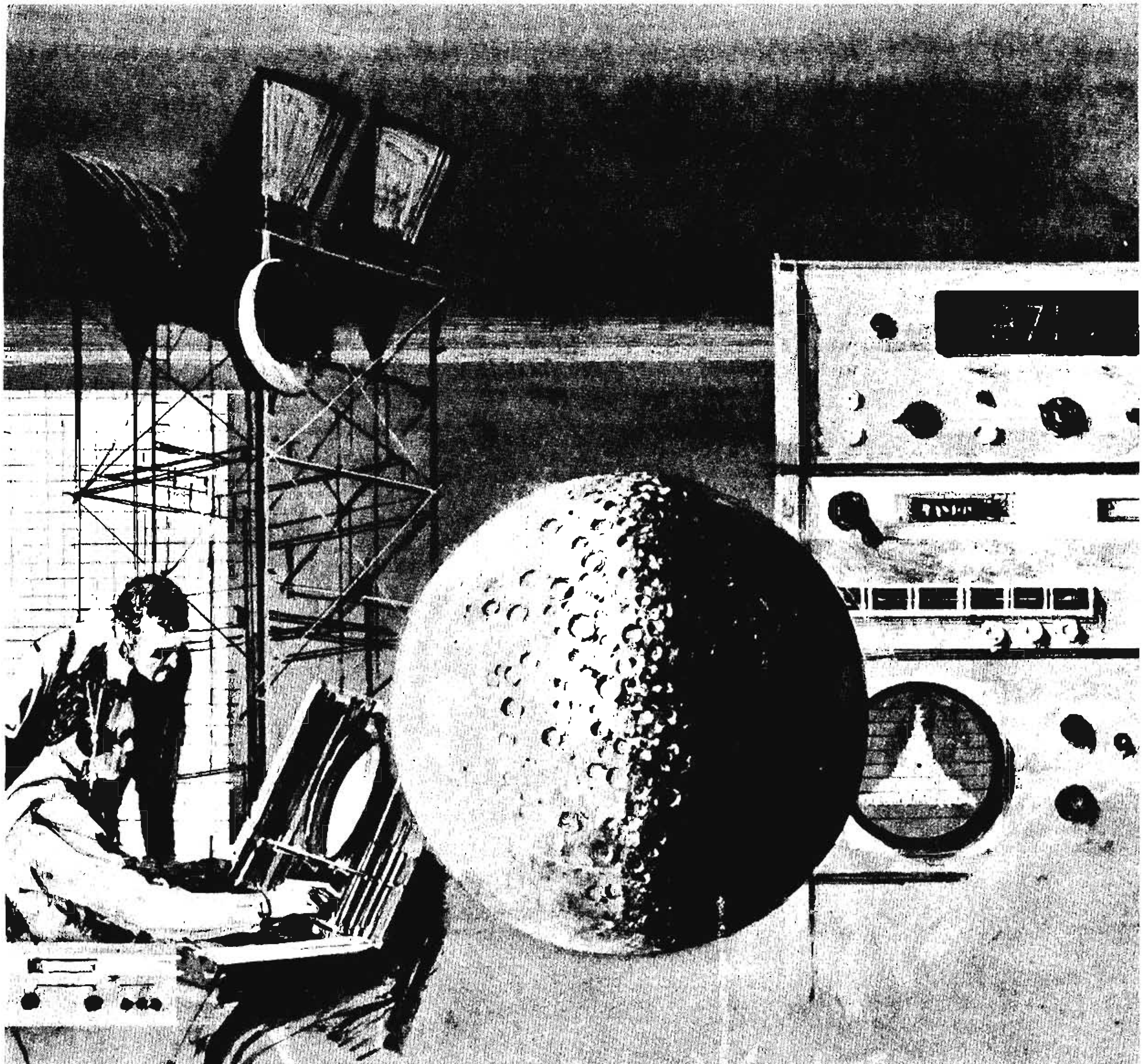
Zero shift: continuously-adjustable offset up to two full scale lengths for each axis.

Zero suppression: switch-selected 2000-count increments.

Operating conditions: specifications apply for ambient operating temperatures from +10 to +50°C; relative humidity up to 95% at 40°C; full accuracy after 30-second warm-up.

Power: 115 v ±10%, 60 cps, 250 w maximum.

Optional modifications: (prices on request) sequential character selection: D-2 Character Printer; automatic character selection: DY-2733A Character Printer and programming modification to x-y translator and recorder; automatic paper advance: includes automatic drive circuitry, for 10" x 15" recorder (bench mount) only; card input: can be added to DY-2031C,D tape input systems to allow operation with punched card input; tape reader-spooler to 2031C,D; rack mount recorder: 10" x 15", no additional charge; line plotting, DY-2702A X-Y Translator; tape editor: DY-2734B, can be added to DY-2031C,D,E,F Systems; no change to system required.



Frequency and time standards, instruments and systems

FREQUENCY AND TIME STANDARDS

Hewlett-Packard frequency and time standard systems are used for frequency and time control or calibration at manufacturing plants, physical research laboratories, calibration centers, astronomical observatories, missile and satellite tracking stations and radio monitoring and transmitting stations. System applications include the following: distributed standard frequencies in factories or research facilities ("house standards"), control of standard frequency and time broadcasts, synchronization of electronic navigation systems, investigation of radio transmission phenomena, frequency synthesizer control and adjustment of single-sideband communications equipment.

Because units of time or frequency cannot be kept in a vault for reference purposes, frequency and time standards require regular comparisons to a recognized primary standard to maintain their accuracy. Hewlett-Packard offers frequency and time standard systems which not only provide locally generated frequencies and time intervals, but also include means for relating these frequencies and time intervals to frequency/time standards such as the United States Frequency Standard (USFS).

While accuracy may be the primary concern, the degree to which a high-accuracy system is useful is a direct function of system reliability. For this reason, increased accuracy and increased reliability are considered inseparable design objectives at Hewlett-Packard. Necessary equipment characteristics provided by Hewlett-Packard systems are: (1) suitable oscillator stability, (2) high-accuracy comparison capability, (3) reliability and (4) operational simplicity.

Frequency standards

Standard broadcast stations make national standards of time and frequency available throughout the world. In the United States, the Bureau of Standards and the Navy operate standards stations whose frequencies are maintained as constant as possible with respect to the United States Frequency Standard. The new Hewlett-Packard cesium beam frequency standard provides an accuracy of 2 parts in 10^{11}, which compares favorably with USFS and is a primary frequency standard. The ease with which required system accuracy may be achieved locally depends primarily on the stability of the oscillator used as the local standard. Improved long-term stability directly increases the permissible time between oscillator adjustments required to maintain a given absolute accuracy.

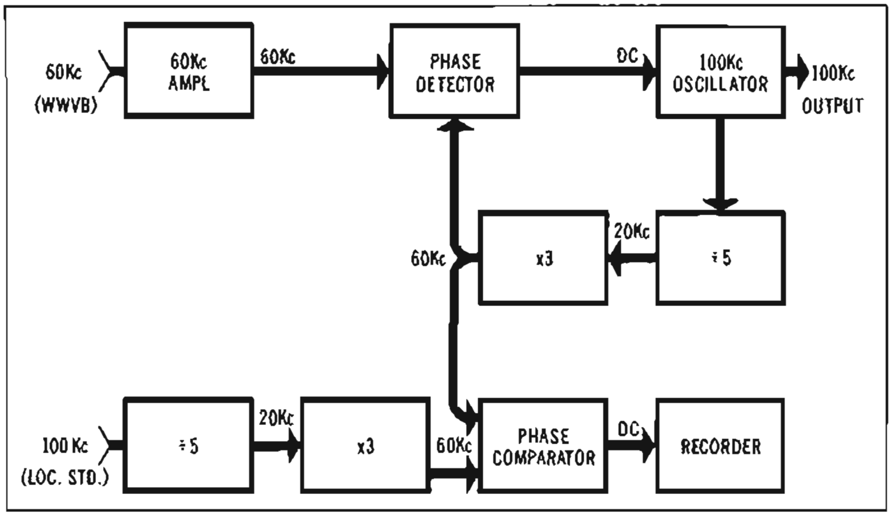


Figure 1

The cesium beam frequency standard utilizes a cesium beam tube to generate a very accurate atomic frequency which is used to stabilize the output of a high-quality quartz oscillator. Thus, this instrument combines the excellent short-term characteristics of a quartz oscillator with the long-term stability of an atomic resonator. The block diagram in Figure 2 illustrates the technique used in generating the spectrally pure 5 mc signal.

Long-term stability of the hp quartz oscillators is conservatively rated ± 5 parts in 10^{10} per day for the hp 107BR, and substantially better performance is experienced under normal operating conditions. Such performance results from use of (a) carefully tested, high-quality crystals, (b) precision temperature-controlled ovens, (c) inherently stable circuitry and (d) low power dissipation in the crystal (approximately 0.2 microwatt). Design of the Hewlett-Packard oscillators includes attention to such details as shock and vibration isolation, shielding, load isolation and stability with respect to supply voltage variations.

In addition to good long- and short-term stability, many applications also require a signal having high spectral purity. This is essential where a high order of frequency multiplication is performed. The hp 106A,B and 107AR,BR were designed specifically for these applications. Spectra less than two cycles wide may be obtained in the X-band region by multiplication of their 5 mc output. Signal-to-noise ratios of 23 db or better, as measured in a 6 cps bandwidth, may be obtained at 10 gc.

Hewlett-Packard frequency and time standard systems can be used in several configurations, depending both on principal systems use (i.e., providing accurate frequency or providing accurate time) and on the source of master time or frequency signals (i.e., hf radio transmission or lf/vlf radio transmissions).

Frequency comparison using vlf transmissions

The low-frequency and vlf standard frequency broadcasts reduce the slight shifts in frequency that are caused by changes in ionospheric reflections that are characteristic of hf broadcasts. Thus, low-frequency and vlf broadcasts have become the preferred media for frequency standard transfer. The new hp 117A VLF Comparator is a complete comparison system which provides a record of the frequency difference between a local standard and the WWVB 60 kc frequency. Figure 1 illustrates the technique used in the 117A. The WWVB 60 kc standard broadcast signal is first amplified and filtered. Schmitt trigger and shaping circuits derive a 60 kc pulse train from the vlf signal for triggering the phase-comparator flip-flop. The 100 kc output of the local frequency standard likewise is converted to a pulse train, divided to 20 kc, multiplied to 60 kc and used to reset the flip-flop.

The width of the flip-flop output pulse is proportional to the phase difference between the received vlf and derived 60 kc signals. These pulses are converted to dc. The dc is applied to the recorder, with the resulting plot indicating local oscillator frequency with respect to the reference signal. The drift rate can be resolved from the rate of change in slope of the recording. The instantaneous slope gives the frequency offset of the local standard. The offset in parts in 10^{10} provides the correction to bring the local oscillator back to proper frequency. The fine tuning adjustment of the 106A,B, 107AR,BR Oscillators has a

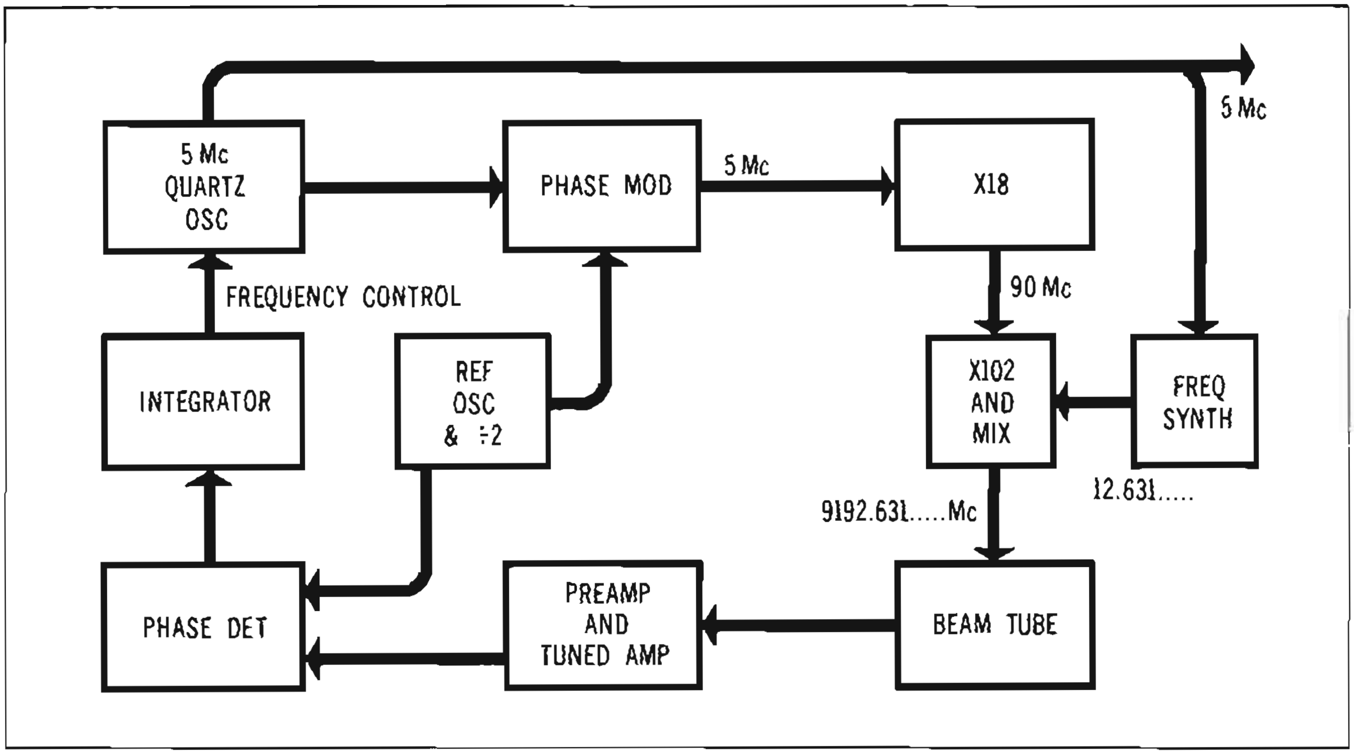


Figure 2

digital indicator, calibrated in parts in 10^{10}, which greatly facilitates making these corrections.

Other systems may be used, depending on the user's requirements and equipment availability. For example, an hp 115BR Frequency Divider and Clock, an hp 5275A Time Interval Counter and an hp recorder can be connected with a local frequency standard driving the clock. The clock output pulse is used as a start trigger to the time interval counter. The time interval measurement is stopped by the zero-axis crossing of the next-occurring cycle of the signal from the vlf receiver. The counter reading is proportional to the phase difference between the local standard and the received standard and is recorded on the system recorder.

HF time comparison methods, clock synchronization

If accurate time-keeping is of paramount importance, the high-frequency standard broadcasts can be used to synchronize a local clock to an accuracy of better than 1 millisecond. HF time-comparison techniques, although serving primarily for clock synchronization, also are used for USFS frequency transfer. The amount by which the Time Reference control on the clock must be adjusted to re-establish the reference condition indicates the time drift of the local oscillator. By plotting the data obtained over a period of time, drift rate and frequency error may be determined accurately, and the oscillator frequency can be readjusted to keep it within predetermined accuracy limits. This method requires many days to achieve a high degree of precision, in contrast to vlf techniques, which require less than 24 hours. Time comparisons made by high-frequency techniques over several days can yield a comparison accuracy of only a few parts in 10^{10}.

Reliability and fail-safe operation

Minimum down-time in any system is important, but the accuracy attained in a frequency or time standard depends directly on continuity of operation. Furthermore, the system must be fail-safe to prevent accumulation of frequency or time errors. Hewlett-Packard frequency and time standards employ simplified, optimized designs displaying a high order of inherent dependability.

Fail-safe operation results mainly from three Hewlett-Packard equipment characteristics: (1) a standby power supply employs batteries to provide continued operation in event of line failure; (2) dividers in hp quartz oscillators and frequency divider and clock will not respond to spurious signals and (3) the divider output signals stop and remain stopped upon any interruption of driving signal or supply power.

Power supply considerations

Interruptions in primary power to a quartz oscillator can cause serious changes in output frequency. When the power interruption is of sufficient length, cooling causes strains in the crystal which can cause a frequency offset and alter the aging rate. The new aging cycle thus incurred may last for days, or even weeks, since the strains can be relieved only with time at the proper operating temperature. Because the accuracy attained in time comparison measurements depends directly on the length of time over which the measurements are made, power interruptions to comparison equipment, such as the frequency divider and clock, also are undesirable.

Hewlett-Packard standby power supplies operate over a range of ac line voltage and frequency and supply regulated dc to operate the quartz oscillator and frequency divider and clock. The batteries in the supplies assume the load immediately, when ac line power fails. Alarm systems include local indication of operating conditions and provisions for remote alarms.

Fail-safe, regenerative dividers

Hewlett-Packard frequency and time standard equipment uses regenerative frequency dividers to insure that short interruptions in power or other irregularities do not affect the time indication. These circuits, when interrupted, will not start unless reset by a pushbutton switch. Since properly designed regenerative dividers have no output in the absence of an input signal, the presence of output from a regenerative divider of the non-self-starting type is a positive indication that the divider output has not "lost" time with respect to the driving signal.

5100A-5110A FREQUENCY SYNTHESIZER, 10511A SPECTRUM GENERATOR

Five billion discrete signals, dc to 50 mc

Advantages:

- Remote programming — 1 millisecond switching speed
- Frequency increments from 0.01 cps to 10 mc
- Search oscillator lends additional versatility
- High stability — all signals derived from single quartz oscillator
- Spectral purity — spurious signals 90 db down
- Solid-state, modular construction

Uses:

Broad range of applications, including:

- Accurate doppler measurements
- Microwave spectroscopy
- Narrow-band telemetry
- Stable local oscillator for transmitter/receiver
- Automatic testing of frequency-sensitive devices
- Harmonics available to 500 mc with hp 10511A Spectrum Generator

The Hewlett-Packard 5100A-5110A Frequency Synthesizer and Driver provide a stable output frequency (0.01 cps to 50 mc) which is adjustable in steps as small as 0.01 cps. The accuracy of the selected output frequency depends on the accuracy of the driving source, since direct synthesis methods are used. The driving source can be the stable internal quartz oscillator provided or an external 1 mc or 5 mc frequency standard. Spurious signals are 90 db or more below the selected output frequency. Output level at the front-panel jack is 1 v rms into 50 ohms for frequencies between 50 cps and 50 mc. Below 50 cps, a rear-panel jack provides 15 mv rms minimum into an open circuit.

The frequency synthesizer system consists of the 5100A Frequency Synthesizer and the 5110A Synthesizer Driver. The 5110A supplies the 5100A with 22 fixed, spectrally pure signals derived from a 1 megacycle internal quartz oscillator or an external 1 mc or 5 mc frequency standard. The 5100A receives the fixed frequencies from the 5110A and provides independent digital synthesis of the output frequency as selected by front-panel pushbuttons or remote programming. An accurate, voltage-tuned search oscillator may be selected which permits continuously variable frequency selection in the vertical column searched. The search oscillator may be substituted for any of the eight right-hand columns on the synthesizer keyboard.

Simple operation

Operation of the frequency synthesizer is straightforward. The output frequency may be selected locally by 10 columns of pushbuttons. Any frequency that can be selected by the pushbuttons can be programmed remotely. Additional versatility results from the combination of local and remote programming. Three 50-pin connectors on the 5100A rear panel provide the connections for remote selection. A Local-Remote switch determines control precedence when both methods are employed.

The Lock-Operate switch prevents accidental operation of the pushbuttons. A Circuit Check switch and meter on both the 5100A and 5110A provide quick and easy checks of internal circuits. The Frequency Standard switch selects either the 1 mc internal quartz oscillator or an external 1 mc or 5 mc frequency standard.

Spectral purity

Synthesizer design and construction make possible output signals whose spurious content is 90 db or more below the selected frequency. Signal-to-noise ratio in a 3 kc band centered on the selected signal is more than 60 db. Particular care in Model 5100A-5110A design results in a very clean output signal over the full 50 mc range.

The high order of spectral purity permits accurate doppler measurements, microwave spectroscopy, narrow-band telemetry, stable local oscillator for a transmitter and/or receiver, automatic testing of crystal filter response and many other applications. Figure 1 illustrates a wave analyzer's response to the synthesizer signal multiplied to 8.75 gc. Spectral purity is maintained when the hp 10511A Spectrum Generator is used to generate harmonic frequencies to 500 mc.

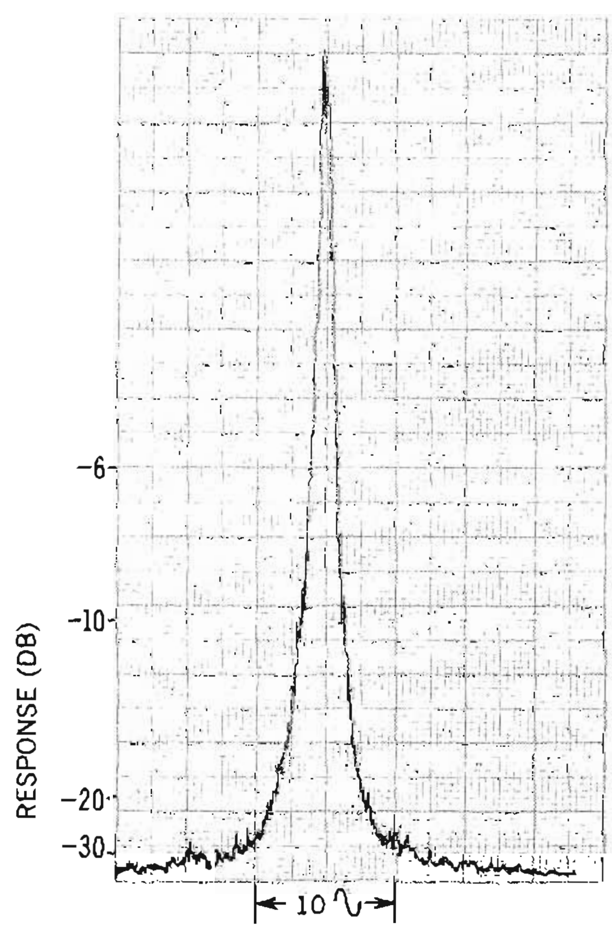


Figure 1

Remote programming

The frequency synthesizer easily lends itself to remote programming. Any search oscillator position or output frequency that can be selected from the synthesizer keyboard can be programmed remotely. Solid-state switching is readily applicable; no actual relay contact closure is required. 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.

Less than 1 millisecond is required for any frequency change. Figure 2 illustrates the rapid, stable switching capabilities of the synthesizer. The synthesizer is switched from 23 mc to 26 mc by the lower waveform. Sweep setting is 200 μsec/cm. Dead time and transients are well within the 1 millisecond specification.

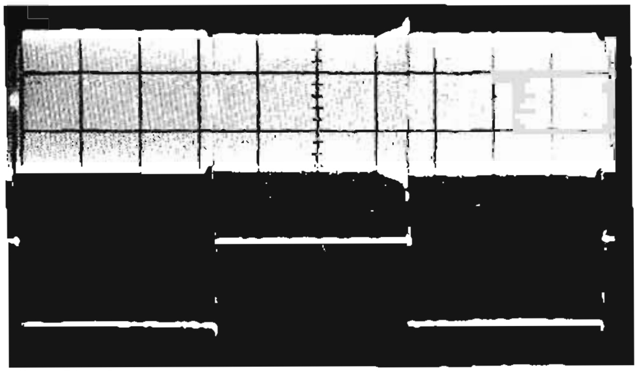


Figure 2

Search oscillator

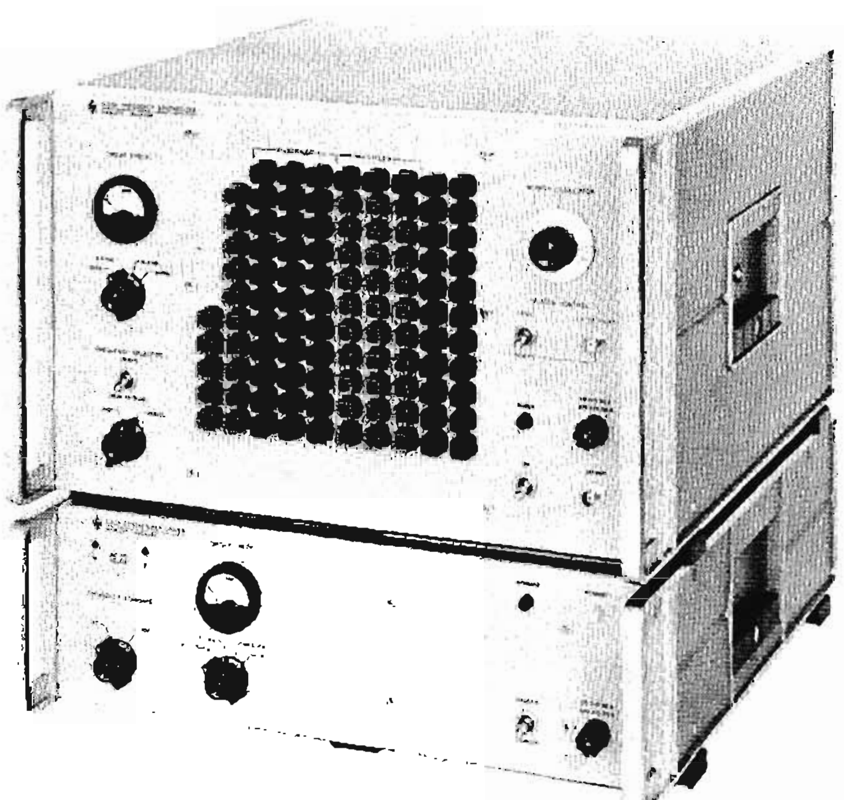
The search oscillator can be selected either locally or remotely and swept either locally or remotely. Besides facilitating searching for an unknown frequency, the search feature permits smooth frequency modulation of the output at a maximum rate of 1000 cps, phase-locking the synthesizer into another system, or sweep operation with a sweep range as small as 0.1 cps. The incremental range of the search oscillator is between 0.1 cps and 1 mc, dependent upon the vertical column selected for search. Any of the right-hand eight columns may be searched.

Specifications, 5100A

Output frequency: dc to 50 mc.

Digital frequency selection: 0.01 cps through 10 mc per step; selection by front-panel pushbutton or by remote switch closure; any change in frequency may be accomplished in less than 1 millisecond.

Output voltage: 1 v rms ±1 db from 100 kc to 50 mc; 1 v rms +2 db, −4 db, from 50 cps to 100 kc, into a 50-ohm resistive load; nominal source impedance is 50 ohms; 15 mv rms minimum open circuit from 100 kc down to dc, at separate rear output connector, source impedance of 10 K ohms with shunt capacitance approx. 70 pf.



5100A-5110A

Signal-to-phase noise ratio: greater than 54 db in a 30 kc band centered on the signal (excluding a 1 cps band centered on the signal).

Signal-to-AM noise ratio (above 100 kc): greater than 74 db in a 30 kc band.

RMS fractional frequency deviation (with a 30 kc noise bandwidth):

	Output frequency			
Averaging time	1 mc	5 mc	10 mc	50 mc
10 milliseconds	3×10^{-8}	6×10^{-9}	3×10^{-9}	6×10^{-10}
1 second	3×10^{-10}	6×10^{-11}	3×10^{-11}	1×10^{-11}

Spurious signals: non-harmonically related signals are at least 90 db below the selected frequency.

Note: when the 5110A Driver utilizes an external frequency standard, this will affect the stability and spectral purity of the output; performance data stated above are based on internal frequency standard, also indicate synthesizer contribution to overall performance with external standard.

Harmonic signals: 30 db below the selected frequency (when terminated in 50 ohms).

Dimensions: 10½" high, 16¾" wide, 18⅜" deep (265 x 425 x 467 mm).

Weight: net 75 lbs (34 kg); shipping 136 lbs (62 kg).

Additional data: search oscillator provides continuously variable frequency selection with an incremental range of 0.1 cps through 1 mc; manual or external voltage (−1 to −11 volts) control with linearity of ±5%.

Price: hp 5100A, $10,250 (requires 5110A).

Specifications, 5110A

Output frequencies: 22 fixed frequencies to the 5100A; 3 through 3.9 mc in 0.1 mc steps (50 mv +1, −3 db), 30 through 39 mc in 1 mc steps, 24 mc, and 3 mc (100 mv ±1.5 db), 50-ohm system; 1 mc buffered output (1 v ±1.5 db into a 50-ohm resistive load) available at rear-panel connector.

Internal frequency standard: 1 mc quartz oscillator.

Aging rate: less than ±3 parts in 10^8 per day.

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, adequate to provide the 5100A performance noted above (1×10^{-11} rms for 1 second averaging on direct output for 30 kc noise bandwidth).

Phase locking capability: a voltage control feature allows 5 parts in 10^8 frequency control for locking to an external source; −5 volts to +5 volts required from phase detector (not supplied).

External frequency standard: input requirements: 1 or 5 mc, 0.2 v rms min., 5 v max. across 500 ohms; stability and spectral purity of 5100A will be partially determined by the characteristics of the external standard if used.

Operating temperature range: 0°C to 55°C.

Interference: complies with MIL-I-6181D.

Power: 115 or 230 volts ±10% 50 to 400 cycles, 35 watts each unit (independent supplies).

Dimensions: 5½" high, 16¾" wide, 16⅜" deep (140 x 425 x 475 mm).

Weight: net 54 lbs (25 kg); shipping 60 lbs (27 kg).

Accessories available: 50-ohm BNC termination (10501A), 22 required for each set of outputs not connected; e.g., max. requirements would be 66 when Option 04. is selected, but only one 5100A is being driven; price, $5 each.

Note: If Option 02., 03. or 04. is selected, the additional outputs must be terminated in 50 ohms when not connected to a 5100A if full specified spurious performance is required.

Price: hp 5110A, $5000.

Options: the 5110A Synthesizer Driver is capable of driving up to four 5100A Frequency Synthesizers.

02. Outputs for driving two 5100A, $125.

03. Outputs for driving three 5100A, $235.

04. Outputs for driving four 5100A, $345.

10511A Spectrum Generator

The Hewlett-Packard 10511A Spectrum Generator is a passive device which generates a series of 1 nanosecond pulses when driven by a signal source. The narrow pulses permit applications where fast, positive triggering is required. Any harmonic to 500 mc can be selected with appropriate filters. The 10511A was designed specifically for use with the 5100A, but also may be driven by a 50-ohm source with input signals between 10 mc and 75 mc.

Specifications, 10511A

Input requirements

Frequency range: 25 to 50 mc*.

Drive level: 1 to 3 volts rms available to 50 ohms.

Output

Pulse width: 1 nanosecond, ±15% at mid-amplitude.

Pulse height: 0.75 volt minimum for minimum drive level.

Impedance: 50 ohms (nominal).

Available harmonic power: −19 dbm minimum for any harmonic number between 1 and 10.

General

Dimensions: 3" long, 1⅝" dia. (76 x 41 mm).

Weight: net 3 oz (85 g); shipping 1 lb (0.45 kg).

Price: hp 10511A, $150.

* Useful operation is obtained for input frequencies from 10 mc to 75 mc.

FREQUENCY SYNTHESIZER APPLICATIONS

The Hewlett-Packard 5100A/5110A Frequency Synthesizer is a signal source (essentially a multiple frequency standard) whose output frequency can be selected by either manual or electronic command to a very high resolution in less than a millisecond. 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 the 5100A/5110A output signals makes it ideal as a local oscillator in receiver applications where very low levels of rf gain are available in the circuitry before the mixer stage.

The very stable output frequencies of the 5100A/5110A make it suitable for use in homodyne receiver circuitry. The advantages of using it 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 media, linking the receiver to the data processing and analysis equipment. However, magnetic tape is not without fault, introducing certain distortions to the data. The 5100A/5110A 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 5110A). 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 the Hewlett-Packard frequency synthesizer. With its rapid, highly repeatable switching capability, the 5100A/5110A 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 the 5100A/5110A to generate test transmissions rapidly over the entire hf spectrum makes it an important tool for radio sounding.

In multiple transmitter installations a single synthesizer may be used to sequence through the desired transmitting frequencies rapidly, providing automatic calibration to all transmitters. The arrangement can phase-lock the transmitter frequencies to the synthesizer, using a circuit with a time constant long enough to maintain the transmitter frequencies for the duration of the sequencing cycle.

The synthesizer may be used in a laboratory receiver as the local oscillator in conjunction with a balanced, broadband mixer and a narrow-band amplifier such as the Hewlett-Packard 415D Tuned Voltmeter. This arrangement, using the tuned voltmeter, can exhibit an exceedingly flat response, 50 kc to 50 mc and better than 10^{-16} watts sensitivity.

Radar

The 5100A/5110A is capable of switching between output frequencies in 0.01 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 a very 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. For accurate velocity measurements, the transmitted source frequency must be exactly the same after the round trip to the vehicle under scrutiny. A 5100A/5110A 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 of different frequency within the narrow receiver bandwidth.

NMR applications for the 5100A/5110A

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. Sophisticated NMR systems use spin-decoupling techniques to neutralize interactions between nuclei and simplify the structural analysis. The 5100A/5110A Frequency Synthesizer finds application in spin-decoupling systems supplying the rf signal through a power amplifier necessary for saturating the nuclei of interest. In this application the broad frequency range and precise 0.01 cps increments of frequency are very valuable.

In NMR systems constructed to analyze a large number of nuclei, the synthesizer is ideally suited to provide rapid accurate band switching. In multi-nuclei NMR analysis each nucleus requires a unique rf frequency and resonant probe (detector). In past systems many chemical analysts have used a probe rf transmitter-receiver set for each nucleus to be analyzed. Now with the 5100A/5110A acting as the master rf oscillator in the transmitter and as the local oscillator in the receiver, the user has at his command an instrument with superior repeatability, frequency selection, frequency stability, and signal-to-noise levels that will provide all rf signal requirements in one unit.

Frequency and level stability measurement

Excellent frequency stability makes the 5100A/5110A an ideal variable-frequency standard in systems measuring short-term frequency stability. Short-term stability, often denoted as phase noise, can then 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. The 5100A/5110A is ideal for use in systems capable of making all three measurements on either signal sources (such as oscillators) or components (such as filters and crystals) which must be excited. In these test systems the 5100A/5110A Frequency Synthesizer may be used as the reference frequency standard and also as the source of excitation for the component under test.

Measurements involving the calibration of voltmeters, power meters and attenuators must depend on a signal source with high stability of output level. The level stability (typically 0.01% over a few-minute period) of the synthesizer is about an order of magnitude better than that available from high-quality generators operating on a regulated power line.

5102A, 5103A FREQUENCY SYNTHESIZERS

Broad frequency coverage, dual-range

The Hewlett-Packard Models 5102A and 5103A Frequency Synthesizers increase synthesizer capability, providing instruments with dual-output frequency ranges of 100 kc and 1 mc (5102A), and 1 mc and 10 mc (5103A).

The 5102A provides output frequencies from 0.01 cps to 100 kc and from 0.1 cps to 1 mc in increments of 0.01 cps and 0.1 cps respectively. Output frequencies from 0.1 cps to 1 mc in increments of 0.1 cps, and from 1 cps to 10 mc in 1 cps 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 mc (or 5 mc) 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 cps) available at the front-panel BNC. For frequencies below 50 cps, 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 hp's 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 μseconds 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, hard to synchronize 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 mc to 0.1 cps 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

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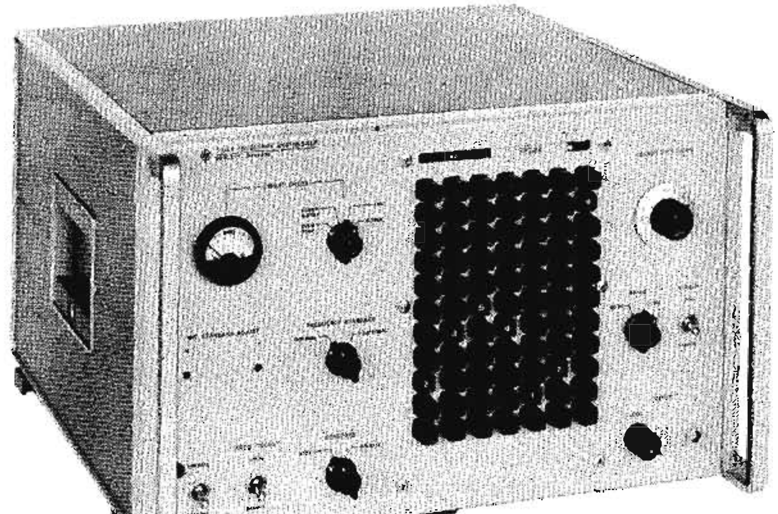

5102A

10% of the selected column's range per volt. The search oscillator may be frequency modulated from an external source at a maximum sine wave rate of 1 kc 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 accurate doppler measurements, narrow-band telemetry or communications, NMR studies, vlf receiver/transmitter work and many similar applications requiring clean and stable frequencies.

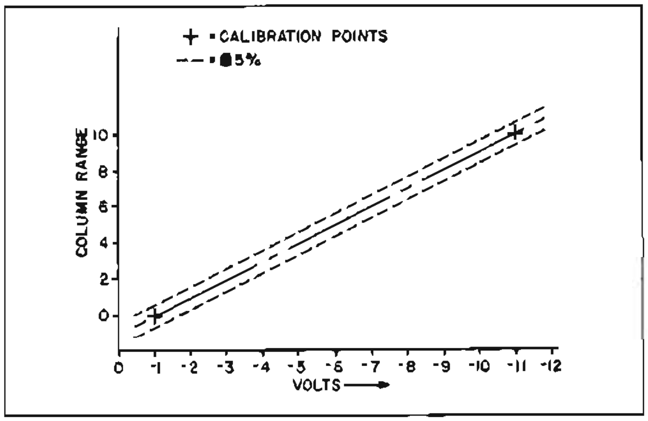

Figure 1.

Specifications

hp Model	5102A	5103A
Output frequency:	100 kc range: 50 cps to 100 kc; 1 mc range: 50 cps to 1 mc	1 mc range: 50 cps to 1 mc; 10 mc range: 50 cps to 10 mc
Output voltages:	continuously adjustable from 300 mv to 1 volt rms; ±1 db, into a 50-ohm resistive load; source impedance 50 ohms nominal (front-panel Output BNC)	
Auxiliary outputs:	(1) Low Level: dc to value of range, both ranges (rear-panel BNC); (2) f_0 + 30 mc (f_0 is selected frequency, dc to 1 mc, both ranges) rear-panel BNC; (3) 1 mc frequency standard (rear-panel BNC)	
Auxiliary output voltage:	(1) Low level 80 mv rms (minimum) open circuit	20 mv rms (minimum) open circuit
	(2) f_0 + 30 mc: 1 volt rms, ±2 db into a 50-ohm resistive load (3) 1 mc: 1 volt rms, ±1.5 db into a 50-ohm resistive load	
Digital frequency selection:	100 kc range: 0.01 cps to 10 kc steps; 1 mc range: 0.1 cps to 100 kc steps	1 mc range: 0.1 cps to 100 kc steps; 10 mc range: 1 cps to 1 mc steps
	selection by front-panel pushbutton or by remote contact closure; any change in frequency may be accomplished in <20 msec, provided front-panel pushbutton or appropriate rear-panel connection is used	
Switching time:	<20 μsec for any change in frequency	
Search oscillator:	search oscillator provides continuously variable frequency selection in any desired column (by depressing the "S" button in that column) over the complete range of that column; manual coverage by a front-panel control or control by an externally applied voltage (—1 to —11 volts)	
Signal-to-phase noise ratio (output)*:	100 kc range: >74 db; 1 mc range: >64 db	1 mc range: >64 db; 10 mc range: >54 db
Signal-to-AM noise ratio (output)*:	100 kc range: >80 db; 1 mc range: >74 db	1 mc range: >74 db; 10 mc range: >74 db
RMS fractional frequency deviation:	100 kc range avg. time / deviation at 100 kc 10 msec / 3×10^{-8} 1 sec / 3×10^{-10} 1 mc range avg. time / deviation at 1 mc 10 msec / 1×10^{-8} 1 sec / 1×10^{-10}	1 mc range avg. time / deviation at 1 mc 10 msec / 1×10^{-8} 1 sec / 1×10^{-10} 10 mc range avg. time / deviation at 10 mc 10 msec / 3×10^{-9} 1 sec / 3×10^{-11}
Spurious signals:	100 kc range: >90 db; 1 mc range: >70 db	1 mc range: >70 db; 10 mc range: >50 db
	(below selected output for non-harmonically related signa s)	
Harmonic signals:	>35 db on all ranges, all outputs	
Internal frequency standard:	1 mc 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 to +55°C $\pm 5 \times 10^{-11}$ for a ±10% change in line voltage	
External frequency standard:	1 mc or 5 mc, 0.2 v to 5 v rms across 500 ohms	
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:	net 75 lbs (34 kg); shipping 127 lbs (58 kg)	

* In a 30 kc band centered on the carrier, excluding a 1 cps band centered on the carrier, and measured on high-level output only.

5060A CESIUM BEAM FREQUENCY STANDARD

Compact primary standard with 2 parts in 10^{11} accuracy

Advantages:

- Accuracy of ± 2 parts in 10^{11}
- Stable quartz oscillator for short-term stability
- Circuit-check meters and lights monitor operation
- All solid-state circuits, low power consumption
- Compact — 8¾ inches high, 63 pounds

Uses:

- Primary frequency standard
- Adjustable UT-2 or A-1 time scale with simple conversion

The Hewlett-Packard Model 5060A is a compact, self-contained primary frequency standard of the atomic beam type, utilizing Cesium 133. A new cesium beam tube resonator stabilizes the output frequency of a high quality quartz oscillator. Solid-state design is used throughout, and the closed-loop, self-checking control circuit yields exceptional accuracy of $\pm 2 \times 10^{-11}$. The 8¾-inch high cabinet occupies only 1.4 cubic feet, weighs less than 63 pounds, and rack-mounting hardware for a standard 19 inch rack is supplied.

In the atomic resonator of the 5060A a neutral beam of Cesium 133 atoms passes through a microwave cavity. When the frequency of the microwave magnetic field is near 9,192-631,770 cps (the hyperfine transition frequency of Cesium 133, defined in A-1 time) it induces transitions from one hyperfine 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 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 atomic resonance the current from the electon 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 and front-panel lights are arranged to present an indication of correct operation. The new, compact cesium beam tubes exhibit frequency perturbations so small that independently constructed tubes compare within a few parts in 10^{12}. Outstanding reliability is obtained from these tubes with a guaranteed life of 10,000 hours. Either A-1 or UT-2 time scale can be supplied on order. A simple change of one component is all that is required for field conversion of the time scale, or for UT-2 offset corrections.

The quartz crystal oscillator used exhibits superior characteristics even without control by the atomic resonator. Drift rate is less than 5×10^{-10} per 24 hours, and short-term stability is better than $\pm 1.5 \times 10^{-11}$ for one second averaging time. The 5 mc quartz crystal is housed in a two-stage, independently thermistor-controlled oven of unique design. Output variation due to temperature is less than $\pm 1 \times 10^{-10}$ from 0 to 50°C.

Output signals provided by the Model 5060A include sine wave 5 mc, 1 mc, and 100 kc with an additional 100 kc clock output. Signal-to-noise ratio for the 5 mc signal

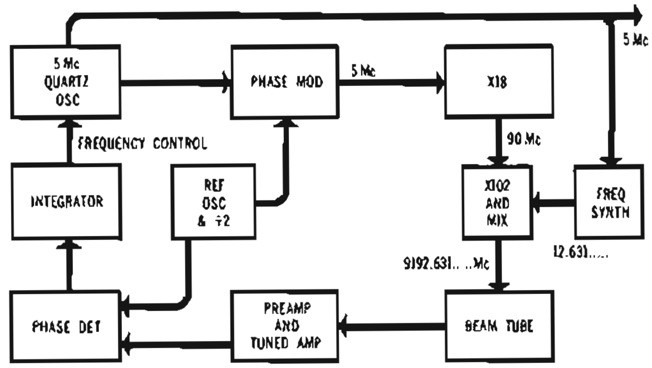

Figure 1

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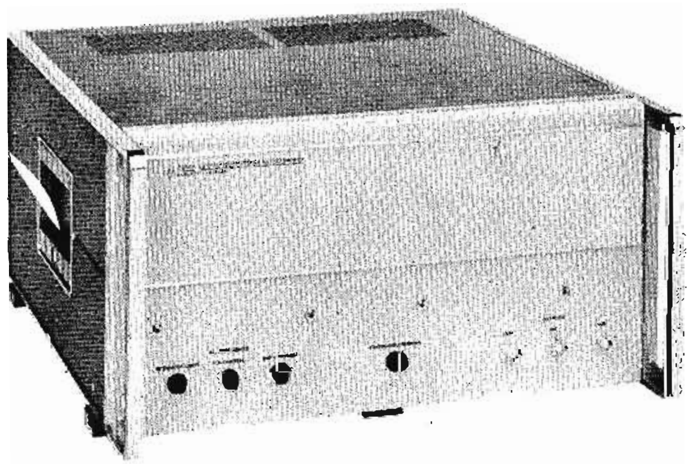


is greater than 83 db below the rated output. Harmonic distortion is down at least 40 db for all outputs except the clock signal. The block diagram in Figure 1 indicates the system used in the 5060A. The cesium beam tube is connected as a passive resonator to stabilize the quartz oscillator frequency. The quartz oscillator output may be used alone with the cesium beam tube switched off or in standby. Either method of operation provides output signals with excellent short-term stability and extends the useful life of the cesium beam tube. Two circuit check switches and meters permit quick and easy checks of 5060A circuits with power applied. The 5060A operates from 115 or 230 v ac power lines or a dc source of 22 to 30 volts. Since the complete instrument is compact and weighs less than 63 pounds, it does not require a permanent, complex installation.

Figure 2 illustrates the hyperfine transitions that occur in the cesium beam tube. Note that the energy level ($\triangle$W) changes for any hyperfine transition (e.g., 0-0) as the magnetic field (X) changes. In the 5060A this relationship is used when the fixed field ("C") is set to a value which ensures that only desired atoms contribute to atomic resonance.

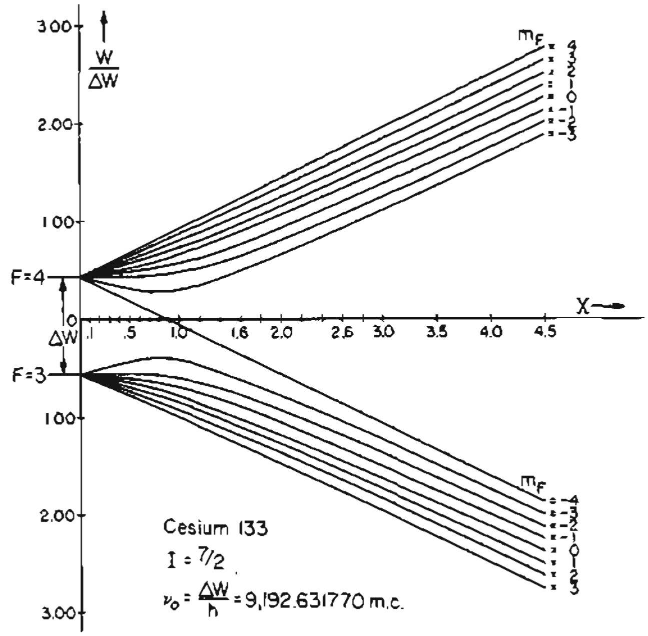


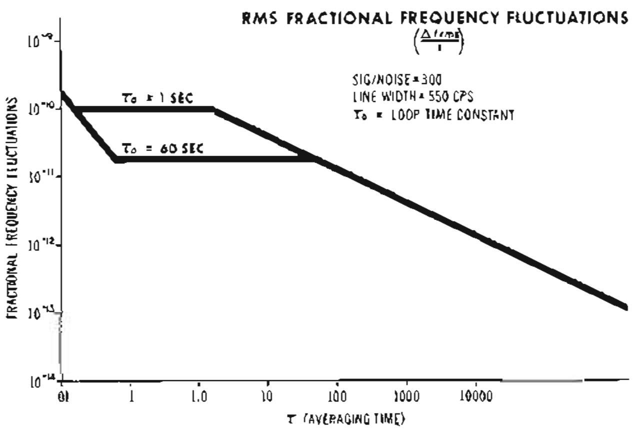
Figure 2

Specifications

Accuracy: $\pm 2 \times 10^{-11}$.

Long-term stability: $\pm 1 \times 10^{-11}$.

Short-term stability:



Warm-up time: 1 hour (time to reach specified accuracy, if oscillator warm); 4 hours (cold start).

Noise-to-signal ratio (5 mc): at least 83 db below rated 5 mc output; output filter bandwidth is approximately 125 cps.

Harmonic distortion: (5 mc, 1 mc, 100 kc) down more than 40 db from rated output.

Non-harmonically related output: (5 mc, 1 mc, and 100 kc) down more than 80 db from rated output.

Output frequencies: 5 mc, 1 mc, 100 kc sinusoidal, 100 kc clock drive.

Output voltages: 1 v rms into 50 ohms; clock drive suitable for hp frequency divider and clocks (page 104).

Output terminals: 5 mc, 1 mc, 100 kc, front and rear BNC connectors; 100 kc clock drive, rear BNC connector.

Cesium beam tube: life, 10,000 hr. guaranteed (operating).

Time scale: A-1 or UT-2 supplied to order; simple change of one component enables field conversion of time scale or adjustment for UT-2 offset corrections.

Quartz oscillator only (with cesium beam tube switched off)

Aging rate: ± 5 parts in 10^{10} per 24 hours after 30 days continuous operation.

Stability: as a function of ambient temperature: less than $\pm 1 \times 10^{-10}$ from 0° to +50°C; as a function of load: less than $\pm 2 \times 10^{-11}$ for any resistive load change; as a function of supply voltage: less than $\pm 5 \times 10^{-11}$ for 22 to 30 v dc.

RMS deviation of 5 mc output (due to noise and frequency fluctuations):

Averaging time	Max. rms fractional-frequency deviation ($\triangle$f/f)	Max. rms phase deviation (milliradians)
1 msec	8×10^{-10}	0.03
10 msec	1.5×10^{-10}	0.04
0.1 sec	1.5×10^{-11}	0.04
1 sec	1.5×10^{-11}	0.4
10 sec	1.5×10^{-11}	4

All data based on at least 100 samples; data taken over a 20-second interval for 1 msec, 10 msec and 0.1 sec averaging times, over 200- and 2000-second intervals respectively, for 1 and 10 sec averaging times; crystal aging rate has been removed from these data.

Frequency adjustments: fine adjustment: 5 parts in 10^8 total, 1 part in 10^9 per revolution, 1 part in 10^{10} per division at 10 divisions per revolution; coarse adjustment: 500 parts in 10^9; coarse and fine controls are screwdriver adjustments, recessed from front panel.

Operating temperature: 0 to 50°C.

Power: 115 or 230 volts ac $\pm 10\%$, 50 to 1000 cps or 22 to 30 volts dc; approximately 50 watts operating.

Dimensions: 8¾" high, 16¾" wide, 16⅜" deep (222 x 425 x 416 mm).

Weight: net 63 lbs (28,6 kg); shipping 105 lbs (48 kg).

Price: hp 5060A, $15,500.

106A,B AND 107AR,BR QUARTZ OSCILLATORS

Plus 100E, 101A Oscillators

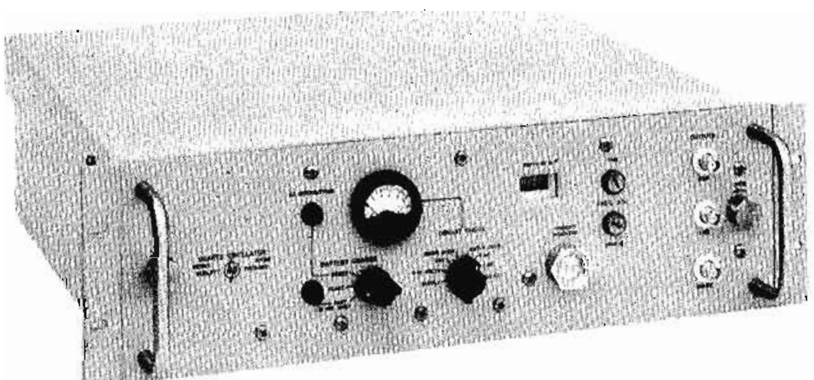
Models 106A,B and 107AR,BR Quartz Oscillators provide state-of-the-art application in primary frequency and time standard systems because of their excellent long- and short-term stability characteristics, spectrally pure outputs, unexcelled reliability and ability to operate under a wide range of environmental conditions.

Models 107AR,BR are rugged, hermetically sealed oscillators, employing 5 mc quartz crystal resonators. The 107 has been designed and tested to meet the stringent shock and vibration requirements of MIL-E-16400E. The oscillators are totally impervious to moisture and will remain stable within ±1 part in 10^{10} between 0°C and 50°C.

The heart of the 106A,B is an extremely stable 2.5 mc quartz crystal. The 106 is distinguished by its unprecedented long-term stability of ±5 parts in 10^{11} per day (24 hours) and excellent short-term stability over a wide range of environmental conditions.

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 724BR 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 724BR or 725AR (page 104).

100E, 101A Quartz Oscillators—These instruments are very stable oscillators for applications requiring something less than the stability provided by highly sophisticated frequency standards such as the 106A,B or the 107AR,BR. The 100E has short-term stability of 5 parts in 10^8 and is ideal for test, production and lab use. Output frequencies are 10 cps, 100 cps, 1 kc, 100 kc, 1 mc sinusoidal and 10 cps, 100 cps, 1 kc, 10 kc pulse. Output pips from the timing comb are at 100, 1000 and 10,000 μsec intervals. Price: hp 100E, $1100 (cabinet); hp 100ER, $1100 (rack mount). The hp 101A One MC Oscillator is designed as a time base for the hp 5275 Time Interval Counter (page 62). Stability is 5 parts in 10^8 per week. Price: hp 101A, $600 (cabinet with rack hardware).



107BR

AVAILABLE MID-1965

106B

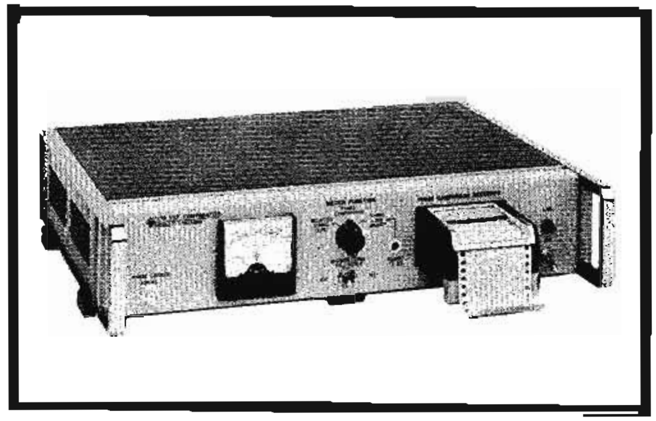
Specifications

Models	107AR,BR	106A,B
Output frequencies	5 mc, 1 mc, 100 kc sinusoidal; 100 kc clock drive	
Output voltages	5 mc, 1 mc, and 100 kc, 1 v rms into 50 ohms; 100 kc for driving hp frequency divider and clocks, 0.5 v rms into 100 ohms	
Stability (long term)	$<\pm 5 \times 10^{-10}$ per 24 hrs	$<\pm 5 \times 10^{-11}$ per 24 hrs
As a function of ambient temperature	$<\pm 1 \times 10^{-10}$ from 0° to +50°C	$<\pm 1 \times 10^{-10}$ from 0° to +40°C
As a function of humidity	instruments are hermetically sealed	basic oscillators are 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	(106A) $<\pm 3 \times 10^{-11}$ 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	(106B) $<\pm 1 \times 10^{-11}$ for ±10% change from 115 or 230 v ac
RMS deviation of 5 mc (short-term stability)	averaging time / max. rms fractional-frequency deviation ($\Delta f/f$) / max. rms phase deviation (milliradians): 1 msec / 8×10^{-10} / 0.03 10 msec / 1.5×10^{-10} / 0.04 0.1 sec / 1.5×10^{-11} / 0.04 1 sec / 1.5×10^{-11} / 0.4 10 sec / 1.5×10^{-11} / 4	
Noise-to-signal ratio (5 mc)	at least 87 db below rated 5 mc output; output filter bandwidth is approximately 125 cps	
Harmonic distortion (5 mc, 1 mc, and 100 kc)	down more than 40 db from rated output	
Non-harmonically related output (5 mc, 1 mc, and 100 kc)	down more than 80 db from rated output	
Output terminals	5 mc, 1 mc, 100 kc, front and rear BNC connectors; 100 kc 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	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
Coarse adjustment	1 part in 10^6 ($\pm 0.5 \times 10^{-6}$)	5 parts in 10^7 ($\pm 2.5 \times 10^{-7}$)
Environmental		
Storage temperature	—65°C to +85°C (mfr. specifies —40°C to +50°C limit for 107BR battery storage)	—40°C to +75°C (mfr. specifies —40°C to +50°C limit for 106B battery storage)
Operating temperature	0°C to +50°C	0°C to +40°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)	106A: net 25 lbs (11.3 kg), shipping 38 lbs (17 kg); 106B: net 35 lbs (16 kg), shipping 53 lbs (24 kg)
Dimensions		
Height	5-7/32" (133 mm)	6-31/32" (177 mm)
Width	19" (483 mm)	16¾" (425 mm)
Depth	16⅜" (416 mm)	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 cps, approx. 25 w operating with battery on trickle charge (30 w on fast charge), 33 w during warm-up (38 w on fast charge)	106A: 22 to 30 v dc, approx. 9 w operating, 14 w during warm-up; 106B: 115 or 230 v ac ±10%, 50 to 1000 cps, approx. 20 w operating with battery on trickle charge (25 w on fast charge), 30 w during warm-up (35 w on fast charge)
Price	hp 107AR, $2400 hp 107BR, $2750	hp 106A,B on request

117A VLF COMPARATOR

Useful for accurate frequency comparisons

117A VLF Comparator



Advantages:

- Complete system for frequency comparison
- Operating phase stability of ± 1 μsec; 0 to 50°C
- Phase-locked 100 kc output
- 1 microvolt signal ensures phase lock
- Comparison accuracy of 1 part in 10^{10}

Uses:

- Accurate comparison between WWVB and local standard
- Quick and easy check of counter time base accuracy
- Applicable throughout continental U.S.
- Secondary frequency standard from 100 kc output

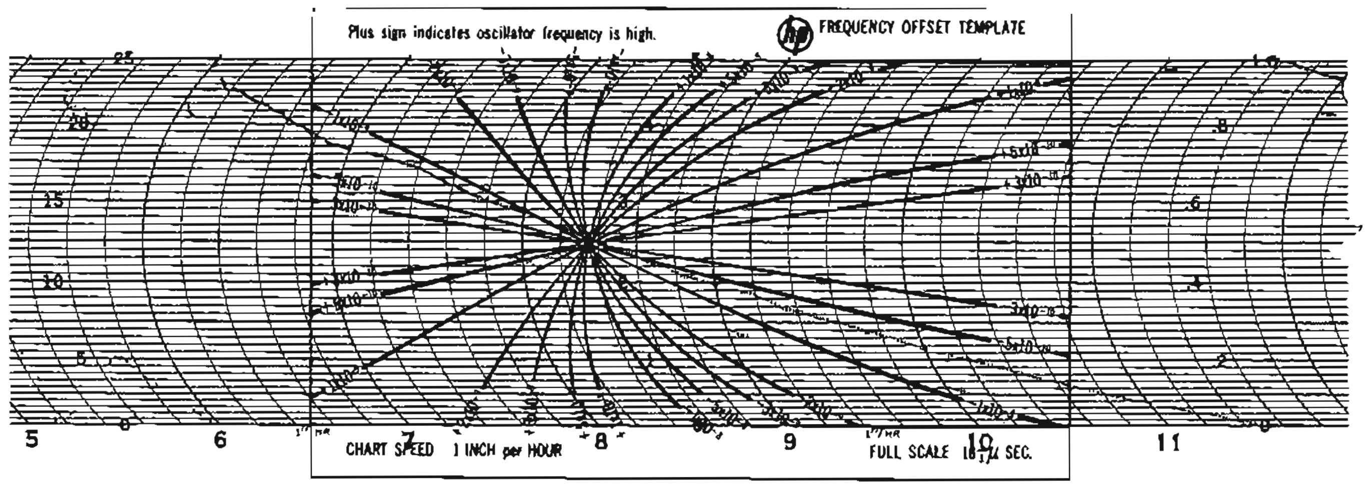
The hp 117A VLF Comparator provides accurate phase comparisons between the 60 kc U.S. frequency standard at Fort Collins, Colorado, (WWVB) and a local standard. Using the 117A, frequency standard comparisons to an accuracy of 1 part in 10^{10} can be approached in an 8-hour period, depending upon the length and condition of the propagation path. The transmitted 60 kc signal has an effective radiated power of 5 kw and provides the primary U.S.F.S. service to the continental U.S. at a precision of about 5 parts in 10^{11} during a 24-hour period. The 117A is readily applicable to checking the accuracy of 100 kc derived from the time base in electronic counters. When accurate frequency measurements are to be performed, the 117A can compare the counter time base frequency with WWVB and the time base frequency can be corrected. The 117A is easily portable and thus could be used in several different locations for several different comparisons.

Method of operation

The operating principle of the 117A is to phase-track a voltage-controlled oscillator with WWVB, using an electronic servo control system. The local frequency standard is compared with the phase tracking oscillator and a continuous phase difference recording is made on a strip-chart recorder. The 117A receives the 60 kc from WWVB and makes a continuously recorded phase comparison of this 60 kc against a local standard input of 100 kc. The amplified WWVB signal and the voltage-controlled oscillator frequency provide two inputs to a phase detector which drives an integrating operational amplifier and then the voltage-controlled oscillator.

The operation of this system is electronically equivalent to an electromechanical servo system, and it functions with zero steady state phase error and negligible long-term total phase error. This servo system is equivalent to having a circuit of very narrow bandwidth in the amplifier section of the 117A. The narrow bandwidth of the servo loop has the important advantage that the center frequency tracks WWVB, and the bandwidth restriction is accomplished with simple resistive and capacitive components. Temperature variations cannot cause the center frequency to shift. Consequently, temperature-dependent phase shifts are minimized. The servo loop and phase-locked oscillator operated in this manner provide a continuous output signal during noise and interfering signals.

The chart width of the phase comparison trace may be either 50 μsec or $16\frac{2}{3}$ μsec, and the 117A recorder chart is calibrated one μsec per small division. Frequency offset templates are included which permit rapid interpolation of the chart trace. Readability of the trace and overall stability of the comparator easily provide a resolution of better than one microsecond under normally encountered laboratory conditions. Rear-panel galvanometer and potentiometer recorder outputs provide phase comparison and relative



signal level information for an external recorder. The galvanometer recorder may be calibrated with controls on the 117A rear panel.

The 60 kc narrow-band antenna and amplifier supplied with the 117A mount easily with standard 1 inch galvanized pipe. The narrow 30 cycle bandwidth of the amplifier minimizes spurious signal interference. The 1 μv sensitivity of the 117A with antenna and amplifier permits operation anywhere in the continental United States.

Crystal oscillator stability check

Shown below is a portion of a 24-hour phase comparison recording made on the 117A, of the 5245L Electronic Counter 1 mc time base crystal oscillator against the 60 kc WWVB standard broadcast. This record was made on 19 September 1964. As shown above, the effect of the diurnal shift on the 60 kc propagation path can be seen around 6:00 a.m. and 6:00 p.m. The crystal time base, during a 6-hour sunlight period, was checked and found to be aging positively at a rate of approximately 4×10^{-10} per 24 hours. (This was easily computed using the frequency offset templates provided with each instrument.) At 8:15 a.m. the slope of the frequency offset plot was -7.5×10^{-10} and at 3:00 p.m. was -6.5×10^{-10}. This shows a positive drift rate of approximately 1×10^{-10} per 6 hours or +4 parts in 10^{10} per 24 hours. A 24-hour check would increase definition and reduce diurnal effects.

The phase shifts occurring shortly after the hour, are identification transmissions by WWVB by a 45 degree phase shift in the 60 kc signal.

Templates

Frequency offset templates calibrated for use with the 117A for either 50 μsec chart width or 16⅔ μsec chart width are provided with each instrument. The overlay on Page 102 shows the 16⅔ μsec Template. These templates provide a fast, accurate check on phase comparison record by showing instantaneous frequency offset. Frequency offset for at least two separate chart times are required to derive the drift characteristic (rate of change of slope) of the standard under study.

NBS

Anyone concerned with standard frequency calibration techniques using the U.S.F.S. broadcast by WWVB should contact NBS to be placed on their mailing list. This is extremely helpful in keeping current on all activities relating to WWVB (and WWVL) broadcasts. NBS can be contacted at the following address: National Bureau of Standards, Frequency-Time Broadcast Services 91.20, Boulder, Colorado 80301.

Specifications, 117A

U.S.F.S. input frequency: 60 kc (WWVB carrier).

Sensitivity: 1 μv rms into 50 ohms.

Local standard input: 100 kc, 1 v rms into 1000 ohms (divider to accept 1 mc available at extra cost).

100 kc phase-locked output: 5 volt rectangular positive pulses into 5000 ohms.

Recorder outputs: phase comparison and relative signal strength: 0 to 1 ma dc into 1400 ohms and 0 to 100 mv dc from 2000 ohms.

Overall phase stability: ±1 μsec, 0 to 50°C.

Chart width: 50 μsec or 16⅔ μsec.

Chart speed: 1 in/hr, standard (chart speeds of 6 or 12 in/hr available upon request).

Meter readings: three switch positions: 1) Relative Signal Level; 2) Phase Comparison—calibrated scales 0 to 50 μsec full scale and 0 to 16⅔ μsec full scale; 3) Phase Lock—indicated range ensures negligible phase error in the phase-locked oscillator.

Adjustments: front-panel control adjusts free-running frequency of the voltage-controlled oscillator to compensate for crystal aging and achieve optimum phase lock over temperature range 0 to 50°C; three rear-panel calibration 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.

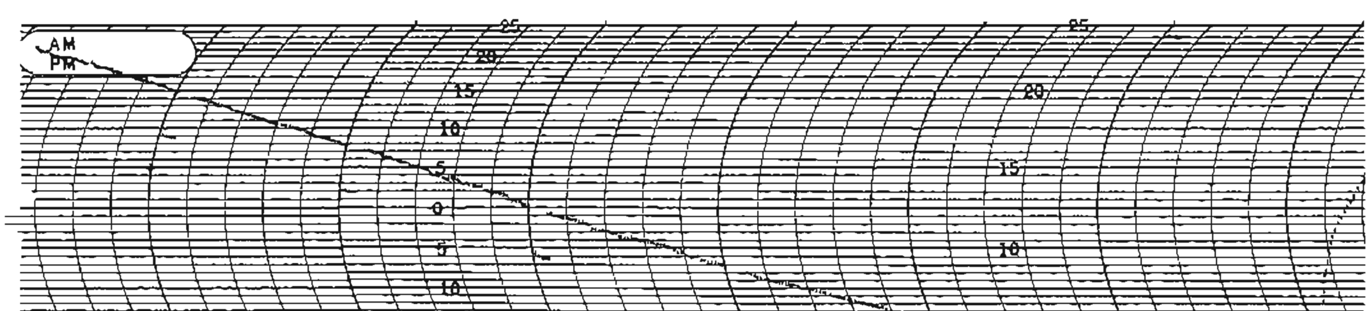
Dimensions: 16¾" wide, 3-15/32" high, 13¼" deep (425 x 88 x 337 mm).

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 volts ±10%, 60 cycles, 40 watts.

Accessories furnished: 10509A Loop Antenna, 43" diameter (1090 mm); 10512A Antenna Cable, 50 ohms, 100' and mounts on 1" pipe thread, operating temperature: −60° to +80°C; 10512A Coaxial Lead-in Cable: 50-ohm, BNC-BNC connectors, 100' (30,5 m) long.

Price: hp 117A with 10509A Antenna/Pre-Amp and 10512A Lead-in Cable, $1150.



115BR,CR FREQUENCY DIVIDERS, CLOCKS
724BR, 725AR POWER SUPPLIES

For comparison of signals with broadcast standards

The Model 115BR or 115CR Frequency Divider and Clock permits adjustment of frequency or time standards for maximum absolute accuracy by making precise comparisons with broadcast standard time and frequency signals. Detailed records of oscillator drift rates, as well as time or frequency differences between oscillators can be conveniently obtained.

Overall time comparison accuracy is ±10 μsec, and jitter is negligible in the output of these compact battery-operated units. The 115BR is designed to meet performance requirements of MIL-E-16400 and is well suited to mobile applications.

For convenience and maximum efficiency in operation, the 115BR and 115CR provide in-line display of time in hours, minutes and seconds, with an additional drum revolving once per second to permit time resolution of 0.1 second or, by stroboscope or camera to 0.01 second. Use of non-self-starting regenerative dividers avoids noise and spurious signal problems, for maximum total accuracy.

Specifications, 115BR,CR

Input frequency: 100 kc for solar time, input bandwidth ±300 cps; 100.3 kc 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: 300 ohms nominal.

Auxiliary output: (115BR only): amplitude, 0.25 v rms minimum; source impedance, approx. 1200 ohms; frequency, 100, 10 and 1 kc (60 cps on special order).

Time reference: continuously adjustable, calibrated in 10 μsec increments; numerical display from 999.9 msec to 000.0 msec, in-line vernier in 10 μsec increments.

Effect of transients: will not gain or lose time because of: (1) ±300 v step function on 100 kc input; (2) 0 to 50 v pulses, 0 to 5000 pps, 1 to 10 μsec duration on 100 kc input; (3) ±4 v step in 26 v dc input.

Characteristic	Positive tick	Negative tick	Auxiliary pulse*	Positive** 1 kc 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 50 ohms	1000 pps +4 v min.
Rise time	2 μsec max.	2 μsec max.	1 μsec max.	2 μsec max.
Duration	20 μsec min.	20 μsec min.	200 μsec	20 μsec min.
Jitter	1 μsec max.	1 μsec max.	1 μsec max.	1 μsec max.
Recommended load impedance	4700 ohms min. shunted by 200 pf max.	1 megohm min. shunted by 100 pf max.	50 ohms min. shunted by 5000 pf max.	1000 ohms min. shunted by 1000 pf max.

*Standard for 115BR, available for 115CR.
**Negative pulses available on special order.
***For any load impedance higher than mimimum recommended.

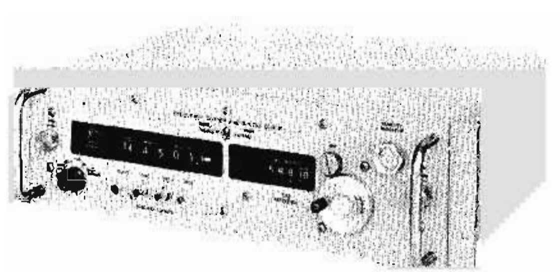
Monitor meter: (115BR only), checks supply voltage, divider operation (100 kc, 10 kc, 1 kc) and total clock current.

Power: 22 to 30 v dc, negative ground for operating with 106A,B or 107AR,BR (see page 101) (may be selected by a switch), approximately 2.5 watts, recommended supply, 724BR or 725AR (positive ground).

Dimensions: 115BR: 19" wide, 5¼" high, 12" deep behind panel (483 x 133 x 356 mm); 115CR: 19" wide, 3½" high, 12" deep behind panel (483 x 89 x 305 mm).

Weight: 115BR: net 35 lbs (15,8 kg), shipping 49 lbs (22,2 kg); 115CR: net 15 lbs (6,8 kg), shipping 21 lbs (9,5 kg).

Accessories furnished: 113A-16E Cable, 6 feet long (1830 mm), connects 115BR or 115CR to 724BR, or 725AR.



115BR

Accessories available: 114BR Time Comparator: allows comparison of local time standards to standard time broadcasts, $1200.

Price: hp 115BR, $2750; hp 115CR, $1500.

724BR, 725AR Supplies

Hewlett-Packard standby power supplies, Models 724BR and 725AR, provide improved performance and reliability of frequency or time standard systems by enabling continued operation in the event of ac line failure.

The hp 724BR and 725AR are designed to operate with standby batteries floating across the regulated output to assume the load automatically in case of ac failure. The hp frequency/time standard system is not affected by transfer of load from any external supply to standby or back again, since switching is not used. When ac power is restored, the supply reassumes the load, and the batteries are recharged automatically.

Specifications, 724BR, 725AR

Output voltage: 24 v, +1, −2 v dc.

Rated current (total external load): 500 ma.

Short circuit protection: prevents damage from momentary short circuits (e.g., when connecting loads) and from overloads of up to twice rated output; continuous overload reduces instrument's life expectancy.

Alarm indicators: panel lamps indicate operating voltage as (1) ac line or (2) battery; additional lamps indicate ac line fuse failure (remote alarm provision is included).

Panel meters: voltmeter and ammeter indicate battery voltage and battery charge/discharge current.

Power: 115 or 230 v ac ±10%, 50 to 1000 cps.

Battery supplied: 724BR: 28 ampere-hour vented nickel-cadmium; 725AR:, 2 ampere-hour sealed nickel-cadmium.

Output connectors: MS type female connectors at rear mate with 106A,B, 107AR,BR, 115BR or 115CR connectors.

Accessory furnished: power cable, 54 in. long (1372 mm), with NEMA line plug and MS3106A10SL-3S plug for rear-chassis power connector.

External battery provision: MS310214S-2S female connector at rear.

Dimensions: 724BR: 19" wide, 7" high, 14¼" deep behind panel (483 x 177 x 361 mm); 725AR: 19" wide, 3½" high, 12¾" deep behind panel and allowing for connectors (483 x 89 x 323 mm).

Weight: 724BR: net 75 lbs (34 kg), shipping 102 lbs (46,3 kg), including battery; 725AR: net 27 lbs (12,2 kg), shipping 45 lbs (20,4 kg), including battery.

Price: hp 724BR with 28 amp-hr vented Ni-Cad battery, $950; hp 725AR with 2 amp-hr sealed Ni-Cad battery, $645.

Option 01.: 724BR without battery, $600.

IMPEDANCE MEASURING INSTRUMENTS

Q and RX meters

These instruments directly indicate Q and indirectly yield the value of the constituents of Z.

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) 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.

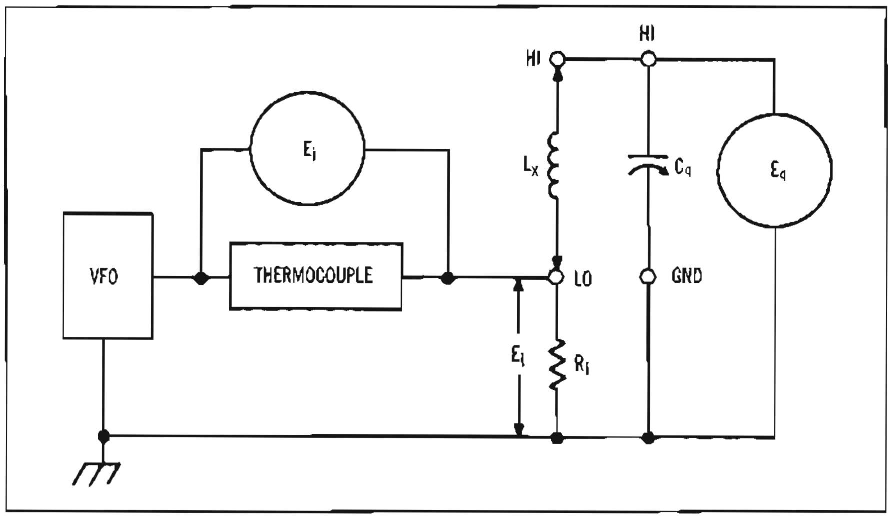


Figure 1. Q meter

To calibrate these meters, Hewlett-Packard's Boonton Division provides Q standards which are standard inductors of calibrated Q. A series of convenient reference inductors also is available from the Boonton Division for use as known constants or substitutes in the L_x position.

There are two Q meters in the Boonton family. Model 260A is for the frequency range 50 kc to 50 mc, which may be extended down to 1 kc by using a suitable external oscillator with a Model 564A Coupling Unit. Model 190A serves the range 20 mc to 260 mc.

The Model 250A RX Meter from Boonton directly presents the parallel resistive and reactive constituents of Z, for two-terminal networks, in the range from 0.5 to 250 mc.

The output of the 0.5 to 250 mc test oscillator (F_1) is fed into a Schering bridge. When the impedance to be measured is connected across one arm of the bridge, its 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 mc oscillator (F_2), tracking 100 kc above F_1, also is fed to the mixer, resulting in a 100 kc 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.

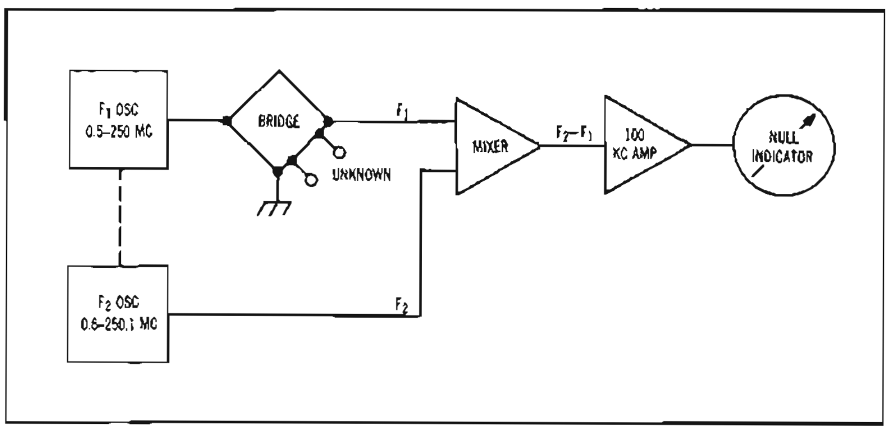


Figure 2. RX meter

The instrument's range of measurement is 15 to 100,000 ohms for parallel resistance (0 to 15 ohms by indirect means), 0.1 to 100 pf (120 pf by indirect means) for C, and 0.001 μh to 100 mh for L. Access to the measurement circuit through Type N coaxial connectors may be had by installing the Model 515A Adapter Kit.

Phase and Z measurements at vhf

The Hewlett-Packard Model 803A VHF Bridge directly indicates Z and phase angle in coaxial circuits, in the range 55 to 500 mc.

The instrument measures impedance by separately sampling the electric and magnetic fields in a transmission line. Two attenuator systems are controlled simultaneously. One responds to the electric field, the other only to the magnetic field. The combination is adjusted for equal output from each attenuator. These equal signals are applied to opposite ends of a transmission line. Phase is determined by finding their points of cancellation. At null, one dial reads the unknown impedance directly in ohms, and the other dial reads phase angle. The Model 417A VHF Detector was specifically designed as a sensitive (5 μv) companion null detector; or an swr meter (hp Models 415B, 415D, pages 232, 233) may be employed to advantage. A suitable signal generator is the hp Model 608C (pages 182, 183). The Model 803A's measurement range, in the band 55 to 500 mc, is 2 to 2000 ohms impedance magnitude, −90° to +90° phase angle.

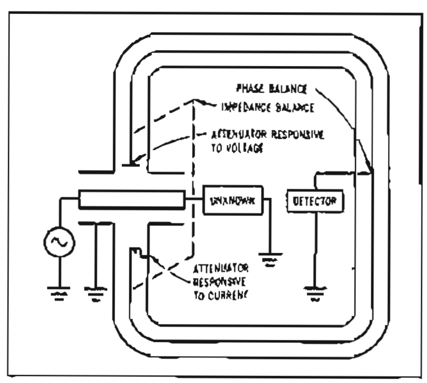
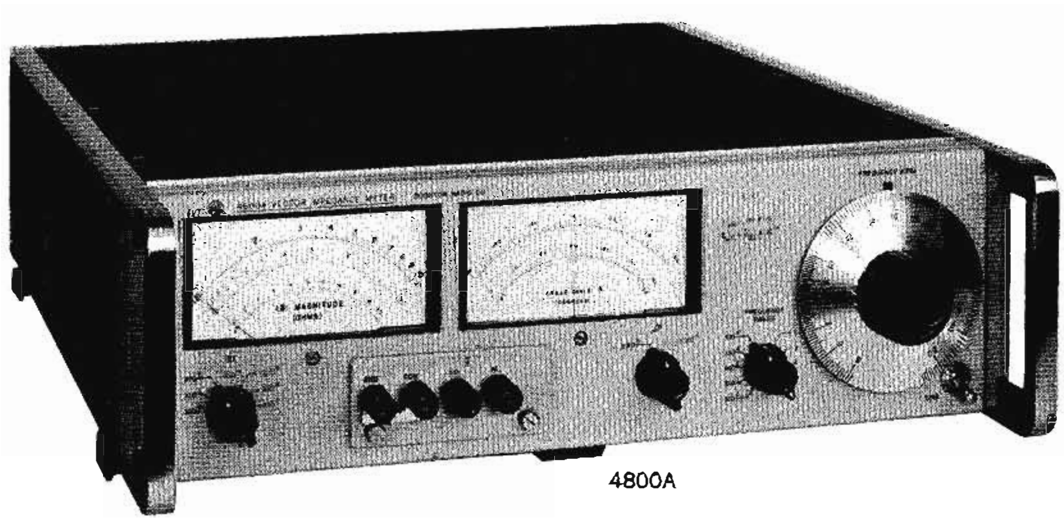


Figure 3. VHF impedance bridge

NEW



4800A

Phase and Z measurements, 5 cps to 500 kc

Completely automatic readings of Z and $\angle\theta$ are directly presented on adjacent meters by the unique new Boonton 4800A Vector Impedance Meter.

This instrument requires only that frequency (and range) be selected, as 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 its direction, if the reactance is capacitive or inductive. Outputs at the rear present dc analog signals proportional to meter deflections, for Z and $\angle\theta$, as well as frequency for convenient recording. Operating range of Model 4800A is 5 cps to 500 kc, 1 ohm to 10 megohms, ±180° phase angle.

Impedance measurements above 500 mc

Facilities for instrumentation of impedance measurements in the ranges above 500 mc are described in the Microwave section of this catalog, pages 230, 231 and following.

Model	Freq. range	Rp range	Cp range	Lp range
Boonton 250A	500 kc to 250 mc	0Ω to 100 KΩ	0.1 to 120 pf	0.001 μh to 100 mh
Model	**Freq. range**	**Q range**	**Lq range**	**L range**
Boonton 260A	50 kc* to 50 mc	10 to 625	30 to 460 pf	0.09μh to 130 mh
Boonton 190A	20 mc to 260 mc	5 to 1200	7.5 to 100 pf	4mμh to 8.5 μh
Model	**Freq. range**	**Z range**	**∠θ range**	
Boonton 4800A	5 cps to 600 kc	1Ω to 10 mΩ	−180° to +180°	
hp 803A	55 mc** to 500 mc	2Ω to 2000Ω	−90° to +90°	

*may be extended downward to 1 kc with external oscillator

**useful over range 5 mc to 1000 mc with reduced ∠θ range and accuracy

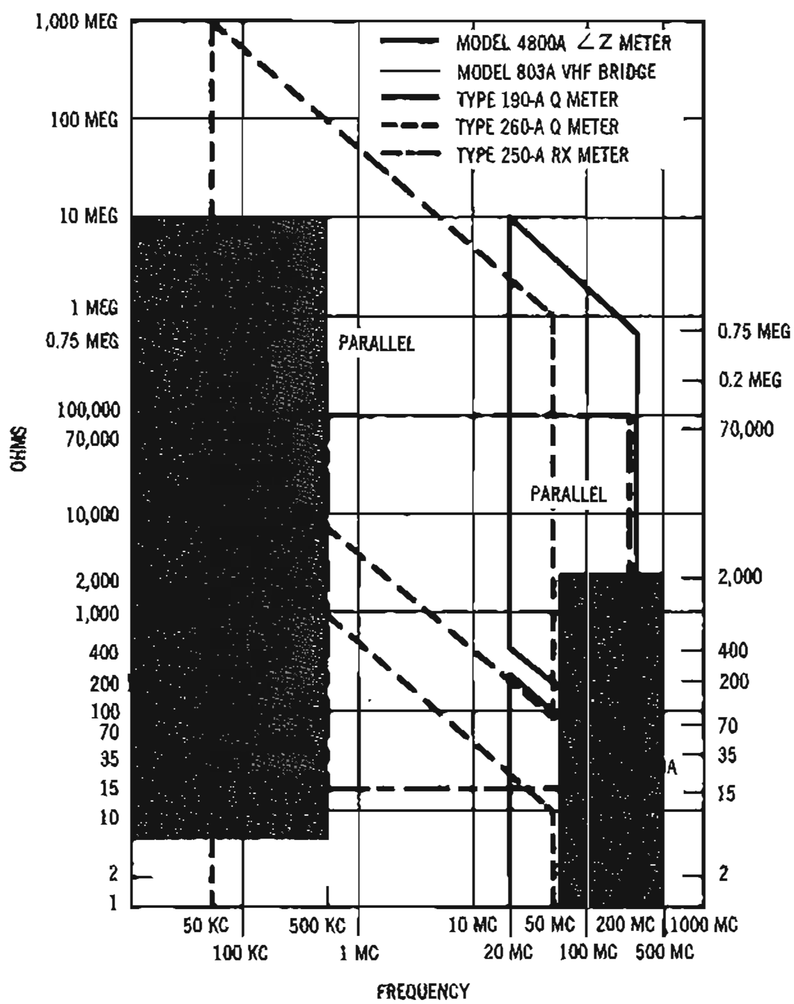


Figure 4. Measurement range—hp Q meters, RX meter, UHF and RF impedance bridges

4800A VECTOR IMPEDANCE METER

Provides direct-reading impedance measurements continuously, 5 cps to 500 kc

Advantages:

- Direct-reading Z ∠θ measurements 5 cps to 500 kc over 10^7 impedance range
- Direct-reading L-C measurements over 10^{11} range
- No balance or nulling required
- Analog outputs for automatic impedance/frequency plotting
- Provides Q measurements by △f method
- Minimum test signal for measuring non-linear devices
- Solid-state modular plug-in construction

The Boonton 4800A Vector Impedance Meter is a unique self-contained instrument providing direct-reading impedance measurements continuously from 5 cps to 500 kc. In operation, the unknown component or circuit is connected to the measuring terminals, the frequency of measurements is selected on the front-panel control, and an instantaneous readout of impedance magnitude (Z) and phase angle (∠θ) is presented on the two front-panel meters. No balancing or nulling adjustments are required, permitting fast, accurate measurements over the instrument's entire range.

Analog outputs directly proportional to impedance magnitude (Z), phase angle (∠θ) and frequency also are provided, so that, by simple connection to an x-y recorder, direct-reading plots of impedance as a function of frequency can be obtained. These outputs also may be used to actuate limit switches or operate digital or expanded scale voltmeters for special applications.

The 4800A also will function as a direct-reading L-C meter covering ranges of inductance and capacitance of 10^{11}. In operation, one of several specific frequencies are selected as indicated on the front-panel dial and inductance (L) in microhenries or capacitance (C) in microfarads is determined by multiplying the reading of the impedance magnitude (Z) meter by an appropriate power of 10.

The 4800A also will function as a Q Meter over the entire range from 5 cps to 500 kc by employing the "Q by delta f" approach. In this method, the 3 db frequency bandwidth is measured and Q is readily computed as the ratio of this bandwidth to the center frequency ($Q = \frac{f_o}{\Delta f}$). For convenience, the impedance magnitude (Z) meter includes an additional scale calibrated directly in db, and an oscillator monitor output is provided to permit precise frequency measurements on an external frequency counter.

Functionally, measurements are performed on the lower impedance ranges by applying a constant current to the unknown and reading the voltage developed across it, which is proportional to impedance magnitude (Z). On the higher impedance ranges, a constant voltage is applied across the unknown, and the current flow is measured. The voltage level applied across the unknown has been carefully minimized so that non-linear devices may be measured under small-signal conditions. Phase angle is measured with a synchronous detector reading the difference between the phase of the current flowing through the unknown and the phase of the voltage across it.

Solid-state circuitry is employed throughout for maximum reliability. All active circuits are designed on plug-in printed wiring boards for convenient accessibility.

Tentative specifications

Frequency characteristics

Total range: 5 cps to 500 kc; number bands: 5; band ranges: 5 to 50 cps, 50 to 500 cps, 0.5 to 5 kc, 5 to 50 kc, 50 to 500 kc.

Monitor output

Level: 2 volts rms minimum; source impedance: 600 ohms.

Recorder output: available as Option 01., voltage source suitable for driving external x-y recorder.

Impedance measurement characteristics

Total range: 1 ohm to 10 megohms; number ranges: 7; ranges (full-scale): 10 ohms, 100 ohms, 1000 ohms, 10 K ohms, 100 K ohms, 1 M ohms, 10 M ohms.

Recorder output: available as Option 01., voltage or current source for driving external x-y recorder.

Phase angle measurement characteristics

Total range: 0 to 360°; number ranges: 2; ranges (full scale): 0 ±90°, 0 ±180°.

Recorder output: available as Option 01., voltage or current source for driving external x-y recorder.

Inductance measurement characteristics

Total range: 1 μh to 100,000 henries; number ranges: 11; ranges (full scale): 10 μh, 100 μh, 1 mh, 10 mh, 100 mh, 1 h, 10 h, 100 h, 1 Kh, 10 Kh, 100 Kh.

Capacitance measurement characteristics

Total range: 0.1 pf to 10,000 μf; number ranges: 11; ranges (full scale): 1 pf, 10 pf, 100 pf, 0.001 μf, 0.01 μf, 0.1 μf, 1 μf, 10 μf, 100 μf, 1000 μf, 10,000 μf.

Input (terminal) characteristics

Input configuration: unbalanced high and low measuring terminals, plus common and separate chassis ground permitting dc biasing of measuring circuit against case.

Physical characteristics

Mounting: cabinet for bench use; readily adaptable for 19" rack mounting.

Finish: gray engraved panel; blue cabinet (other finishes available on special order).

Dimensions: 16¾" wide, 5-7/32" high, 16⅜" deep (425 x 133 x 416 mm).

Weight: net 25 lbs (11,3 kg); shipping 36 lbs (16,2 kg).

Power: 100 to 130 or 200 to 260 v, 50 to 60 cps, 15 w.

Price: available on request.

260A Q METER

Direct-reading expanded scale for Q measurement to 10

The direct-reading expanded scale of the Boonton 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.

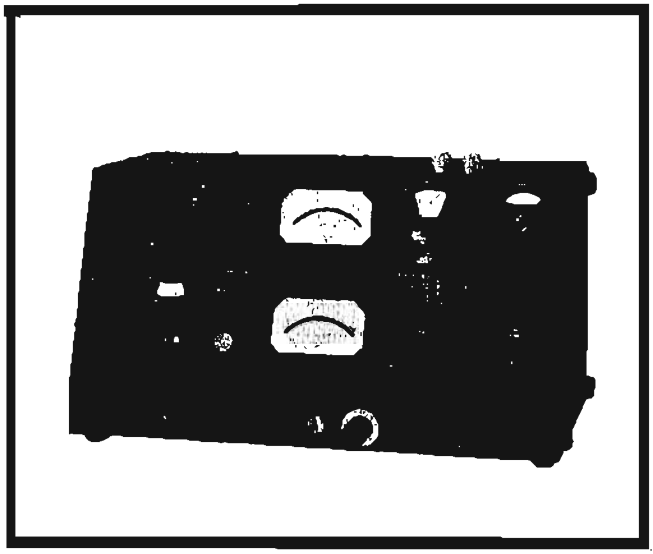
Usefulness, special features of the 260A

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 capacity, 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 Boonton 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 (Boonton 564A) to provide operation below 50 kc down to 1000 cps. A scale also is provided to read inductance directly at selected frequencies.



Specifications

Radio frequency characteristics

- **RF range:** total range: 50 kc to 50 mc, 1 kc to 50 kc (with external oscillator); number bands: 8; band ranges: 50 to 120 kc, 120 to 300 kc, 300 to 700 kc, 700 to 1700 kc, 1.7 to 4.2 mc, 4.2 to 10 mc, 10 to 23 mc, 23 to 50 mc.
- **RF accuracy:** $\pm 1\%$ approximately.
- **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:** $\pm 5\%$, 50 kc to 30 mc; $\pm 10\%$, 30 mc to 50 mc (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:** $\pm 3\%$ (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: $\pm 1\%$ 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:** 20" wide, 12½" high, 8½" deep (508 x 317 x 216 mm).
- **Weight:** net 40 lbs (18 kg); shipping 55 lbs (24.8 kg).

Power: 260A: 95 to 130 volts, 60 cps, 65 watts; 260AP: 95 to 130 volts, 50 cps, 65 watts.

Accessories available: 103A Inductors, 513/518A Q Standards, 564A Coupling Unit.

Price: Boonton 260A,AP, $990.

103A INDUCTORS, 513A, 518A Q STANDARDS, 564A COUPLING UNIT

Reference inductors, calibration standards, coupling transformer for Q meters

103A Inductors

The Boonton 103A 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: Boonton 103A, $17.75 each; set of 16 inductors for 260A, $255; set of 17 inductors for 160A, $270.

Specifications, 103A

Boonton model	Inductance	Approx. resonant frequency for tuning capacitance of:			Approx. Q	Capacitance pf
		400 pf	100 pf	50 pf		
103-A1	1 μh	8	16	20 mc	180	6
103-A2	2.5 μh	5	10	14 mc	200	6
103-A5	5 μh	3.5	7	10 mc	200	6
103-A11	10 μh	2.5	5	7 mc	200	6
103-A12	25 μh	1.5	3	4.5 mc	200	6
103-A15	50 μh	1.1	2.2	3 mc	200	6
103-A21	100 μh	800	1600	2000 kc	200	6
103-A22	250 μh	500	1000	1400 kc	200	6
103-A25	500 μh	350	700	1000 kc	170	7
103-A31	1 mh	250	500	700 kc	170	7
103-A32	2.5 mh	150	300	450 kc	170	8
103-A35	5 mh	110	220	300 kc	160	8
103-A41	10 mh	80	160	200 kc	140	9
103-A42	25 mh	50	100	140 kc	110	9
		100 pf		35 pf		
103-A50	0.5 μh	20 mc		35 mc	225	5.5
103-A51	0.25 μh	30 mc		50 mc	225	5.5
103-A52	0.1 μh	45 mc		75 mc	225	3.5

513A Q Standards

Boonton 513A 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, Boonton 513A, $97 each.

Nominal values for Boonton 513A			
L-250 μh		Cd-8 pf	
	0.5 mc	1 mc	1.5 mc
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 kc are obtained with tuning capacitances of 400, 100 and 50 pf, respectively.

518A Q Standards

Boonton 518A Q Standards, used in conjunction with the 513A Q Standards, provide frequency coverage from 50 kc to 50 mc—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: Boonton 518A, $97 each; set of five 518A and one 513A, $525.

Specifications, 518A

Boonton model	518-A1	518-A2	518-A3	518-A4	518-A5
Inductance	0.25 μh	2.5 μh	25 μh	2.5 mh	25 mh
Low freq. data: Frequency	15 mc	5 mc	1.5 mc	150 kc	50 kc
Resonating C	420 pf	395 pf	440 pf	440 pf	400 pf
Indicated Q	175	195	175	170	90
Middle-freq. data: Frequency	30 mc	10 mc	3 mc	300 kc	100 kc
Resonating C	100 pf	95 pf	105 pf	100 pf	85 pf
Indicated Q	235	235	225	180	130
High-freq. data: Frequency	45 mc	15 mc	4.5 mc	450 kc	150 kc
Resonating C	40 pf	40 pf	45 pf	40 pf	35 pf
Indicated Q	225	205	230	135	125

(Table shows nominal values)

564A Coupling Unit

The 564A 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 kc. The oscillator should supply a variable voltage of 22 volts maximum into an impedance of 500 ohms. Price: Boonton 564A, $39.75.

190A Q METER, 590A INDUCTORS

Direct Q measurements, 20 to 260 mc

190A Q Meter

The Boonton 190A Q Meter finds applications similar to those described for the 260A Q Meter (page 108), 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 mc; number bands: 4; band ranges: 20 to 40 mc, 40 to 80 mc, 80 to 160 mc, 160 to 260 mc.

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 mc; ±15% 100 to 260 mc (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: 590A Inductors.

Physical characteristics

Dimensions: 13⅛" wide, 10½" high, 9½" deep (333 x 267 x 241 mm).

Weight: net 25 lbs (11,3 kg); shipping 32 lbs (14,4 kg).

Power: 190A: 95 to 130 volts, 60 cps, 55 watts; 190 AP: 95 to 130 volts, 50 cps, 55 watts.

Price: Boonton 190A,AP, $1075.

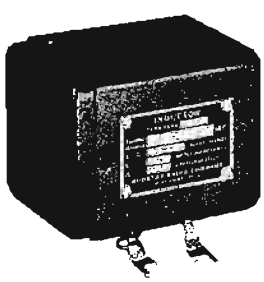
590A Inductors

Boonton 590A Inductors are designed specifically for use in the Q Circuit of the 170A and 190A Q Meters 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.

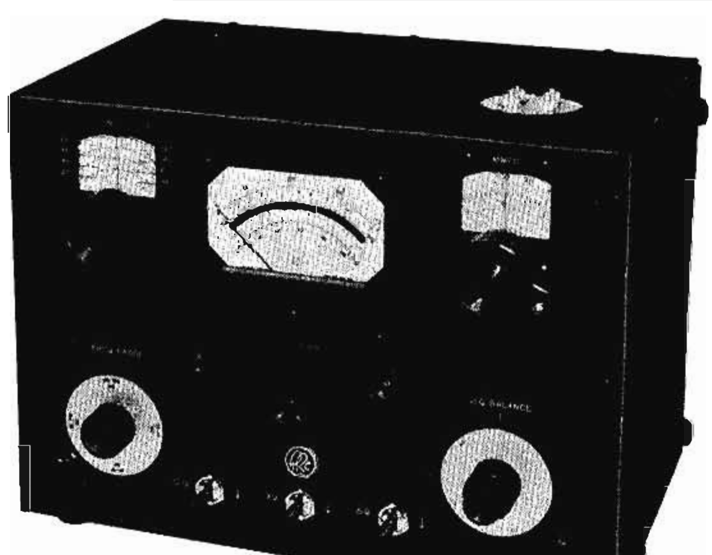
Specifications, 590A

Boonton model	Inductance μh	Capacitance pf	Approx. resonant freq. mc.	Approx. Q	Approx. distributed C pf
590-A1	0.05	95—7.5	70—230	350	1.5
590-A2	0.1	95—7.5	50—160	320	1.7
590-A3	0.25	100—7.5	30—100	380	2.3
590-A4	0.5	80—7.5	25—70	360	2.3
590-A5	1.0	60—7.5	20—50	350	2.9
590-A6	2.5	15—8.0	20—30	330	2.9

Price: Boonton 590A, $17.75 each; $95 for complete set of six.



590A



190A

250A RX METER

Completely self-contained rf bridge, 500 kc to 250 mc

The Boonton 250A 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 indicating meter.

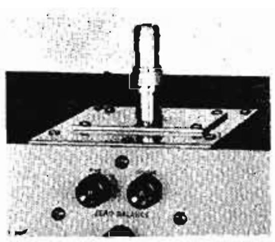
The oscillator, which is carefully designed to minimize temperature effects, is mounted inside a rigid casting in order to obtain a high degree of accuracy, stability and low leakage. A long-life sub-miniature triode is used, and the unit is carefully shielded to avoid any leakage of signal to the amplifier-detector 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.

Quality variable components

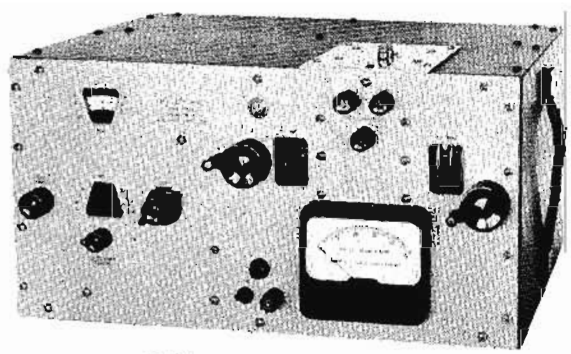
All calibrated variable elements of the bridge are special low-inductance, high-quality variable capacitors driven by anti-backlash gears. Connections to the unknown impedance are arranged for almost zero lead length. Convenient, easily adjusted bridge balance controls are available.

The amplifier-detector null indicator has high, automatically controlled gain and a very low noise level. The power supply is internally regulated.

13510A



515A



250A

Specifications

Radio frequency characteristics

RF range: total range: 500 kc to 250 mc; number bands: 8; band ranges: 0.5 to 1 mc, 1 to 2 mc, 2 to 4 mc, 4 to 9 mc, 9 to 21 mc, 21 to 48 mc, 48 to 110 mc, 110 to 250 mc.

RF accuracy: ±1%.

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 (mc), R = RX Meter R_p reading (ohm), $Q = \omega CR \times 10^{-12}$, 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 (mc), 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 upon frequency (may be reduced to 20 mv by installation of auxiliary potentiometer).

DC: 0 v; (external dc current up to a 50 ma, may be passed through RX meter terminals).

Accessories available: 515A 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), $49.50; 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 kc to 250 mc), $195.

Physical characteristics

Dimensions: 20" wide, 10" high, 12" deep (508 x 254 x 305 mm).

Weight: net 40 lbs (18 kg); shipping 50 lbs (22,5 kg).

Price: Boonton 250A, $1795.

803A VHF BRIDGE, 417A VHF DETECTOR

Fast, accurate impedance measurements

Model 803A VHF Bridge provides direct impedance measurements from 55 to 500 mc by sampling the electric and magnetic fields in a transmission line. Two attenuators are controlled simultaneously; one receives energy proportional to the electric field in the transmission line, and the other receives energy proportional to the magnetic field. The magnitude of the unknown impedance is determined by adjusting this combination for equal output from each attenuator. The two equal signals also are applied to opposite ends of another transmission line, and phase angle is found from their point of cancellation. This method permits fast, accurate impedance measurements without the cumbersome calculations required to convert slotted line swr to impedance.

Specifications, 803A

Measurement range: impedance magnitude, 2 to 2000 ohms; higher and lower values may be measured by using a known length of transmission line as an impedance transformer; phase angle from $-90°$ to $+90°$ at 55 mc and above.

Calibration: impedance, directly in ohms; phase angle, directly in degrees at 100 mc; may be readily computed at other frequencies: phase angle (actual) = phase angle (read) × frequency (mc)/100.

Accuracy (over range 55 to 500 mc): impedance magnitude, better than $\pm\left(5+\frac{\text{frequency mc}}{500}\right)\%$; phase angle, better than $\pm\left(3+\frac{\text{frequency mc}}{500}\right)$degrees; graphs are provided with each instrument so that magnitude readings may be corrected to better than ±2% and phase angle to better than ±1.2° over the rated frequency range.

Frequency range: maximum accuracy 55 to 500 mc; useful down to 5 mc and up to 1000 mc; maximum measureable phase angle at 5 mc is $-8.8°$ to $+8.8°$.

External rf generator: requires an amplitude-modulated rf signal source with at least 1 mw output; for better resolution, a 10 mw, 100% amplitude-modulated, rf signal source is recommended; (608C VHF Signal Generator, pages 182, 183, is ideal for this purpose).

RF detector: requires a well shielded vhf receiver of better than 5 μv sensitivity; (417A VHF Detector is designed for this use).

Dimensions: 14¼" wide, 15¼" high, 9" deep (362 x 387 x 229 mm).

Weight: net 28 lbs (12,6 kg); shipping 41 lbs (18,6 kg).

Accessories furnished: one 803A-16D Cable Assembly; one 803A-16E Cable Assembly; one 11512A Shorting Plug.

Price: hp 803A, $1250.

Model 417A VHF Detector is a super-regenerative (AM) receiver covering all frequencies between 10 and 500 mc in 5 bands. Designed for use with the hp 803A VHF Bridge, the 417A provides a high sensitivity of approximately 5 microvolts over the entire frequency band. It has a single, convenient frequency control directly calibrated in megacycles.

Specifications, 417A

Frequency range: 10 to 500 mc, continuous coverage, 5 bands; calibrated directly in mc.

Sensitivity: approx. 5 mv over entire frequency range.

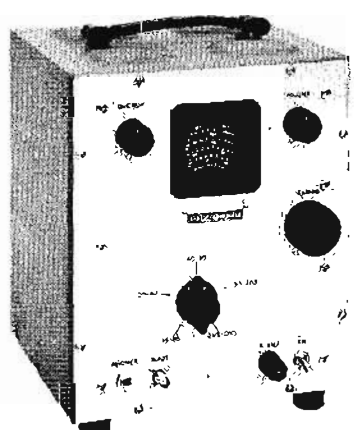
Power: 115 or 230 volts ±10%, 50 to 1000 cps, 35 watts.

Dimensions: 9¼" wide, 12½" high, 9" deep (235 x 318 x 229 mm).

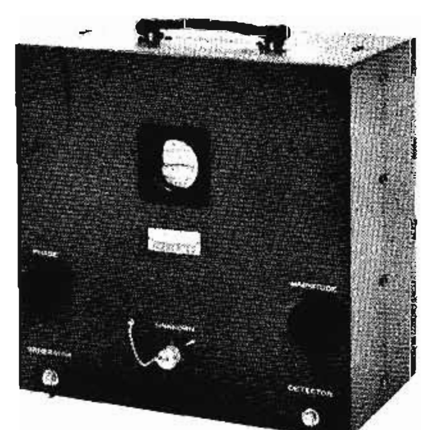
Weight: net 18 lbs (8,1 kg); shipping 28 lbs (12,6 kg).

Accessories available: 11001A Cable Assembly, $5.50; 10503A Cable Assembly, $6.50; 803A-16E Cable Assembly, $9.

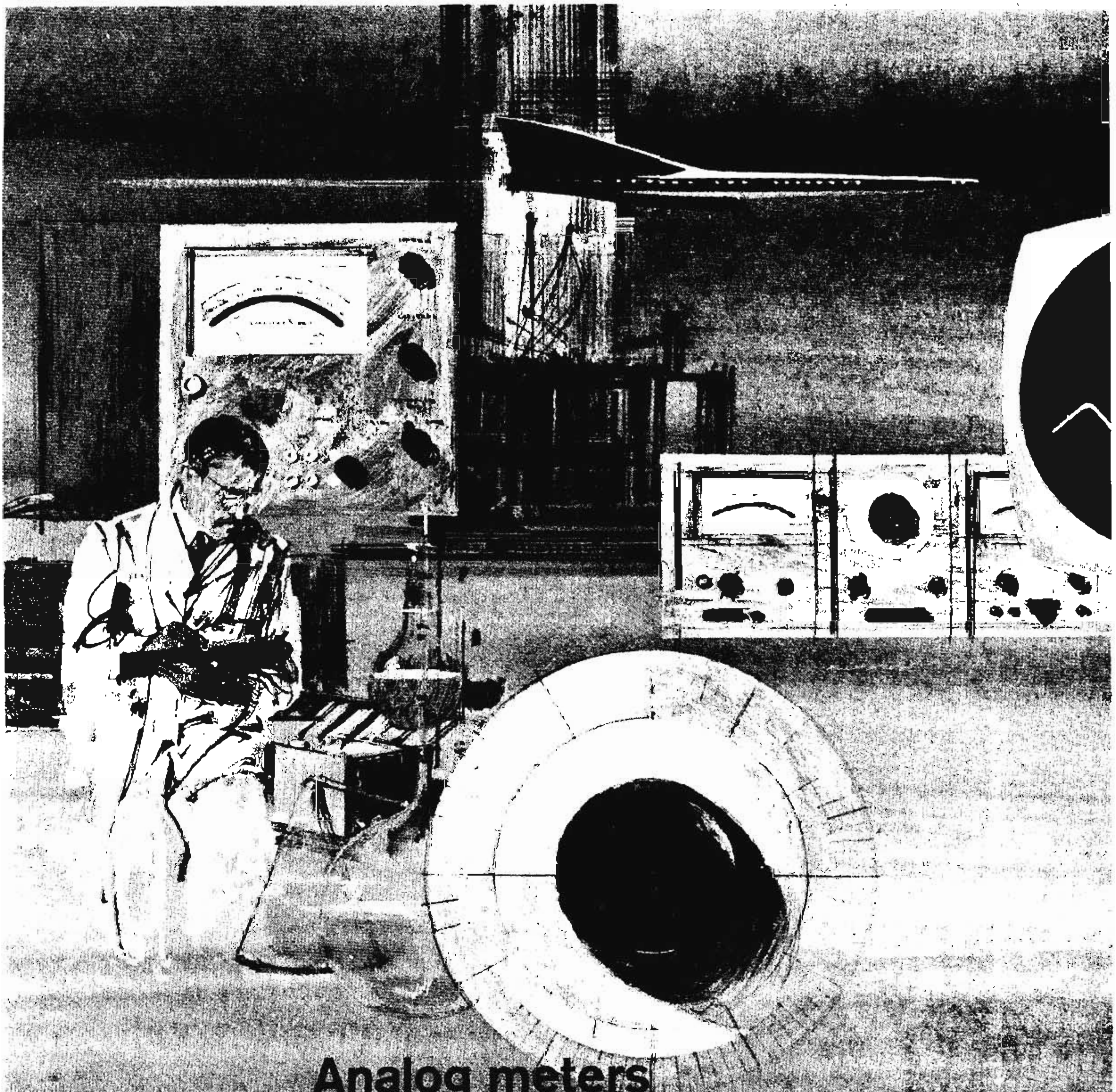
Price: hp 417A, $550.



417A



803A



Analog meters

ANALOG MEASURING EQUIPMENT

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, in turn, drives a meter movement. Devices of this type are called analog instruments.

The meter movements in these instruments consist of a pointer attached to a coil, which usually is supported by pivots and jewels. Hewlett-Packard substitutes a taut-band suspension, in place of pivots and jewels, in its high-accuracy instruments. The moving coil in the taut-band meter mechanism is suspended on a platinum alloy ribbon, eliminating friction and repeatability problems. In order to eliminate tracking error on mass-produced meters, an automatic system, developed by Hewlett-Packard, custom-calibrates and photographically prints meter faces to match exactly the linearity characteristics of each individual meter movement at all points. Figure 1 shows scales for two different meters printed by Hewlett-Packard's calibrator on one face. By combining an hp produced taut-band meter movement with custom calibration, outstanding ruggedness and precision are inherent in all meter movements which are produced, in volume, for Hewlett-Packard's electronic instruments.

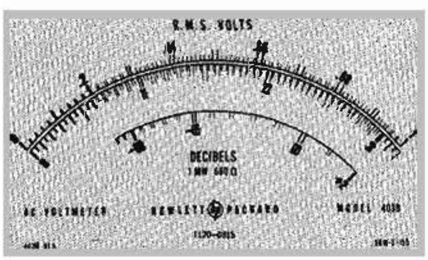


Figure 1. Scales for two different meters printed by Hewlett-Packard's calibrator on one face.

Some of the operating principles of Hewlett-Packard's electronic instruments for measuring E, I and R are outlined briefly here to help the user select the proper instrument for his application.

DC voltage measurements

The dc voltmeter represents a straightforward application of electronics to measuring instruments. This instrument usually has a direct-coupled amplifier preceding the meter movement, as shown in Figure 2. The amplifier performs two important functions. First, it increases the input impedance of the meter, so that the instrument draws negligible current from the circuit under test. Because of the amplifier, the electronic voltmeter is a voltage-driven device, whereas the simple meter movement is a current-operated device. This distinction is important, since the voltage in many circuits can be altered by the current required for operating a meter movement alone.

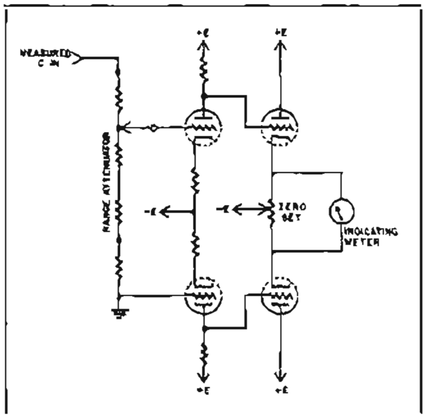


Figure 2. Basic dc voltmeter circuit.

A second amplifier function is to increase the effective sensitivity of the meter movement. An amplifier changes the measured quantity into a current of sufficient magnitude to deflect the meter. 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 410C is representative of this class of instruments, including dc voltage measurements among its capabilities. Input impedance is typically 100 megohms, offering negligible loading effect on most circuits under test. The 410C uses a chopper-stabilized amplifier which minimizes the drift characteristic of direct-coupled amplifiers. Because of the low drift rate of this circuit, no zero-set control is required. The measuring range of the 410C is from 15 millivolts full scale, to 1000 volts.

A widely used technique for eliminating drift in low-level measurements is to convert the dc into a comparable ac signal by alternately applying and removing the dc signal. The resulting chopped signal is amplified in ac amplifiers and then synchronously rectified at a high level for operating the meter movement. Overall dc feedback assures accuracy of the dc gain. DC drift is reduced to a value set by the input chopper. The hp 410C uses this principle in its dc mode of operation.

The chopper technique also is used in the hp 425A High-Sensitivity DC Voltmeter. The most sensitive scale on this instrument reads 10 microvolts end scale (the taut-band meter face on this instrument has a center-scale zero, for use as a null indicator).

The 425A photo-conductive chopper converts the dc to a comparable ac by shining light on photo-sensitive resistors periodically. This results in a low-noise, high-impedance chopper action.

The same technique is used in the versatile 412A Volt-Ohm-Milliammeter which, without a zero-set control, still maintains 1% voltage measurement accuracy. The same circuitry also is adapted to the 413A DC Null Voltmeter which, like the hp 425A, has a center-scale zero, for use as a null detector.

The new hp solid-state 419A DC Null Voltmeter has 0.1 μv resolution, with 18 ranges from 3 μv to 1000 volts. An internal adjustable bucking voltage allows the operator to null the input signal with a front-panel control, to eliminate the effects of loading by the nullmeter on the 3 μv to 300 mv ranges. This dc null voltmeter is powered by rechargeable batteries. Refer to page 132 for details.

Automatic ranging dc voltmeter

The new solid-state Hewlett-Packard 414A Automatic Ranging Volt-Ohmmeter provides the "touch-and read" convenience of a digital instrument with the economy of an analog instrument. Range changing and polarity selection both are automatic and take less than 300 milliseconds, providing rapid, accurate "hands-free" measurement of voltage or resistance. A chopper-stabilized dc amplifier, input attenuator, gain attenuator and metering circuit form the basic circuit, which is illustrated in Figure 3. Range changing decisions are indicated by means of a lighted display and are based on two signal levels, one near full scale on a given range and the other at one-fourth full scale. An amplitude comparator produces an "up-range signal" whenever the input voltage tends to rise above the level which is near full scale and a "down-range signal" whenever the input voltage tends to fall below the level near one-fourth full scale. Range switching and indicating logic are a set of four multivibrators, which define the twelve ranges of the instrument.

DC current measurements

For most measurements of appreciable amounts of dc current, 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, though, the sensitivity of the meter movement must be increased, usually by using more turns in the coil.

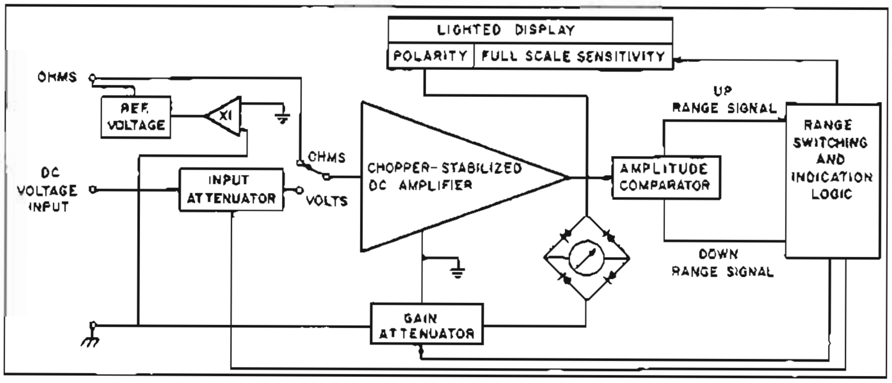


Figure 3. Block diagram of hp 414A Automatic-Ranging Voltmeter.

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 in this way without accessory equipment. These instruments cover the range from 10 pa to 1 ampere full scale (412A, 1 μa to 1 amp full scale; 425A, 10 pa to 3 ma full scale; 410C, 1.5 μa to 150 ma full scale).

Current measurements using a series resistor have the obvious disadvantage of interrupting the circuit under test. In many applications, insertion of a resistance in the line of current flow may alter the current being measured or even alter the circuit operation. To overcome this difficulty, the hp 428B Clip-on DC Milliammeter uses current probes which simply clip around the current-carrying wire and measure direct currents from 0.1 ma to 10 amperes without interrupting the circuit.

These probes use the second-harmonic flux gate principle to sense magnetic flux around the wire. (Refer to Figure 4.) The probe encircles the wire with a magnetic core which is saturated periodically by a 20 kc driving current. Saturation interrupts the magnetic circuit, thus effectively "gating" any flux induced in the core by current in the wire. This gated ac flux couples to sensing coils on the core, inducing a 40 kc voltage proportional to the current in the wire. The instrument's circuitry amplifies the coil voltage and drives the indicating meter accordingly. High linearity is achieved by using negative dc feedback current, balancing input ampere-turns against feedback ampere-turns.

The hp 428B enables current measurements to be made as easily as voltage measurements, requiring no alteration of the circuit under test.

The clip-on probes are finding wide use in solid-state circuit measurements, where current flow has to be monitored carefully. Sensitivity is such that even base current can be measured. There are a variety of other uses, such as measuring the current in ground loops, where the impedance is too low for the series-resistance technique to be applied.

A unique feature of these probes is that the sums and differences of currents in several wires can be determined by running the wires through the probe at the same time. This technique is useful for balancing push-pull amplifier stages, by running the two plate leads in opposite directions through the probe and then adjusting for a null on the current meter. The Model 3528A Current Probe allows current measurements in conductors up to 2½ inches in their maximum dimensions. Such conductors are not limited to wires, but can be pipes, multiconductor cables, lead-sheathed cables or microwave waveguides. With this large aperture probe, difficult-to-measure quantities, such as corrosion current in small structural members, circulating dc and low-frequency currents in ground straps and waveguides, can easily be determined. Low-frequency current to 300 cps is measured by connecting an oscilloscope or ac voltmeter to the 428B recorder output.

The hp 3529A Magnetometer Probe is an accessory to the 428B which allows measurements of magnetic field intensity and direction. The conversion factor of the 3529A is 1:1, producing a reading from the 428B in milliamps which is directly equal to the measured field strength in milligauss. The hp 3529A is useful in acoustical design and other Zeeman effect investigations.

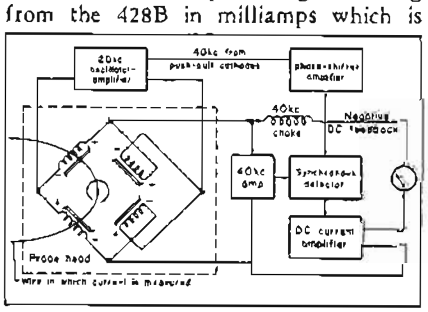


Figure 4. **Simplified block diagram of clip-on milliammeter. Plus and minus signs indicate polarities of voltages induced by gated flux, which is proportional to current in wire. Bridge is balanced for 20 kc driving signal but is not balanced for induced 40 kc signal.**

Resistance measurements

Resistance is usually determined through the familiar Ohm's relation: $E = IR$. Traditionally, this is done by applying a known voltage, E, to the unknown resistance, R, and then measuring the current, I, passing through it. With E and I known, R can be computed.

A modified procedure for doing this with electronic voltmeters is shown in Figure 5. Here, the current flowing in the circuit depends on the series combination of the unknown resistor R_x and the internal resistor R_i. This means, of course, that both the voltage and current in the external circuit will change according to the value of the unknown. Instruments which include the ohmmeter functions, such as the hp 410B, 410C, 412A and 414A have taut-band meters with scales individually calibrated to account for this. If R_x were infinite, the meter would read the full battery voltage E_i. Full-scale deflection, therefore, would correspond to a resistance of infinity. If R_x were zero (short circuit) the meter would read zero. The mid-scale range then occurs when R_x equals R_i.

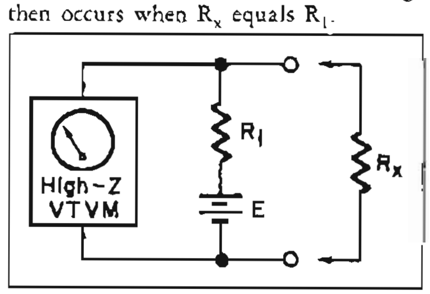


Figure 5. Resistance measurement with an electronic voltmeter.

The resistance R_i, included as part of the ohmmeter, provides a convenient means of changing the range of the instrument. The 410C has mid-scale resistance readings ranging from 10 ohms to 10 megohms in seven ranges. The 414A employs a feedback stabilized current source which allows the use of a linear ohms scale and avoids a special meter scale for resistance measurements. The resulting meter scales are easy to read.

When values of low resistance are being measured, the finite resistance of the ohmmeter leads, included in the total resistance measurement, can contribute considerable error. To meet this problem (Figure 6) the resistance of the current-carrying leads is calibrated as part of R_i, while the resistance in the voltmeter leads is insignificant, compared to the high input impedance of the metering circuit. This arrangement, using four

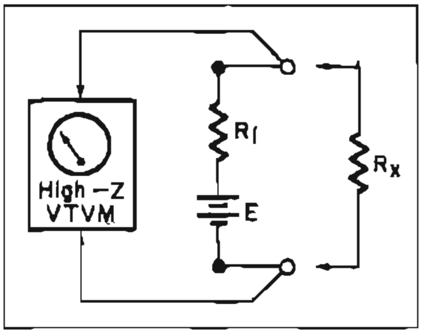


Figure 6. Measurement of low-value resistances.

leads, is found in the hp Model 412A.

To measure extremely low resistances, such as found in short lengths of large wire or in relay contacts, a constant current source, such as the hp 726AR Power Supply, may be used to supply a fixed amount of current through the unknown resistance. A sensitive voltmeter (hp 425A, for example) then is used to measure the voltage drop across the resistance being measured. With this combination, resistance measurements as low as one micro-ohm may be made.

High resistance measurements can be disturbed by the impedance of the measuring voltmeter when this impedance is comparable to the resistance being measured. The 412A accounts for this by adjusting the value of R_f on the high-resistance ranges to compensate for the voltmeter input impedance. On the 100-megohm scale, for example, R_f is actually 200 megohms. The parallel combination of the 200-megohm R_f and the 200-megohm input impedance of the meter gives effective internal impedance of 100 megohms.

For very high resistances, a high voltage is applied to the unknown, and the current flow is measured on a sensitive current meter. For instance, the most sensitive current range of the 425A, used with a 500-volt supply, such as the hp 711A, can measure resistances as high as 5×10^{14} ohms.

AC voltage measurements

Electronic instruments for measuring ac voltages also use an amplifier with the meter movement but add a rectifier circuit to convert the ac to dc. Meter-indicating ac voltmeters built by Hewlett-Packard fall into three broad categories: average-responding, peak-responding and rms-responding meters.

The circuit principle of the average-reading meter is shown in Figure 7. Here, the ac signal is amplified in a gain-stabilized ac amplifier and then is rectified by the diodes. The resulting current pulses drive the meter. The meter deflection is proportional to the average value of the waveform being measured.

The peak-responding voltmeter, shown

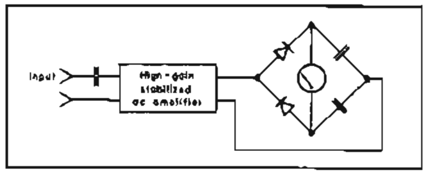


Figure 7. Average-responding voltmeter.

diagrammatically in Figure 8, places the rectifier in the input circuit, where it charges the small input capacitor to the peak value of the input signal. This volt-

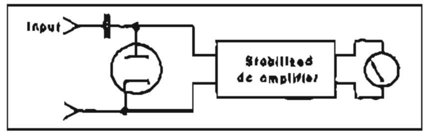


Figure 8. Peak-responding voltmeter.

age is passed to a dc amplifier, which drives the meter. Meter deflection here is proportional to the peak amplitude of the input waveform.

Both of these meters (average-responding and peak-responding) have scales calibrated such that the rms value of a sine-wave input voltage is indicated, since the meters are used primarily for sine-wave measurements. The average-responding type, therefore, reads 1.11 times higher than the average voltage, while the peak-responding type indicates 0.707 of the peak voltage. Consequently, both meters may be in error if the measured signal is not a pure sine wave. The amplitude and phase of the harmonics present affect the peak and average values of the waveform, upsetting the rms calibration. The average-reading voltmeter is not affected by distortion as much as the peak-reading type is. However, if highly complex waveforms are to be measured, then a true rms-responding voltmeter is recommended. Write or ask for hp Application Note 60 for additional information concerning measurement error from harmonics or other spurious voltages.

The widely used hp 400 Series Vacuum Tube Voltmeters are average-responding meters. The 400D is a low-priced precision voltmeter, offering voltage ranges from 1 mv to 300 v full scale, 2% accuracy and a frequency coverage from 10 cps to 4 mc. The 400H is similar, but offers 1% accuracy and has a taut-band custom-calibrated 5-inch, mirror-backed meter.

The 400L also has the same circuitry and a 5-inch mirror-backed scale, but, in this case, the meter movement is logarithmic. The 400L scale is evenly divided into db units for the convenience of acoustical and communications engineers. The new 400E and 400EL Solid-State AC Voltmeters are average-responding voltmeters offering voltage ranges from 1 mv to 300 v rms full scale, covering a frequency range from 10 cps to 10 mc.

The portable, solid-state, battery-operated 403A and 403B are, likewise, average-responding meters.

The peak-responding meters are used for higher frequency measurements because of their lower input capacitance. The capacitance to ground of the input circuit and probe of a voltmeter must be included as part of the input impedance. This capacitance acts as a high-frequency by-pass to the input resistance and limits the frequency range of most ac voltmeters.

Since the diode rectifier of peak-responding voltmeters is placed in the probe tip preceding the amplifier, shortening the signal path, the ac capacitance is low. Input capacitances of one to three picofarads are characteristics of these instruments. The hp 410C general-purpose vacuum tube voltmeter uses a special probe for high-frequency ac measurements and employs a diode expressly designed for hp. The frequency range of this instrument is from 20 cps to more than 700 mc.

The extension of this technique into the millivolt range is impractical because of the non-linear response of diodes at low signal levels. A variation of the rectifying technique is required to eliminate the diode non-linearity. The 411A RF Millivoltmeter does this by using two diodes. The most sensitive scale on the hp 411A is 10 millivolts over a range of 500 kc to 1 gc. Sensitivity of 1 millivolt over a range of 1 kc to 1 gc will be available soon from Hewlett-Packard. This new instrument, designated the Model 3406A, uses broadband sampling techniques.

As mentioned previously, complex waveforms are measured most accurately by an rms-responding voltmeter. Mathematically, the root-mean-square (rms) value of any complex quantity is obtained by summing the squares of each component and then taking the square root of this sum.

This operation is performed by sensing the waveform's heating power, which is proportional to $(E_{rms})^2$. The indicating circuitry responds to the square root of the heating power. Heating power is measured by feeding an amplified version of an input waveform to the heater of a thermocouple, the voltage output of which is proportional to the waveform's heating power.

Previously, the primary difficulty with that technique has been the non-linear behavior of the thermocouple, slow response and burnout, which complicate the calibration of the indicating meter. The new hp 3400A True RMS Voltmeter overcomes this difficulty with the use of two thermocouples mounted in the same thermal environment. Non-linear effects in the measuring thermocouple are cancelled by similar non-linear operations of the second thermocouple.

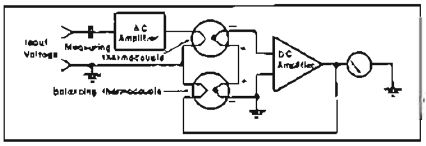


Figure 9. True rms-responding voltmeter.

As shown in the block diagram of Figure 9, the amplified input signal is applied to the measuring thermocouple, and a dc feedback voltage is fed to the balancing thermocouple. The dc voltage is derived from the voltage output difference between the thermocouples. The circuitry may be looked upon as a feedback control system which matches the heating power of the dc feedback voltage to the input waveform's heating power. Meter deflection is proportional to the dc feedback voltage, which, in turn, is proportional to the rms of the input signal. The meter indication, therefore, is linear.

This arrangement allows the Model 3400A to provide highly accurate readings of the rms value of complex waveforms. Full-scale accuracy is maintained with waveforms having crest factors (ratio of peak-to-rms) as high as 10:1. At 10% of full-scale deflection, where there is less likelihood of amplifier saturation, waveforms with crest factors as high as 100:1 are accommodated.

The 3400A reads voltages throughout a range of 100 μv to 300 v rms within a frequency range of 10 cps to 10 mc.

AC current measurements

AC current measurements can be made by the use of a sensitive ac voltmeter and a series resistance, as described under "DC current measurements." Hewlett-Packard calibrated shunt resistors are designed for use with the 400 series meters, making these instruments direct-reading in current units. The 11029A-11034A shunt resistors are described on pages 138, 139.

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 in a battery-operated solid-state amplifier, and the amplifier's voltage output 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, therefore, is read directly on the voltmeter.

The basic specifications for Hewlett-Packard analog voltmeters are summarized in Table 1. These types of voltmeters may be summarized 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 high-frequency measurements (>1 mc), 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.

(4) 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.

(5) For very wide bandwidths and high-sensitivity measurements of sinusoidal or non-sinusoidal waveforms the new hp 3406A Sampling Voltmeter is the appropriate choice.

Table 1. Which voltmeter to select.

Instrument	Primary uses	Frequency range; typical accuracy	Voltage or current range	Input impedance	Refer to page
400D,* 400H,* 400L*	Wide-range ac measurements, high sensitivity, amplifier, log voltages	10 cps to 4 mc; 1%	0.001 to 300 v full scale, 12 ranges	10 meg; 25 pf shunt	118, 119
400E,* 400EL*	Log voltages, linear db measurements, amplifier, converter	10 cps to 10 mc; 1%	0.001 to 300 v full scale, 12 ranges	10 meg; 25 pf shunt	120, 121
403A*	Battery-operated portable; fast, accurate, hum-free ac measurements	1 cps to 10 mc; ±3%	0.001 to 300 v full scale, 12 ranges	2 meg; 40, 20 pf shunt	126
403B*	AC voltage measurements in lab or field, ac line or battery operation	5 cps to 2 mc; ±2%	1 mv to 300 v full scale	2 megohms	126
410B**	Audio, rf, vhf measurements; dc voltages; resistances	dc; ac, 20 cps to 700 mc; ±3%	dc, 1 to 1000 v full scale ac, 1 to 300 v full scale	dc, 122 megohms ac, 10 megohms/1.5 pf	129
410C**	DC voltage; resistance, current; audio, rf, vhf measurements with ac probe	dc; ac, 20 cps to 700 mc; ±2%	dc v, 15 mv to 1500 v full scale, dc amps, 1.5μa to 150 ma full scale, ac v, 0.5 to 300 v full scale	dc, v, 100 megohms ac, 10 megohms/1.5 pf	128
411A**	Millivolt, db readings to gc range	500 kc to 1 gc; ±3%	10 mv to 10 v full scale, 7 ranges	typically 200 K at 1 mc, 1 v	123
412A	Precision voltage, current resistance measurements	dc; ±1%	1 mv to 1000 v full scale, 1 μa to 1 amp	10 to 200 megohms, depending on range	134
413A	DC null meter, dc voltmeter, amplifier	dc; ±2%	1 mv to 1000 v full scale, 13 ranges	10 to 200 megohms, depending on range	133
414A	Automatic ranging volt-ohmmeter	dc; ±0.5%	5 mv to 1500 v full scale, 12 ranges	10 to 100 megohms, depending on range	130
419A	DC nullmeter, dc voltmeter, recorder, amplifier	dc; ±2%	±3 μv to ±1000 v, 18 ranges 0.1 μv resolution	100 K to 100 megohms, depending on range	132
425A	Read μv, μμa; 100 db amplifier; medical, biological, physical, chemical	dc voltages; 100 db amplifier; ±3%	10 μv to 1 v full scale, 10 μa to 3 ma full scale	1 megohm ±3%	135
428B	Clip-on milliammeter; recorder output	dc on meter, dc to 400 cps on recorder; ±3%	1 ma to 10 amps full scale, 9 ranges		136
3400A†	True rms readings of complex ac waveforms; crest factor 10:1	10 cps to 10 mc; ±1%	0.001 to 300 v full scale	10 megohms, 15, 40 pf shunt	122
3406*	Millivolt, db readings to gc range	1 kc to 1 gc; ±3%	1 mv to 1 volt rms, 7 ranges	100 K ohms at 100 kc	124, 125

Note: typical accuracy listed; for specific data refer to page number *average-responding **peak-responding †rms-responding

400D, 400H, 400L VACUUM TUBE VOLTMETERS

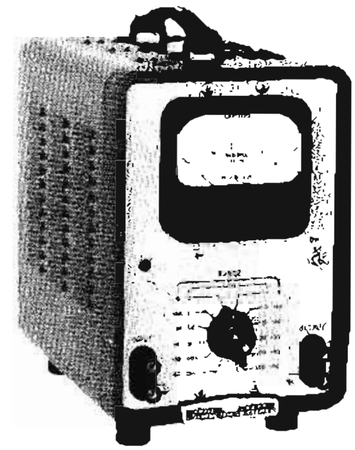
Highest quality, highest accuracy linear and log voltmeters

Advantages:

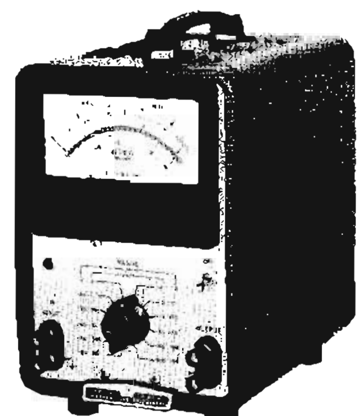
- Exceptional long-term stability
- Large voltage range; high sensitivity
- Broad 10 cps to 4 mc frequency coverage
- 400H, 400L custom-calibrated to eliminate tracking error
- Taut-band meter
- High 10-megohm input impedance
- Premium quality throughout; easy to service
- Usable as a stable, high-gain amplifier
- Large overvoltage capacity

Uses:

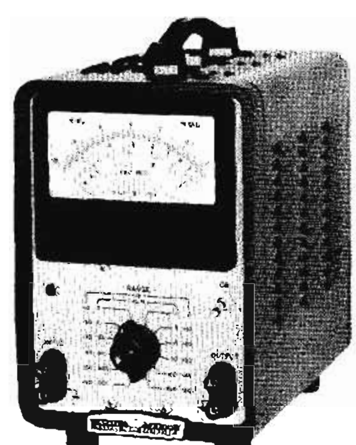
- Research and development laboratory
- Production test
- Communications
- Service departments



400D



400H



400L

On these pages Hewlett-Packard presents three of the industry's most widely used vacuum tube voltmeters. Basically similar instruments, Models 400D, 400H and 400L have specific characteristics which render them suited to given applications.

Model 400D is essentially a low-priced precision voltmeter offering wide voltage range, 2% accuracy and the broad frequency coverage 10 cps to 4 mc.

Model 400H is an adaptation of Model 400D but offering individual meter-face calibration and the extreme accuracy of 1% 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.

Custom-calibration

The Model 400H and 400L are custom-calibrated to eliminate tracking error. Scale tracking error is one of the major and inherent causes of inaccuracy in a voltmeter, but this has been eliminated, on *a production basis and at no extra cost to the buyer,* in these precision hp instruments. To eliminate tracking error, hp developed an automatic system which custom-calibrates and photographically prints a meter face to match the linearity characteristics of each individual meter movement. A taut-band meter movement (Instead of pivots and pivels, the moving coil in the taut-band meter mechanism is suspended on a platinum alloy ribbon — eliminating friction and insuring excellent repeatability.) and custom-calibration offer ruggedness, precision and maximum accuracy.

General features

Models 400D,H, and L are engineered to give you the best possible combination of measuring accuracy, frequency and voltage range, and the trouble-free service life you expect from hp — in short, perhaps the best multi-purpose voltmeters available.

An important feature of each is the hp-developed amplifier providing approximately 60 db of feedback at mid-range. This assures highest stability and freedom from calibration change due to external conditions.

High stability

Stability long term is such that a reduction in the G_m of the amplifier tubes to 75% of nominal value causes an error of less than 0.5%, 50 cps to 1 megacycle. And even line voltage variations as high as ±10% cause negligible change.

Other features common to these three rugged voltmeters include a high 10-megohm input impedance, preventing loading to circuits under test, generous overload protection guarding the instruments even against peaks of 600 volts, special circuitry minimizing transients during switching, premium quality construction throughout, and output circuitry permitting the voltmeters to be used as broadband, high-gain amplifiers throughout their full frequency range.

High-accuracy, log models

As indicated above, Model 400H is similar to Model 400D but offers 1% accuracy. Details of accuracy at various frequencies are found in the table.

Designed specifically for acoustical and communications engineers and for those working with decibel measurements, 400L incorporates a special logarithmic meter movement. The log voltage scale and unusually long scale length provide an instrument of maximum readability and accuracy which is a *constant percentage* (±2%) *of reading*. The decibel scale is more than 5" long, and voltage scales spread across the full scale length. The meter is mirror-backed for utmost accuracy. A range switch changes voltage sensitivity in 10 db levels. This feature, with the 12 db scale, provides the wide overlap desirable in decibel level measurements.

Special db-measuring options, accessories

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.

See page 263 for line matching bridging transformers and page 139 for capacitive voltage dividers and other useful accessories for hp vacuum tube voltmeters. A complete voltmeter calibration system and an ac current probe are described on page 140.

Specifications

	400D,DR	400H,HR	400L,LR
Voltage range:	1.0 mv to 300 v full scale, 12 ranges		
Frequency range:	10 cps to 4 mc		
Accuracy: (as % of full scale on 400D,DR and 400H,HR)	±2%, 20 cps to 1 mc; ±3%, 20 cps to 2 mc; ±5%, 10 cps to 4 mc	±1%, 50 cps to 500 kc; ±2%, 20 cps to 1 mc; ±3%, 20 cps to 2 mc; ±5%, 10 cps to 4 mc	±2% of reading or ±1% of full scale, whichever is more accurate, 50 cps to 500 kc; ±3% of reading or ±2% of full scale, 20 cps to 1 mc; ±4% of reading or ±3% of full scale, 20 cps to 2 mc; ±5% of reading, 10 cps to 4 mc
Long-term stability:	reduction in G_m of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 50 cps to 1 mc		
Calibration:	reads rms value of sine wave; voltage indication proportional to average value of applied wave; linear voltage scales 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 scales 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 15 pf on ranges 1 to 300 v; 25 pf on ranges 0.001 to 0.3 v		
Amplifier:	output approx. 0.15 v max; internal impedance 50 ohms; max. gain approx. 150 on 0.001 range		
Power:	115 or 230 volts ±10%, 50 to 1,000 cps; approx. 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 23 lbs (10,3 kg) (cabinet mount); net 21 lbs (9,45 kg), shipping 30 lbs (13,5 kg) (rack mount)		
Price:	hp 400D, $250* hp 400DR, $255**	hp 400H, $325* hp 400HR, $330**	hp 400L, $325* hp 400LR, $330**

*Cabinet **Rack Mount

400E,EL AC VOLTMETERS

Measure 10 cps to 10 mc, 1 mv to 300 v

Advantages:

- 10 megohms input impedance
- Constant low input capacity
- DC recorder output
- High-gain amplifier
- 100-division individually calibrated taut-band meters
- Front-panel relative switch allows reference adjustments for relative measurements
- Large overload capacity
- Outstanding long-term stability
- Solid state
- Compact

The hp 400E,EL Solid-State AC Voltmeters are ruggedly built solid-state precision instruments for measuring ac voltages from 1 millivolt to 300 v rms full scale. They cover a frequency range from 10 cps to 10 mc and have constant 10 megohm input impedance on all ranges. The instruments are simple to operate and give direct voltage and dbm readings.

These ac voltmeters have exceptional long-term stability because their calibration is not dependent on active component parameters which are subject to aging. The 400E,EL also may be used as stable, high-gain ac amplifiers or ac-to-dc converters.

The 400E has all the characteristics mentioned above with 1% accuracy on a 4½" mirror-backed taut-band meter. The meter scale is individually calibrated for its particular movement with 100 divisions to give an added measure of readability.

The 400EL has all the characteristics above with 1% of reading accuracy on a linear db logarithmic voltage meter scale. This meter is also individually calibrated with 120 divisions and is ideal for db measurements.

The specifications in the chart on the next page show these compact, lightweight, solid-state voltmeters will give premium performance at an economical price.

Circuit description

The Model 400E,EL AC Voltmeters use high-gain amplifiers having high stability and wide bandwidth. The solid-state metering circuit is stabilized by an overall feedback loop to provide maximum stability. The impedance converter circuit also uses a large amount of overall feedback. These features insure a high degree of accuracy independent of line voltage changes or other external effects. Additionally, the overall feedback technique provides a stable high-gain, wideband ac amplifier with a 50-ohm output impedance.

AC-to-DC converter

The Models 400E,EL provide a dc output proportional to meter deflection which can be used to drive a potentiometer or galvanometer recorder. This dc output is available at the rear panel of the instrument.

Easy to use

A front-panel range switch which changes sensitivity in 10 db steps, combined with the db calibration of the meter, permits reading of dbm directly without calibration or conversion from −72 to +52 dbm (0 dbm = 1 milliwatt into 600 ohms). In addition, the 10 db range spacing provides 2 voltage scales so that readings are always greater than one-third full scale. Consequently, the highest possible readability and accuracy are provided.

Logarithmic model, 400EL

The hp 400EL is designed for greater resolution in db measurements. This instrument is useful for acoustical and communications applications. It incorporates an hp taut-band mirror-backed logarithmic meter movement. For utmost accuracy, the meter scale is individually calibrated, using the new hp logarithmic meter calibrator. The meter scale provides maximum readability and a constant ±1% of reading accuracy. The decibel scale is more than 4⅜" long, and voltage scales spread across the full length. A range switch changes sensitivity in 10 db steps which, combined with the 12 db scale, provides the overlap desirable in decibel level measurements.

Options and accessories

Special db-measuring options—The Model 400E reads directly in volts and db, with the voltage scale uppermost. The Model 400E (Option 01.) with db scale uppermost is recommended for greater resolution in db measurements. Refer to figure 1.

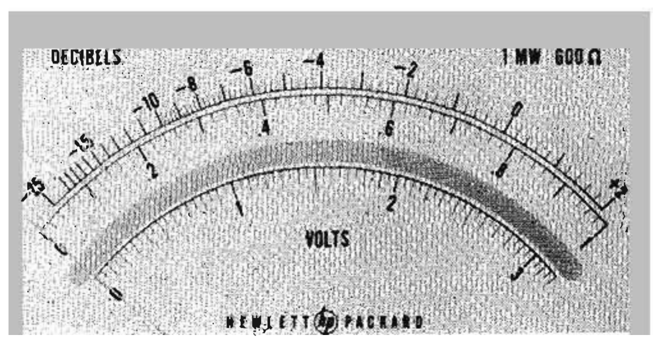
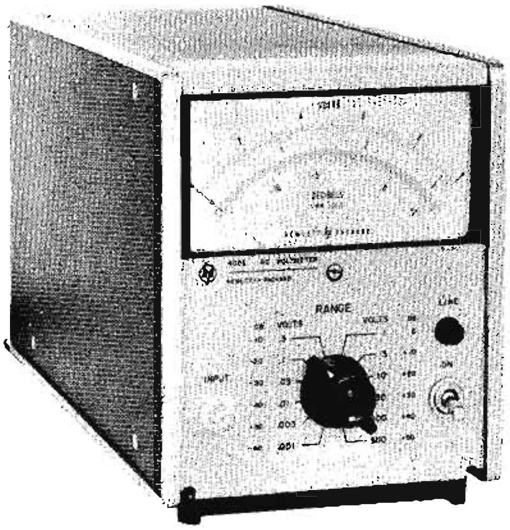


Figure 1. Meter face on Model 400E (Option 01.).

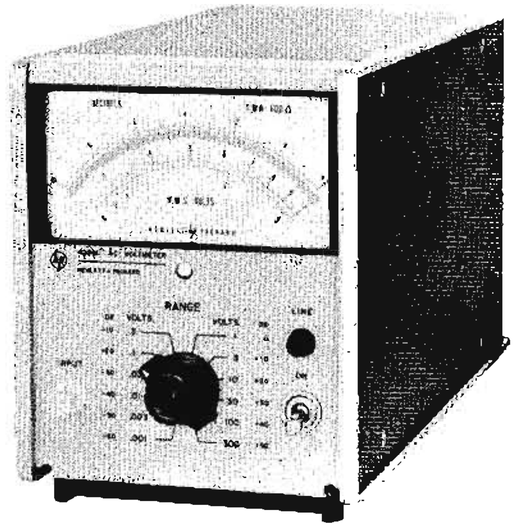
Relative signal reading option—Available on special order, the 400E,EL (Option 02.) provides a front-panel relative control allowing a 3 db reduction in sensitivity on each calibrated range. This feature enables the user to set the meter to a convenient level for relative voltage measurements. The control is detented in the calibrate position to disconnect the relative circuitry and to ensure calibration accuracy.

Accessories—Refer to page 263 for line matching and bridging transformers; and page 139 for capacitive voltage dividers. Other useful accessories for the hp 400 series voltmeters are the 456A AC Current Probe described on page 140.

AVAILABLE
LATE 1965



400E



400EL

Tentative specifications

hp Model	400E	400EL
Voltage range	1 mv to 300 v full scale, 12 ranges	
Frequency range	10 cps to 10 mc	
Accuracy	per cent of full scale	per cent of reading

Accuracy	range	±1%	±2%	±3%	±5%	±3 db	range	±1%	±2%	±3%	±5%	±3 db
	1 mv	100 cps-500 kc	50 cps-1 mc	20 cps-2 mc	20 cps-4 mc	10 cps-8 mc	1 mv	100 cps-500 kc	50 cps-1 mc	20 cps-2 mc	20 cps-4 mc	10 cps-8 mc
	3 mv-100 v	40 cps-1 mc	20 cps-2 mc	15 cps-4 mc	10 cps-10 mc	10 cps-15 mc	3 mv-100 v	40 cps-1 mc	20 cps-2 mc	15 cps-4 mc	10 cps-10 mc	10 cps-15 mc
	300 v	40 cps-500 kc	20 cps-1 mc	15 cps-2 mc	10 cps-4 mc	10 cps-10 mc	300 v	40 cps-500 kc	20 cps-1 mc	15 cps-2 mc	10 cps-4 mc	10 cps-10 mc

hp Model	400E	400EL
Calibration	reads rms value of sine wave; voltage indication proportional to absolute average value of applied wave; linear voltage scales 0 to 1 and 0 to 3; db scale —12 to +2 db, 10 db between ranges	reads rms value of sine wave; voltage indication proportional to absolute 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
Input impedance	10 megohms shunted by 25 pf on all ranges, 1 mv to 300 v	
AC-to-DC converter output	1 v dc for full-scale meter indication; output impedance, 1 K ohm	
Amplifier ac output	150 mv rms for full-scale meter indication; output impedance, 50 ohms	
AC power	115 or 230 volts ±10%, 50 to 1000 cps, approx. 5 watts	
External battery operation	terminals are provided on rear panel; positive and negative voltages between 28 v and 50 v are required; current drain from each voltage is 40 ma	
Dimensions	standard hp 1/3 module, 5⅛" wide, 6½" high, 11" deep (130 x 165 x 279 mm)	
Weight	net 7¼ lbs (3,3 kg); shipping 11 lbs (5 kg)	
Accessories available	10110A BNC male-to-dual-banana female, $5; 11001A Cable, 45" long, male-BNC-to-dual-banana plug, $5.50; 10503A Cable, 4' long, male BNC connectors, $6.50; 11002A Test Lead, dual banana-plug-to-alligator clips, $7.50; 11003A Test Lead, dual banana-plug-to-probe and alligator clip, $10; 456A AC Current Probe, 1 mv/1 ma, $190; 11056A Handle Kit for 400E,EL, $5	
Price	on request	
Option 01.	read directly in volts and db with the db scale uppermost	
Option 02.	front-panel relative control allows a 3 db reduction in sensitivity on each calibrated range	

3400A RMS VOLTMETER

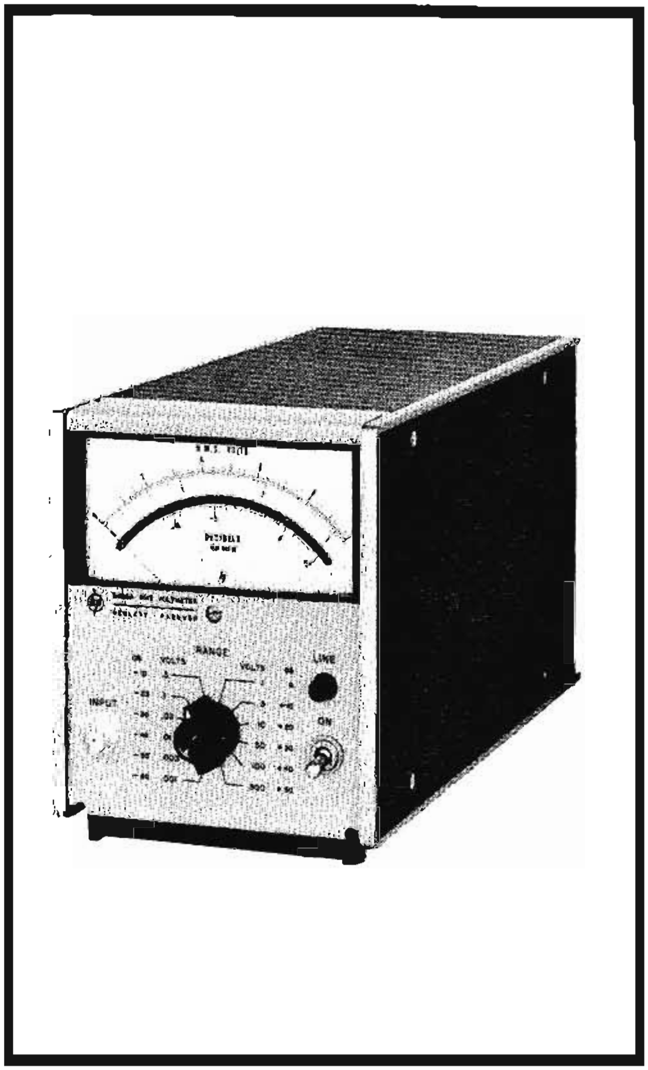
Fast, accurate true rms measurements

Model 3400A RMS Voltmeter is a rugged precision instrument which measures the actual root-mean-square value of ac voltages which are between 100 μv and 300 v rms and in the frequency range of 10 cps to 10 mc. These voltages may be sinusoidal or non-sinusoidal and have crest factors (ratio of peak to rms) as high as 10 at full-scale deflection and as high as 100 at 10% of full-scale deflection. The ability of the hp 3400A to accept waveforms having such large crest factors insures that your measurements will be accurate, even when measuring non-sinusoidal waveforms such as noise and pulse trains, without the need for correction factors.

Built-in protection

Model 3400A withstands overloads of 40 db (or 425 v rms, whichever is less) on each range. This reduces the possibility of damage to the instrument, and protective circuitry prevents thermocouple burnout. The 3400A is extremely simple to operate because it requires no zero-set control and voltages are read from a linear voltage scale or in dbm. The voltmeter's 10-megohm input resistance minimizes circuit loading. In addition, the meter scale has a mirror back for precise readings. Each meter face is custom-calibrated in a Hewlett-Packard-developed servo system which prints the meter scales to the specific taut-band meter movement used in each hp 3400A.

Model 3400A supplies a dc voltage from a rear-panel connector that is proportional to the rms value of the input signal. Because of the high stability and linearity of this dc signal, you may use it to drive accessory equipment such as x-y and strip-chart recorders for permanent records and plots, or to drive a digital voltmeter such as the hp 405CR (page 153) or hp 3440A (pages 150-152) for high-resolution measurements. You also can measure the rms value of an ac current merely by using the hp 456A Current Probe (page 140). The jaws of the 456A, which sample the magnetic field about a conductor, are simply clamped around the conductor without breaking the circuit and without disturbing the measured circuit. Model 456A produces a 1 mv output for a 1 ma input; consequently, the 3400A's scales may be read directly without scale conversion.



Specifications

Range: 12 full scale ranges from 1 mv to 300 v in a 1, 3, 10 sequence; −72 to +52 dbm (usable indications to 100 μv).

Meter scales: voltage, 0.1 to 1 and 0.3 to 3; decibel, −12 to +2 dbm (0 dbm = 1 mw, 600 ohms); scales are individually calibrated to the meter movement.

Frequency range: 10 cps to 10 mc.

Accuracy: within ±1% of full scale, 50 cps to 1 mc; within ±2% of full scale from 1 to 2 mc; within ±3% of full scale, 2 to 3 mc; within ±5% of full scale from 10 to 50 cps and from 3 to 10 mc (usable readings to 5 cps and 20 mc).

Response: responds to rms value (heating value) of the input signal for all waveforms.

Crest factor (ratio of peak amplitude to rms amplitude): 10 to 1 at full scale, inversely proportional to pointer deflection, e.g., 20 to 1 at half-scale, 100 to 1 at tenth-scale.

Maximum input: 425 v rms.

Input impedance: from 0.001 v to 0.3 v range: 10 megohms shunted by 40 pf; from 1 v to 300 v range: 10 megohms shunted by 15 pf.

Response time: typically <2 sec to within 1% of final value for a step change.

Overload protection: 40 db or 425 v rms, whichever is less, on each range.

Output: negative 1 v dc at full-scale deflection, proportional to pointer deflection open circuit (from 10 to 100% of full scale); 1 ma maximum; nominal source impedance is 1000 ohms.

Power: 115 or 230 v ±10%, 50 to 60 cps, approximately 7 w.

Dimensions: 5⅛" wide, 6½" high, 11" deep (130 x 165 x 279 mm).

Weight: net 7¼ lbs (3,3 kg); shipping 11 lbs (5 kg).

Accessory furnished: 10110A Adapter, BNC to dual banana jack.

Accessories available: 11001A Cable, 45" long, male BNC to dual banana plug, $5.50; 10503A Cable, 4' long, male BNC connectors, $6.50; 11002A Test Lead, dual banana plug to alligator clips, $7.50; 11003A Test Leads, dual banana plug to probe and alligator clip, $10; 456A AC Current Probe, 1 mv/1 ma, $190; 11056A Handle Kit for 3400A, $5 each.

Price: hp 3400A, $525; hp 3400A (Option 01.) spreads out the db scale by making it the top scale of the meter, add $25.

411A RF MILLIVOLTMETER

"Touch-and-read" measurement, 3 mv to 10 v, 500 kc to 1000 mc

Two linear voltage scales in a 1:3 ratio and millivolt sensitivity up to 1 gc set the hp Model 411A RF Millivoltmeter apart from previous rf voltmeters. Its temperature-compensated probe results in low drift, even on the most sensitive range, so that you can measure millivolts of rf energy conveniently and with confidence. Model 411A simplifies your measurements of voltage from 0.5 to 1000 mc.

Full-scale sensitivity from 10 millivolts full scale to 10 volts full scale is selected in seven 10 db steps, so that most measurements may be made in the upper two-thirds of the scale for greater accuracy. Further, you can read db directly from −42 to +33 for convenient gain measurements. Accessory probe tips suit it for measurements in many different kinds of circuits.

Further, an output is provided for galvanometer recording. Five probe tips have been designed for use with the 411A, ranging from the BNC open circuit probe tip, furnished with the instrument, to a pen-size probe having retractile alligator jaws for probing conveniently into restricted areas. The probe tips, available individually, are offered along with a spare diode cartridge as a complete set in a compact kit; it provides an immediate and versatile selection to meet all measurement requirements normally encountered.

11027A Accessory Probe Kit; contains probe tips to meet all measurement requirements normally encountered. The storage case has room for the BNC tip furnished with the instrument. See specifications for details.

Specifications

Voltage range: 10 mv rms full scale to 10 v rms full scale in 7 ranges; full-scale readings of 0.01, 0.03, 0.1, 0.3, 1, 3 and 10 v rms.

Frequency range: 500 kc to 1 gc with accessory probe tips; usable indications to 4 gc.

Accuracy: 500 kc to 50 mc, ±3% of full scale; 50 mc to 150 mc ±6% of full scale; 150 mc to 1 gc, ±1 db (using appropriate probe tips).

Meter scales: two linear voltage scales, 0 to 1 and 0 to 3, calibrated in the rms value of a sine wave; db scale, calibrated from +3 to −12 db; 0 db = 1 mw in 50 ohms.

Input resistance: depends on probe tip, frequency and input voltage; typically 200 K ohms at 1 mc and 1 v rms. (For specific information contact your local hp sales office.)

Probe tip furnished: 11025A BNC Open Circuit Probe Tip, 500 kc to 500 mc; shunt capacity: less than 5 pf; maximum input: 200 v dc and 30 v ac p-p; input resistance at 10 mc: typically 80 K ohms.

Accessories available at additional cost

Probe tips

11022A Pen Type Probe Tip, 500 kc to 50 mc; shunt capacity: less than 5 pf; maximum input: 200 v dc and 30 v ac p-p; input resistance at 10 mc: typically 80 K ohms; $25.

11023A VHF Probe Tip, 500 kc to 250 mc; shunt capacity: less than 2.5 pf; maximum input: 200 v dc and 30 v ac p-p; input resistance at 10 mc: typically 80 K ohms; $20.

11024A Type N "Tee" Probe Tip, 1 mc to 1 gc; swr is less than 1.15 when terminated in 50 ohms; maximum input: 10 v dc and 30 v ac p-p to 250 mc and 15 v ac p-p from 250 mc to 1 gc: $40.

11026A 100:1 Capacity Divider Probe Tip, 500 kc to 250 mc; division accuracy: ±1%; shunt capacity: 2 pf; maximum input: ±1000 volts peak (dc + peak ac); $35.

Probe kit: 11027A Accessory Probe Kit includes the 11022A, 11023A, 11024A, 11026A Probe Tips and a replacement diode cartridge, 5082-5004, in a convenient storage case; price, $152.50.

50-ohm termination: 908A Coaxial Termination, $35.

Galvanometer recorder output: proportional to meter deflection, 1 ma into 1000 ohms at full-scale deflection.

Power: 115 or 230 volts ±10%, 50 to 60 cps, 35 watts.

Dimensions: cabinet: 11¾" high, 7½" wide, 12" deep (298 x 191 x 305 mm); rack mount: 6-31/32" high, 19" wide, 10⅜" deep behind panel (177 x 483 x 264 mm).

Weight: net 12 lbs (5,4 kg), shipping 18 lbs (8,1 kg) (cabinet); net 15 lbs (6,8 kg), shipping 28 lbs (12,6 kg) (rack mount).

Price: hp 411A, $450 (cabinet); hp 411AR, $455 (rack mount).

3406A SAMPLING VOLTMETER

Advantages:

- Average-reading sampling voltmeter
- Translator
- Linear voltage scales
- Wide-band operation
- High input impedance
- Resolve signals as small as 50 μv
- Retain measured indication
- Taut-band meter

Uses:

- Make measurements 1 kc to 1 gc, 1 mv to 1 volt full scale
- Measure wideband signals accurately
- Versatile probe tips for wide application
- Use with true rms or peak-reading devices

The hp Model 3406A provides wide bandwidth (1 kc to 1 gc), 1 millivolt full-scale sensitivity and exceptionally high input impedances through the use of a new incoherent sampling technique. The ability of this sampling voltmeter to accept waveforms having large crest factors insures that measurements will be accurate when measuring non-sinusoidal voltages. Full-scale sensitivity, from 1 millivolt to 1 volt, is selected in seven 10 db steps; signals as small as 50 μv may be resolved. DB may be read directly from −62 dbm to +13 dbm for gain and power measurements.

Accessory probe tips make the 3406A suitable for measurement in many different kinds of circuits. Voltages in receivers, amplifiers and coaxial transmission lines may be measured. Depressing a pushbutton located on the probe retains the indication on the meter, making it possible to take measurements from awkward positions. A dc output is provided for an external recorder; an ac output is provided for connection to peak, or true rms voltmeters.

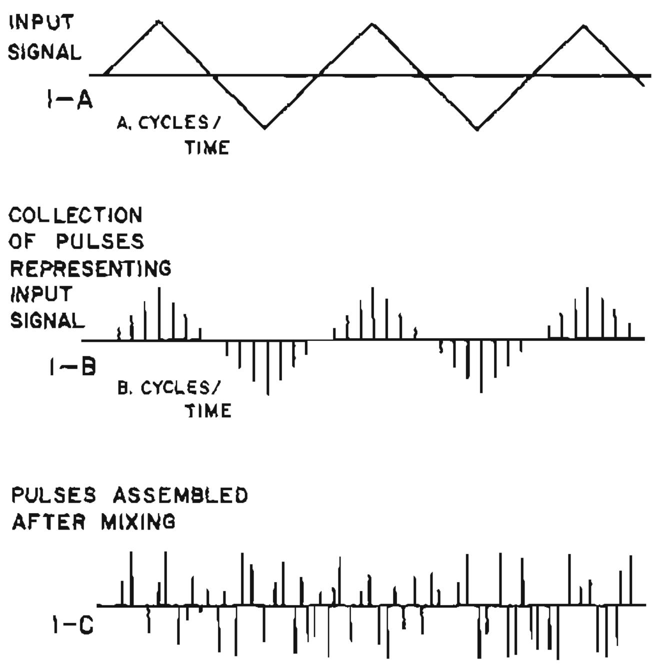


Figure 1. New incoherent sampling technique.

The hp 3406A uses a new incoherent sampling technique which has many of the advantages of conventional sampling techniques combined with the economy of conventional analog voltmeters.

Figure 1 illustrates the technique used in the hp 3406A. The technique is best explained by representing each sample with a pulse whose height is proportional to the amplitude of the input signal at the instant the sample is taken. The average, rms or peak value of the collection of pulses in Figure 1 (b) differs from the input signal in Figure 1 (a) only by a scale factor. Imagine that these pulses are collected and scrambled. The order in which the pulses appear after being scrambled together results in a waveform similar to Figure 1 (c). Since the pulses are the same, the average, rms and peak values of this rearranged waveform are identical to the average, rms and peak values of the waveform in Figure 1 (b).

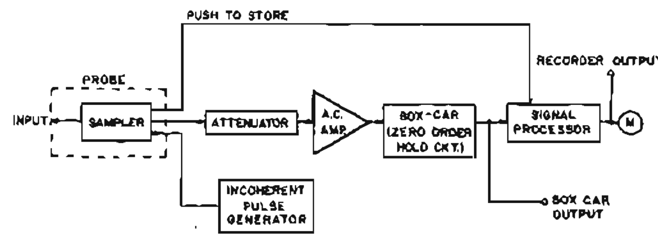


Figure 2. Block diagram hp 3406A.

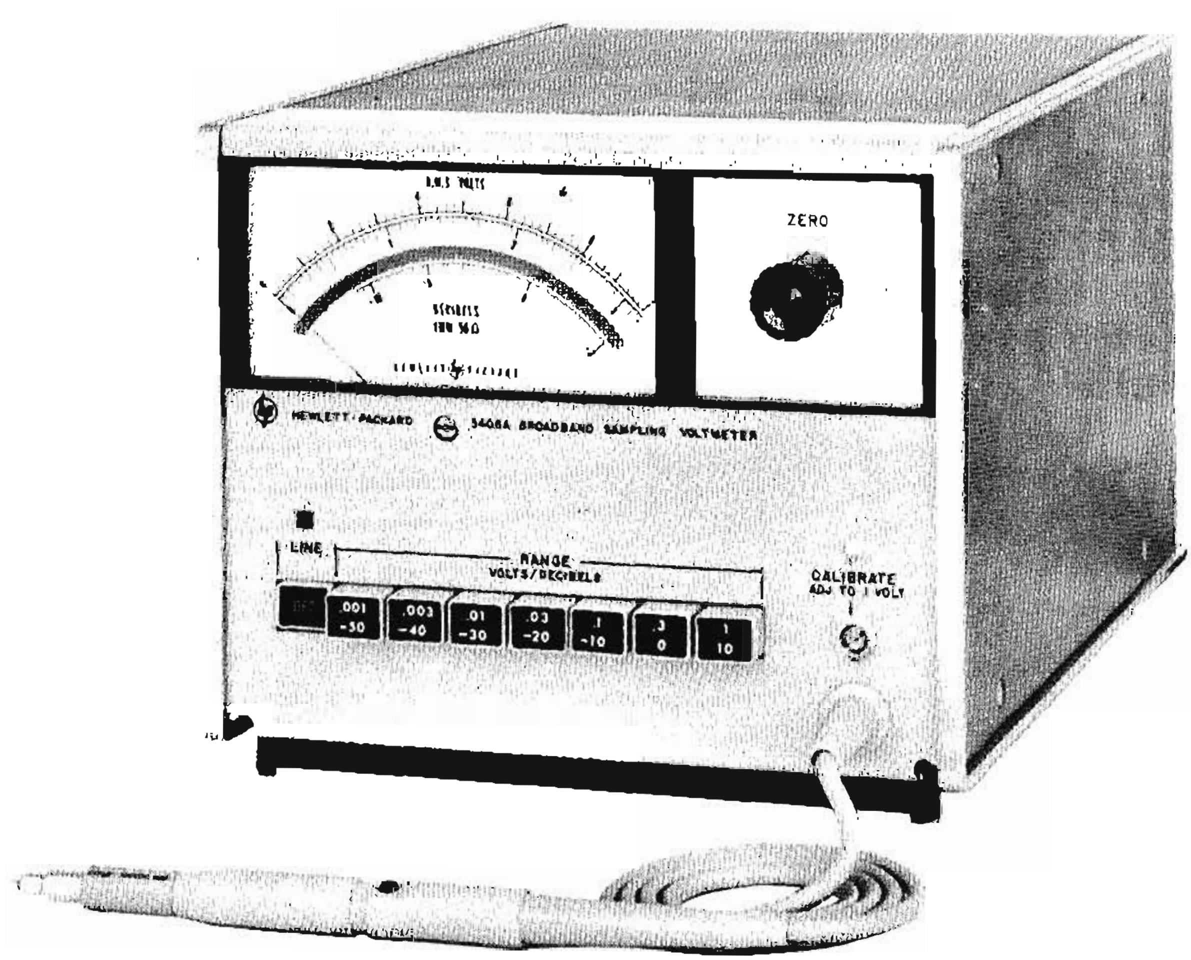
Figure 2 illustrates the basic block diagram of the hp 3406A Sampling Voltmeter. Samples taken in the probe are fed through attenuators and amplifiers to the box-car (zero-order hold) circuit. The hold circuit stores each sample until the next sample is taken. The output of this circuit is available at rear terminals of the 3406A on the 10 mv range and above. This output may be used to obtain true rms measurements when used with an hp 3400A rms voltmeter (page 122) or peak measurements when used with a peak-reading voltmeter. The output of the box-car circuit is also fed to a special signal processor which contains noise suppression circuits for the lower ranges.

Accessory probe tips are available for use with the 3406A, ranging from the blocking capacitor tip (furnished with the instrument) to a tee-connector for measurements in coaxial lines. The probe tips, available individually or in a complete kit, provide a versatile selection to meet most measurement requirements normally encountered.

The hp 3406A has a pushbutton located on the probe to retain the meter indication when the probe is removed from the circuit. When the pushbutton is released, the 3406A is operational to make another measurement. This feature makes possible measurements in awkward positions, where it is difficult for the operator to place the probe in the circuit under test and at the same time read the meter.

Two voltage scales are used so that the meter may be read quickly and easily without the confusion of multiple scales. The two scales, calibrated from 0 to 1 and 0 to 3, permit convenient measurements in the upper two-thirds of the scale and the convenience of 10 db range separation.

AVAILABLE LATE 1965



Tentative specifications

Voltage range: 1 mv to 1 volt full scale in seven ranges; decibels from —50 to +10 dbm (0 dbm = 1 mw in 50 ohms); absolute average-reading instrument calibrated to rms.

Frequency range: 1 kc to 1 gc; useful sensitivity from 100 cps to beyond 2 gc.

Full-scale accuracy: ±3%, 10 kc to 100 mc; ±1 db, 1 kc to 1 gc.

Input impedance: 100,000 ohms at 100 kc.

Outputs

DC recorder output: 1 ma into 1000 ohms at full scale, proportional to meter deflection.

AC output: provides box-car signal statistically equal to measured signal (on ranges 0.01 volt and above).

Meter scales: voltage, 0 to 1 and 0 to 3; decibel, —12 to +3.

Probe tip furnished: 11059A Blocking Capacitor Tip.

Accessories available: 11059A Blocking Capacitor (10,000 pf) Tip; 11060A Blocking Capacitor (100 pf) Tip; 11061A 10:1 Divider Tip; 11062A BNC Tip; 11063A Type 874 "Tee"; 11064A Probe Kit.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approx. 10 watts.

Dimensions: standard 1/2 module 6½" high, 8⅞" wide, 11½" deep (165 x 225 x 292 mm).

Weight: net 8 lbs (3,6 kg); shipping 10½ lbs (4,8 kg).

Price: on request.

403A,B SOLID-STATE AC VOLTMETERS

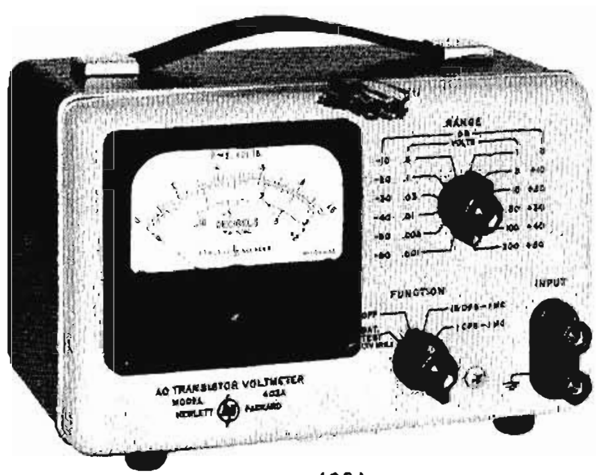
Compact, battery-operated, portable

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.

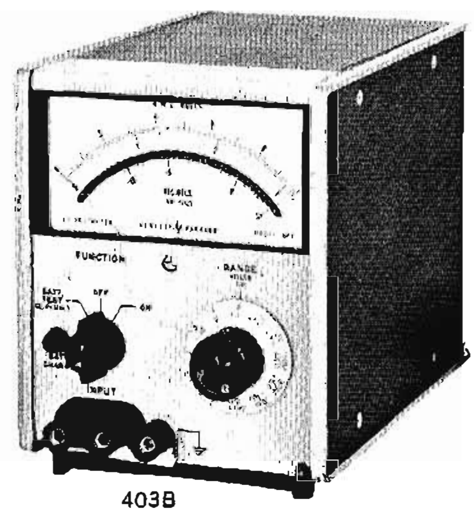
Both measure from 100 microvolts to 300 volts, the 403A covering 1 cps to 1 mc and the 403B covering 5 cps to 2 mc. Both operate from internal batteries and, thus, may be completely isolated from the power line and external grounds, permitting accurate measurements at power line frequency and its harmonics, 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.



403A



403B

Specifications

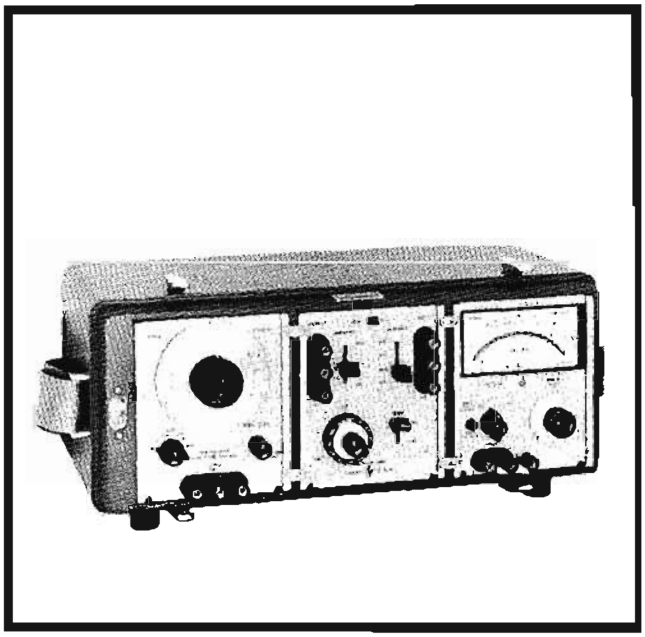
hp Model	403A	403B	403B (Option 01.)
Frequency range	1 cps to 1 mc	5 cps to 2 mc	5 cps to 2 mc
Accuracy	within ±3% of full scale, 5 cps to 500 kc; within ±5% of full scale, 1 to 5 cps and 500 kc to 1 mc	within ±2% of full scale from 10 cps to 1 mc; within ±5% of full scale from 5 to 10 cps and 1 to 2 mc, except ±10% 1 to 2 mc on the 300 v range (0 to 50°C)*	within ±0.2 db of full scale from 10 cps to 1 mc; within ±0.4 db of full scale from 5 to 10 cps and 1 to 2 mc, except ±0.8 db 1 to 2 mc on the 300 v range (0 to 50°C)*
Nominal input impedance	2 megohms shunted by approx. 40 pf, 0.001 to 0.1 v ranges; 20 pf, 0.3 to 10 v ranges; 15 pf, 30 to 300 v ranges	2 megohms shunted by approx. 50 pf, 0.001 to 0.03 v ranges; 25 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	600 v peak, 0.3 to 300 v range; 25 v rms, 60 v peak, 0.001 to 0.1 v ranges	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	8¼" wide, 5½" high, 6⅜" deep (210 x 140 x 162 mm)	5⅛" wide, 6-3/32" high, 8" deep (130 x 160 x 203 mm)	same as 403B
Weight	net 4¾ lbs (2,1 kg); shipping 9 lbs (4 kg)	net 6½ lbs (2,9 kg); shipping 10 lbs (4,5 kg)	same as 403B
Price (batteries furnished)	$275	$310	decibel scale uppermost, $335

*use 10001A 10:1 Divider and 10111A Adapter to retain ±5% (±0.4 db) accuracy while measuring up to 425 v rms at 1 to 2 mc.

For all models:
Range: 0.001 to 300 v rms full scale, 12 ranges.
Meter: responds to average value of input waveform, calibrated in the rms value of a sine wave.

3550A PORTABLE TEST SET

Convenient tool for measuring transmission line, system characteristics



This portable test set is designed specifically to measure transmission line and system characteristics such as attenuation, frequency response or gain, and it is particularly useful for lineup and maintenance of multi-channel communication systems.

It consists of a wide-range oscillator, a voltmeter and an attenuator with impedance-matching networks that are mounted in a combining case equipped with a splash-proof cover. The oscillator, voltmeter and attenuator with its impedance-matching transformer may be used separately, in or out of the combining case. The attenuator is particularly useful with the hp 400 Series Voltmeters to match 135-, 600- or 900-ohm lines.

Versatile components

The oscillator has a frequency range of 5 cps to 560 kc, and its output is fully floating isolated from instrument case and power line (see 204B, page 254).

The voltmeter (see 403B, page 126) features a sensitive range, 1 mv full scale, for measuring voltages as small as 100 μv rms from 5 cps to 2 mc. A db scale, which is at the top of the meter face for better resolution, also permits measurement from −75 to +52 dbm.

The patch panel portion of the test set (353A) includes a precision attenuator, variable in 1 db steps to 110 db and two sets of impedance-matching transformers which match both oscillator and voltmeter to 135-, 600- and 900-ohm lines. One set of transformers also terminates the line in 10 K ohms for bridging measurements.

Both oscillator and voltmeter are solid state and operate from their own 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.

Telephone versions

Two special versions of the 353A available on special order are the hp Model H02-353A and H03-353A Patch Panels designed specifically for the telephone industry. The Model H02 or H03 offer convenience in testing of telephone circuits, both active and passive. Both versions provide matching to 135-, 600- and 900-ohm balanced lines and can be mounted in place of the 353A in the 3550A Portable Test Set.

The H02-353A features a holding coil at the Send terminals, and the H03-353A features holding coils at the Rec and Send terminals which permit testing of active telephone lines at voice, as well as carrier frequencies. A single-step 23 db attenuator enables the operator to select standard telephone levels of +7 dbm and —16 dbm. Jacks have been supplied to accept standard telephone type plugs.

Specifications, 3550A

Oscillator (H20-204B)

Frequency range: 5 cps to 560 kc in 5 ranges, venier.
Dial accuracy: ±3%.
Frequency response: ±3% into rated load.
Output impedance: 600 ohms.
Output: 10 mw (2.5 v rms) into 600 ohms; 5 v rms open circuit; completely floating (isolated).
Distortion: less than 1%.
Hum and noise: less than 0.05%.
Temperature range: −20°C to +50°C.
Price: hp H20-204B, $390 when purchased separately.

Voltmeter (403B Option 01.)
(see specifications on opposite page)
Price: hp 403B Option 01., $335.

Patch panel (353A)

Input (receiver)
Frequency range: 50 cps to 560 kc.
Balance: better than 70 db at 60 cps for 600 ohms and 900 ohms; better than 60 db at 1 kc for 600 and 900 ohms; better than 40 db over entire frequency range for 135, 600 and 900 ohms.
Frequency response: ±0.5 db, 50 cps to 560 kc.
Impedance: 135, 600, 900 ohms and Bridging (10 K); center-tapped.
Insertion loss: less than 0.75 db at 1 kc.
Maximum level: +22 dbm (10 v rms at 600 ohms).

Output (source)
Frequency range: 50 cps to 560 kc.
Balance: same as Input (receiver).
Frequency response: ±0.5 db, 50 cps to 560 kc.
Impedance: 135, 600, and 900 ohms, center-tapped.
Insertion loss: less than 0.75 db at 1 kc.
Distortion: less than 1%, 50 cps to 560 kc.
Maximum level: +22 dbm (10 v rms at 600 ohms).
Attenuation: 110 db in 1 db steps; accuracy. 10 db section: error less than ±0.25 db at any step; accuracy, 100 db section: error is less than ±0.5 db at any step.

Connectors: two 3-terminal binding posts for external circuit connection and two BNC female connectors for oscillator and voltmeter connection.
Price: hp 353A, $260 when purchased separately.

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 1000 cps, 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 45 lbs (20,3 kg).
Accessories available: 10503A Cable, BNC-to-BNC, $6.50; 11002A Test Leads, banana-plug-to-alligator clip, $7.50.
Accessories furnished: detachable power cord; two 11035A Cables (1 foot long, dual banana-plug-to-BNC); splash proof cover and storage compartment.
Price: hp 3550A, $1150.

410C ELECTRONIC VOLTMETER

Zero drift multi-function meter

The hp Model 410C is a versatile general-purpose instrument. This one instrument measures dc voltages from 1.5 mv to 1500 volts, direct current from 0.15 nanoamps to 150 ma, and resistance from 0.2 ohm to 500 megohms. With the plug-in-probe, ac voltages from 50 mv to 300 volts at 20 cps to 700 mc and comparative indications to 3 gc are attainable.

These measurements are made with laboratory precision previously not available in a single instrument. The versatile easy-to-use hp 410C will be valuable in any laboratory, production line, or service department.

Photochopper

Model 410C uses a unique hp-developed photoconductor chopper amplifier. This amplifier is a hybrid circuit which makes possible the high input impedance of 100 megohms on the dc voltmeter and the low resistance recorder output of less than 3 ohms. It also eliminates the need for a zero adjustment on the dc current, voltage and resistance ranges. Additionally, no adjustment for infinite resistance is needed. The 410C will recover in less than 3 seconds when overloaded at up to 100 times full scale.

When using the hp 11036A AC Probe the 410C will measure ac voltages with 3% accuracy over the range 100 cps to 100 mc. This special probe permits measurements of 10% accuracy from 20 cps to 700 mc and will produce comparative indications to 3 gc. High input resistance of 10 megohms and capacitance of only 1.5 pf minimize loading of the circuit under test.

The 11045A 100:1 DC Divider is available for measuring dc voltages to 30 kv. Other accessories include ac voltage dividers and adapters for measurements in Type N systems. (See pages 138, 139.)

Each meter face is custom-calibrated in a hp-developed servo system which prints the meter scales to the specific taut-band meter movement used in each 410C.

Specifications

DC Voltmeter

Voltage ranges: ±15 mv to ±1500 v full scale in 15, 50, 150 sequence (11 ranges).

Accuracy: ±2% of full scale on any range.

Input resistance: 100 megohms ±1% on 500 mv range and above; 10 megohms ±3% on 15 mv, 50 mv, and 150 mv ranges.

DC Ammeter

Current ranges: ±1.5 μa to ±150 ma full scale in 1.5, 5, 15 sequence (11 ranges).

Accuracy: ±3% of full scale on any range.

Input resistance: decreasing from 9 K ohms on 1.5 μa scale to approximately 0.3 ohm on the 150 ma scale.

Special current ranges: ±1.5, ±5 and ±15 nanoamps, may be measured on the 15, 50 and 150 millivolt ranges using the voltmeter probe, with ±5% accuracy and 10-megohm input resistance.

Ohmmeter

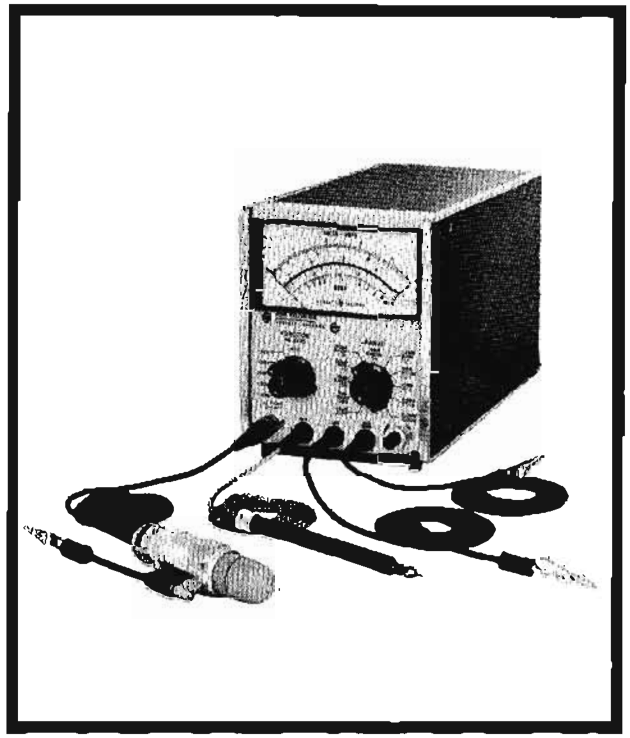
Resistance range: 10 ohms to 10 megohms center scale (7 ranges).

Accuracy: zero to midscale: ±5% of reading or ±2% of midscale, whichever is greater; ±7% from midscale to scale value of 2; ±8% from scale value of 2 to 3; ±9% from scale value of 3 to 5; ±10% from scale value of 5 to 10.

Amplifier

Voltage gain: 100 maximum.

AC rejection: 3 db at 0.5 cps; approximately 66 db at 50 cps and higher frequencies for signals less than 1600 v peak or 30 times full scale, whichever is smaller.



Isolation: impedance between common and chassis is >10 meg in parallel with 0.1 μf; common may be floated up to 400 v dc above the chassis for dc and resistance measurements.

Output: proportional to meter indication; 1.5 v dc at full scale; maximum current, 1 ma.

Output Impedance: less than 3 ohms at dc.

Noise: less than 0.5% of full scale on any range (p-p).

DC drift: less than 0.5% of full scale/year at constant temperature; less than 0.02% of full scale/°C.

Overload recovery: recover from 100:1 overload in <3 sec.

AC Voltmeter

Ranges: 0.5 v full scale to 300 v in 0.5, 1.5, 5 sequence (7 ranges).

Accuracy: ±3% of full scale at 400 cps for sinusoidal voltages from 0.5 to 300 v rms; the ac probe responds to the positive peak-above-average value of the applied signal.

Frequency response: −3% ±2% at 100 mc; ±10% from 20 cps to 700 mc (400 cps reference); indications to 3 gc.

Frequency range: 20 cps to 700 mc.

Input Impedance: input capacity 1.5 pf, input resistance >10 megohms 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 ground.

Meter: individually calibrated taut-band meter responds to positive peak-above-average; calibrated in rms volts for sine wave input.

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 or 230 volts ±10%, 50 to 1000 cps, 13 watts (20 watts with 11036A AC Probe).

Dimensions: 6½" high, 5⅛" wide, 11" deep behind panel (165 x 130 x 279 mm).

Weight: net 8 lbs (4 kg); shipping approx. 14 lbs (6 kg).

Price: hp 410C with detachable ac probe, $425.

Option 02.: hp 410C less ac probe, $375.

410B VACUUM TUBE VOLTMETER

All-purpose test instrument measures to 700 mc

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 megohms input impedance, and an ohmmeter capable of measuring resistance, 0.2 ohm to 500 megohms. It is easy to use, compact, lightweight.

An important reason for the 410B's popularity is its special diode probe. The probe has very low capacity to minimize disturbance to circuits under test.

Other features of the 410B include low drift (maintains calibration over long periods of time), only one zero adjustment for all ranges, front-panel function switching (leads are permanently attached), storage space for leads and probes at rear of the sturdy, lightweight instrument cabinet.

Specifications

AC voltmeter

Range: 1 to 300 v full scale, 6 ranges..

Frequency range: 20 cps to 700 mc.

Frequency response: flat within ±1 db to 700 mc; drops off less than 1 db at 20 cps; indications obtainable to 3000 mc.

Input impedance: input capacity 1.5 pf, input resistance 10 megohms at low frequencies; at high frequencies resistance drops off due to dielectric loss.

DC voltmeter

Range: 1 to 1000 v full scale.

Input resistance: approx. 122 megohms, all ranges.

Ohmmeter

Range: 0.2 ohm to 500 megohms in 7 ranges; midscale readings of 10, 100, 1000, 10,000, 100,000 ohms, and 1 and 10 megohms.

General

Accuracy: ±3% of full scale, all ranges, on sinusoidal ac voltages and dc voltages; ac portion of instrument is peak-responding, calibrated in rms volts.

Power: 115 or 230 v ±10%, 50 to 1000 cps, 40 w.

Dimensions: cabinet, 7⅜" wide, 11½" high, 8¾" deep (187 x 292 x 223 mm); rack mount, 19" wide, 6¾" high, 6" deep behind panel (483 x 172 x 152 mm).

Weight: net 12 lbs (5,4 kg), shipping 17 lbs (7,7 kg) (cabinet); net 12 lbs (5,4 kg), shipping 20 lbs (9 kg) (rack mount).

Accessories available: 11039A Capacitive Voltage Divider, 25 kv max., $150, requires 11018A Adapter, $35; 11040A Capacitive Voltage Divider, 2 kv max., $35; 11042A Probe Coax T Connector for Type "N" systems, $40; 11043A Probe Coax N Connector adapts to Type "N" systems, $37.50; 11044A DC Divider, 30 kv max., $50.

Price: hp 410B, $245 (cabinet); hp 410BR, $265 (rack mount).

414A AUTOVOLTMETER

Touch-and-read voltage and resistance measurements automatically

The 414A Autovoltmeter provides the "touch-and-read" convenience of a digital instrument with the economy of an analog instrument. Range changing and polarity selection are both automatic, occurring in less than 300 milliseconds. DC voltages can be measured at sensitivities ranging from 5 mv to 1500 volts full scale. Resistance measuring sensitivities range from 5 ohms to 1.5 megohms full scale. Measuring accuracy for voltage is ±0.5% of reading ±0.5% of full scale and for resistance is ±1% of reading ±0.5% of full scale.

This auto-ranging voltmeter is solid state. The dc amplifier is chopper-stabilized, using hp-produced photocell choppers for long life and reliability. A lighted display unit, placed conveniently above the meter provides the user with the full-scale sensitivity for the range and function selected. For voltage measurements, the polarity of the input voltage also is indicated. Ranges can be selected and held manually.

Range changing decisions are based on two preset signal levels, one near full-scale meter deflection, and the other near one-fourth full scale. An amplitude comparator produces an "up" range signal whenever the input voltage tends to rise above the level which is near full scale, and a "down" range signal whenever the input voltage tends to fall below the level near one-fourth full scale. Range switching and indication logic consist of a set of four solid-state multivibrators which define the twelve ranges of the instrument. The ohmmeter function employs a feedback-stabilized current source which allows the use of a linear ohms scale and avoids a special meter scale for resistance measurements. The resulting meter scales are easily interpreted.

Convenience, versatility

The 414A's modular design and light-weight construction contribute to its easy portability. Elimination of tedious range selection suits the voltmeter to production line work or similar situations where repetitive voltage measurements over a wide range are made.

AVAILABLE FALL 1965

Tentative specifications

DC voltmeter

Voltage range: ±5 mv to 1500 v full scale in 12 ranges (manual or auto-ranging).

Accuracy: ±0.5% of reading ±0.5% of full scale.

Input resistance: 10 megohms on 5 and 15 mv ranges, 100 megohms on 50 mv range and above.

Ohmmeter

Resistance range: 5 ohms to 1.5 megohms in 12 ranges (manual or auto-ranging with linear scale).

Accuracy: ±1% of reading ±0.5% of full scale on any range.

Source current:

Range	Current through unknown
up to 1500 ohms	1 ma
above 1500 ohms	1 μa

General

Range selection: voltage and resistance: automatically selects correct range in less than 300 msec; a particular range may be selected manually.

Polarity selection: automatic.

Meter: individually calibrated taut-band meter with mirror scale; linear scales, 0 to 5 and 0 to 15.

Isolation resistance: at least 100 megohms shunted by 0.1 mf between common terminal and case (power line ground).

Floating input: may be operated up to 500 v dc above ground.

Power: 115 or 230 v ±10%, 50 to 1000 cps, approx. 18 w.

Dimensions: (½ module), 6-18/32" high, 7-25/32" wide, 12" deep (167 x 197 x 305 mm).

Weight: net 10¼ lbs (4,6 kg); shipping 13 lbs (6,4 kg).

Price: on request.

735A TRANSFER STANDARD

Use as standard, standard comparator, 0 to 1000 μv standard source

Advantages:

Voltage standard output
Exceptional stability
Short circuit proof
Very low temperature coefficient
Direct-reading comparisons
Low thermal emf
Floating guarded output
Compact

Uses:

1 volt reference for volt boxes and potentiometers
Standard cell comparator
Stable microvolt source

The hp 735A is a general-purpose laboratory transfer standard. It may be used as a one volt standard output with standard cell accuracy, a standard cell comparator, or as a 0 to 1000 μv standard source for dc and potentiometric measurements.

This guarded high accuracy transfer standard has 4 functions:

1. 1.018 +△* reference for saturated standard cell comparisons.
2. 1.019 +△* reference for unsaturated standard cell comparisons.
3. 1 volt reference for volt box and potentiometric measurements.
4. 0 to 1000 microvolt source with 1 μv resolution.

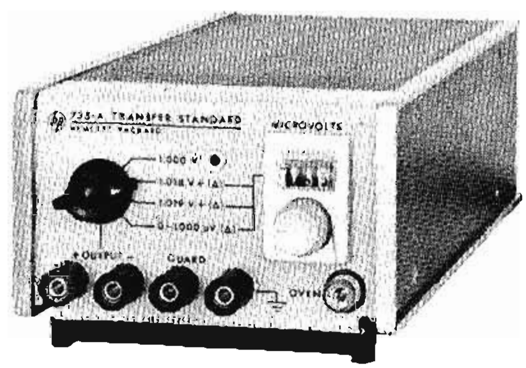
Reference supply

The basic stability of the 735A is derived from a reference supply enclosed in a proportionally controlled oven. The temperature of the reference diode is held to within ±0.03°C for an ambient temperature of 0° to +50°C. The reference supply maintains a stability better than 10 ppm/month. The overall temperature and long term stability of the 735A is assured by using hp-produced ultra-stable resistors with temperature coefficients matched to within 0.5 ppm/°C.

Circuit guard

The 735A Transfer Standard features a guard shield which isolates the floating output from the chassis.

AVAILABLE LATE 1965



Tentative Specifications

Standard outputs: 1 v; 1.018 +△*; 1.019 +△*; variable 0 to 1000 μv (△*).

Transfer accuracy: 2 ppm between saturated standard cells or unsaturated standard cells; 10 ppm standard cell to 1 volt; 10 ppm saturated standard cell to unsaturated standard cell.

Stability: better than 10 ppm/month.

Output impedance: 1 K ohm.

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% ±0.5 μv.
Linearity: 0.1%.
Output impedance: 100 ohms.

Output noise: <1 μv p-p.

Effective guarded capacity: <25 pf (capacity between circuit and chassis ground with guard shield driven).

Floated output: the guarded output terminals allow the instrument to be used as a floating or grounded two-terminal device (up to ±500 v dc).

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approx. 12 watts.

Output terminals: four banana jacks having positive and negative terminals, circuit guard shield and chassis ground; positive and negative terminals are solid copper with gold flash.

Dimensions: standard 1/3 module, 3-14/32" high, 5⅛" wide, 11" deep (87 x 130 x 279 mm).

Weight: net 5½ lbs (2,5 kg); shipping 8 lbs (3,6 kg).

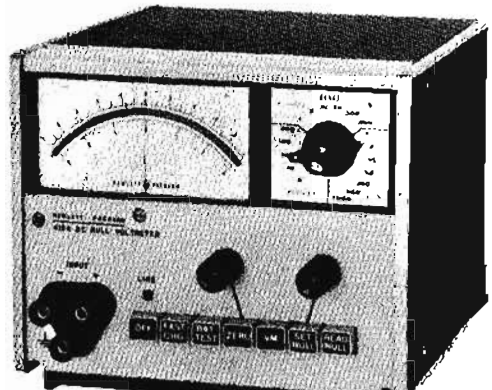
Price: on request.

*A 3-digit direct-reading 0 to 1000 μv offset voltage.

419A DC NULL METER

Floating, 18 ranges, 0.1 μv resolution

AVAILABLE FALL 1965



Eighteen voltage ranges with 0.1 μv resolution set this Hewlett-Packard solid-state dc null meter apart from previous dc null meters. The accuracy of this rechargeable battery-operated dc voltmeter is ±2% of end scale on all ranges. Noise is less than 0.1 μv rms, 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 rapidly to select the desired function of the hp 419A. This dc null meter operates from the ac line or from the internal rechargeable batteries with any of the pushbuttons depressed, except the Off button.

A Fast-Charge pushbutton is provided to increase the charging rate, recharging the batteries in approximately 16 hours. During normal operation, when operated from the ac line, the batteries are trickle charged at approximately 4 ma. Battery charge may be easily checked with the Battery Test pushbutton to assure reliable measurements. 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 Voltmeter pushbutton is depressed, the hp 419A functions as a zero center scale-3 μv to 1000 v dc voltmeter.

To eliminate measurement errors caused by large values of source impedances when the 3 μv to 300 mv ranges are used, a Set Null pushbutton is provided. When this pushbutton is depressed, an internal bucking voltage is placed in series with the input. A front-panel control enables the operator to null the input voltage with the hp 419A's bucking voltage. At this time the bucking voltage is equal to the input voltage, resulting in an infinite input impedance and elimination of any loading error. The Read Null pushbutton may then be depressed, disconnecting the input. The voltage of the bucking supply which is the same as the input voltage is now displayed on the meter. The maximum bucking voltage is adjustable to approximately 120% of full scale on the 3 μv to 300 mv range.

Recorder, amplifier

An output proportional to meter deflection makes the hp 419A an exceptionally stable dc amplifier. Its high voltage gain, high stability and low noise make the dc null meter suitable for many control applications. For recording applications, one volt with currents up to 1 ma for full-scale meter indication is available at the rear output terminals.

The 419A's clean design, functional utility and lightweight modular construction contribute to its easy portability. Careful attention to human engineering has resulted in highly visible rectangular pushbuttons for reduction of user fatigue and ease of operation. Function ambiguity is prevented by mechanical interlocks which allow only one pushbutton to be depressed at a time.

Tentative specifications

Voltmeter

Ranges: ±3 μv to ±1000 volts dc end scale in 18 zero-center ranges.

Accuracy: ±2% of end scale, ±0.1 μv.

Limits of zero control: ±15 μv.

Input resistance: 3 μv to 3 mv ranges: 100 K ohms (infinite when nulled); 10 mv to 30 mv ranges: 1 megohm (infinite when nulled); 100 mv to 300 mv ranges: 10 megohms (infinite when nulled); 1 volt to 1000 volt ranges: 100 megohms.

Bucking voltage: approximately 120% full scale (3 μv to 300 mv range), 360 mv maximum.

Response time: 95% of final reading within 3 sec on the 3 μv range; 95% of final reading within 1 sec on the 10 μv to 1000 v ranges.

Superimposed ac rejection: ac voltages (60 cps and above) 80 db greater than end scale affects reading less than 2% (300 v rms max.).

Noise: less than 0.1 μv rms.

Drift: less than 0.5 μv/day after 30-minute warm-up.

Recorder, amplifier

Gain: 110 db maximum at recorder output terminals (gain depends on range).

Output: ±1 volt for full-scale meter deflection (adjustable from 0 to 1 v at full scale; 1 ma max.).

Output impedance: approximately 0 ohms.

Output terminals: dual banana jacks.

AC rejection: same as voltmeter.

Gain accuracy: ±2% of full output.

Linearity: 0.1%.

Noise: same as voltmeter.

General

Overload protection: 50 v max. 3 μv to 3 mv ranges; 500 v max. from 10 mv to 300 v ranges; 1200 v on 1 v range and above.

Overload recovery time: meter indicates within 2 seconds for a 10^{+6} overload.

Input terminals: pos., neg., and chassis ground banana jacks.

Input isolation: greater than 10^{10} ohms shunted by 250 pf; may be operated up to 500 v dc or 130 v ac above ground.

Power source: 4 rechargeable batteries (furnished); forty-hour operation per recharge; null meter may be operated during recharge from ac line; 115 v or 230 v ±10%, 50 to 1000 cps, approximately 3 w.

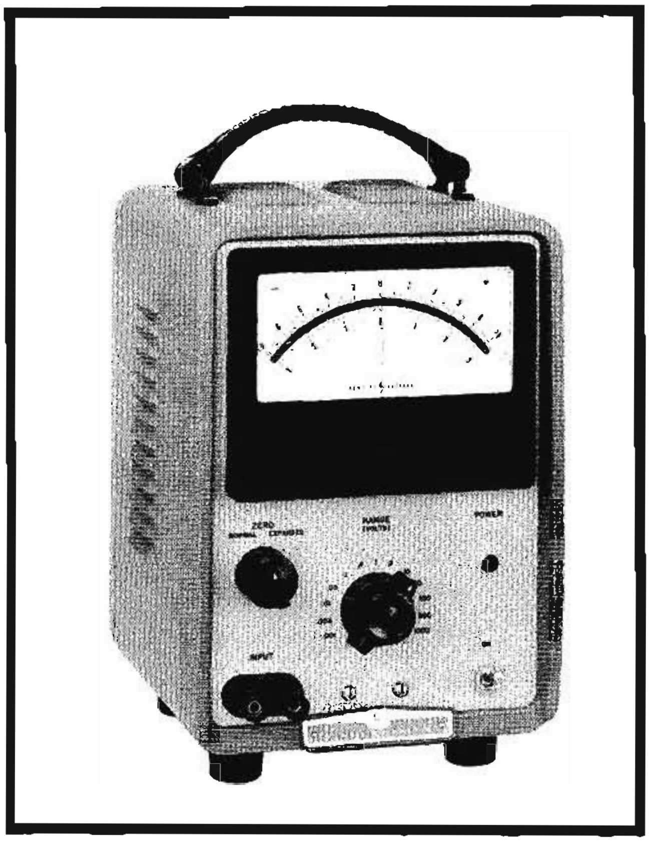
Dimensions: (½ module) 6" high, 7¾" wide, 8" deep (152 x 197 x 203 mm).

Weight: net 8 lbs (3,6 kg); shipping 12 lbs (5,4 kg).

Price: hp 419A, $450.

413A DC NULL VOLTMETER

Floating, high-impedance input; 1 mv end-scale sensitivity



Advantages:

Wide range
High input impedance
High stability and low noise
2% end-scale accuracy
Input isolated from ground
Sensitive output for control systems

Model 413A uses the sensitive and precise circuitry of the hp 412A to provide a dc null voltmeter of outstanding stability and resolution. The 413A has 13 zero-centered ranges running from 1 mv to 1000 v end scale. When using expanded zero, you may set the meter pointer to either end-scale position and measure voltages as large as twice end scale as long as the input does not exceed 1500 volts. The input terminals are isolated from ground, allowing operation up to 500 v dc or 130 v ac from ground potential.

High input impedance (10 megohms on the most sensitive range, 200 megohms 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; drift and noise are virtually imperceptible.

Stable dc amplifier

Because the dc null voltmeter provides an output proportional to meter deflection, it is an exceptionally stable dc amplifier. Its high voltage gain, high stability and low noise make the 413A suitable for many control applications, particularly where the amplifier must be left unattended for long periods of time. For instance, the 413A can amplify the output of a thermocouple by 1000 for controlling other equipment. You can use the zero control to set an arbitrary reference.

For dc voltmeter use, Model 413A offers high input impedance, voltage ranges from 1 mv to 1000 volts end scale, 2% accuracy and virtually drift-free operation.

Specifications

Voltmeter

Range: positive and negative voltages from 1 mv to 1000 volts end scale in 13 zero-center ranges.

Accuracy: ±2% of end scale.

Limits of zero control: more than ± end scale on any range when using expanded scale.

Input resistance: 10 megohms on 1, 3 and 10 mv ranges; 30 megohms on 30 mv range; 100 megohms on 100 mv range; 200 megohms 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 volts.

Amplifier

Gain: 0.001 to 1000 in 13 steps.

Gain accuracy: ±1.5%.

Linearity: ±0.2%.

Noise: less than 2 μv rms (typically less than 15 μv p-p) referred to the input.

Output: 1 v for end-scale deflection, same polarity as input signal; end scale corresponds to 1 on upper scale; maximum load current is 1 milliamp.

Output impedance: less than 2 ohms at dc.

Output terminals: dual banana jacks.

AC rejection: approximately 3 db at 1 cps, 80 db at 50 and 60 cps.

General

Input terminals: dual banana jacks.

Input isolation: greater than 100 megohm 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 volts ±10%, 50 to 60 cps, approximately 35 watts.

Dimensions: cabinet: 11½" high, 7½" wide, 10" deep (292 x 110 x 254 mm); rack mount: 5-7/32" high, 19" wide, 6⅝" deep (134 x 483 x 168 mm).

Weight: net 12 lbs (5,4 kg), shipping 16 lbs (7,2 kg) (cabinet); net 12 lbs (5,4 kg), shipping 19 lbs (8,6 kg) (rack mount).

Price: hp 413A, $350 (cabinet); hp 413AR, $355 (rack mount).

412A PRECISION DC VOLTMETER-OHMMETER-AMMETER

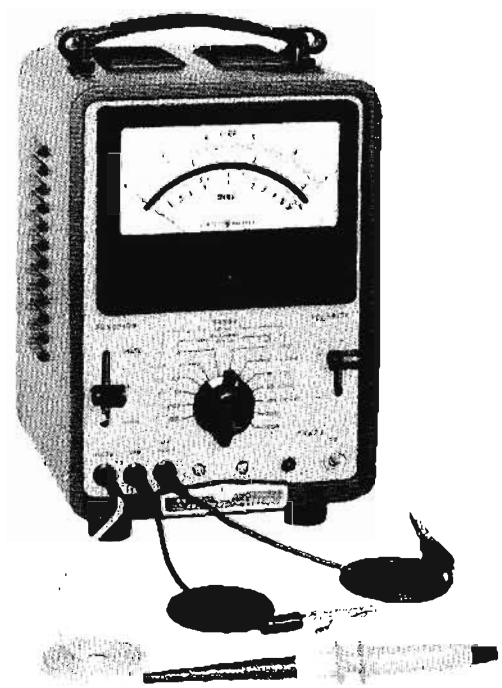
1% accuracy vtvm is also precision ohmmeter, ammeter

Here is one compact instrument that makes all normally used dc measurements with precision and simplicity. The hp 412A provides 1% voltage, 2% current and 5% resistance measurement accuracy. The 412A also is a stable 60 db amplifier whose output is proportional to meter indication.

The precision six-inch taut-band meter has two scales used for both voltage and current and a third scale which is calibrated in ohms. Each meter face is custom-calibrated in an hp-developed servo system which prints the meter scales to the specific taut-band movement.

The 412A measures voltages over the wide range from 0.02 millivolt to 1000 volts on 13 ranges arranged in a 1, 3, 10 sequence from 1 mv full scale to 1000 v full scale. With the Model 412A you can measure any dc current from 0.02 microampere to 1 ampere with precision.

A wide range of resistance values may be measured with the 412A. The ohmmeter function provides 9 ranges from 1 ohm to 100 megohms center scale arranged in decade steps for an overall range from less than 0.05 ohm to greater than 5000 megohms.



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.

Ammeter

Current range: pos. and neg. currents from 1 μamp to 1 amp full scale, 13 ranges.

Accuracy: ±2% of full scale on any range.

Input resistance: decreasing from 1000 ohms on 1 μamp scale to 0.1 ohm on 1 amp scale.

Ohmmeter

Resistance range: resistance from 1 ohm to 100 megohms center scale, 9 ranges.

Accuracy: ±5% of reading, 0.2 ohm to 500 megohms; ±10% of reading, 0.1 to 0.2 ohm and 500 megohms to 5000 megohms.

Amplifier

Voltage gain: 1000 maximum.

DC bandwidth: dc to 0.7 cps on 100 μv range and above.

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 (typically less than 15 μv p-p) referred to the input.

Drift: negligible.

Common signal rejection: may be operated up to 500 v dc, or 130 v ac above ground.

Power: 115 or 230 volts ±10%, 50 to 60 cps, 35 watts.

Dimensions: cabinet: 11½" high, 7½" wide, 10" deep (292 x 191 x 254 mm); rack mount: 5-7/32" high, 19" wide, 7½" deep behind panel (134 x 483 x 191 mm).

Weight: net 12 lbs (5,5 kg), shipping 17 lbs (7,6 kg) (cabinet); net 12 lbs (5,5 kg), shipping 19 lbs (8,6 kg) (rack mount).

Price: hp 412A, $400 (cabinet); hp 412AR, $405 (rack mount).

425A DC MICROVOLT-AMMETER

Read directly 1 pa and 1 μv with compact, portable instrument

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 microvolt to 1 volt and dc currents from 1 picoamp 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, to study the chemically generated emf's, 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 vacuum tube grid 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 volt 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 end scale; line frequency variations ±5 cps affect accuracy less than ±2%.

Amplifier

Gain: 100,000 maximum.

AC rejection: at least 3 db at 1 cps, 50 db at 50 cps and approximately 60 db or more above 60 cps; a power line frequency or twice power line frequency signal 40 db greater than end scale causes less than 1% error.

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: less than 0.2 μv rms (typically less than 1.2 μv p-p) referred to the input.

Drift: after 15 minutes' warm-up, drift is less than ±4 μv per day referred to input.

General

Power: 115 or 230 volts ±10%, 60 cps, 40 watts; 50 cps operation on special order.

Dimensions: cabinet: 7⅜" wide, 11¾" high, 12" deep (187 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 23 lbs (10,4 kg) (cabinet); net 21 lbs (9,5 kg), shipping 30 lbs (13.5 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, $500 (cabinet); hp 425AR, $505 (rack mount).

Option 01.: For operation from 50 cps power, no extra charge.

428B CLIP-ON DC MILLIAMMETER, PROBES

Measure without interrupting circuit; no circuit loading

Direct current from 0.1 milliampere to 10 amps 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 cps) current measurements.

3528A Large Aperture Current Probe

This large aperture current probe permits the 428B to make measurements on any conductor up to 2-9/16" in diameter. It is useful for measuring common mode, ground and electrolysis currents in pipes, multi-conductor cables (including lead-sheathed), ground straps, even microwave waveguide. Current range of this large diameter probe is the same as the 428B. The bandwidth is dc to 300 cps. Accuracy is ±1 ma ±3% of full scale when the probe is calibrated with the instrument. Inductance less than 3 μh is introduced into the measured circuit.

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 milliamps 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 cps, and accuracy is ±3% of full scale when the probe is calibrated with the instrument.

Specifications, 428B

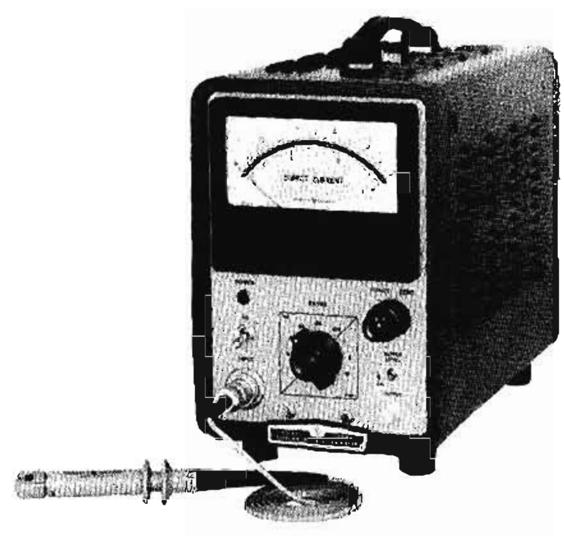
Current range: 0.1 ma to 10 amperes; nine full-scale ranges from 1 ma to 10 amperes in a 1, 3, 10 . . . sequence.

Accuracy: ±3% of full scale, ±0.1 ma, from 0°C to +55°C.

Probe inductance: less than 0.5 μh; no noticeable loading, even up to 1 mc.

Probe induced voltage: less than 15 mv peak (at 20 kc and harmonics).

Output: approx. 1.5 v and 1 ma max. for full scale; 100-ohm source; variable linear output level with switch provision for calibrated 1 v (corresponds to full-scale deflection).



428B

Noise level: less than ±0.015 ma.

AC rejection: ac with peak value less than full scale affects meter accuracy less than 2% at frequencies different from the carrier (approx. 40 kc) and its harmonics; the above applies to frequencies greater than 5 cps; also, total instantaneous current must not exceed full scale below 5 cps; on the 10 amp range, ac peak value is limited to 4 amps.

Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 70 w.

Operating temperature range: −20°C to +55°C.

Storage temperature: −40°C to +65°C.

Probe insulation: 300 volts maximum.

Probe tip size: approximately ½" by 21/32"; aperture diameter 5/32".

Dimensions: cabinet: 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 19 lbs (8,6 kg), shipping 24 lbs (10,8 kg) (cabinet); net 24 lbs (10,8 kg), shipping 35 lbs (15,8 kg) (rack mount).

Accessories available: 3528A Large Aperture Probe (with degausser), $450; 3529A Magnetometer Probe, $75.

Price: hp 428B, $600 (cabinet); hp 428BR, $605 (rack mount).

Options

01. hp 3528A Current Probe (aperture 2-9/16") in lieu of 428A-21A Probe normally supplied, add $375.
02. hp 3529A Magnetometer Probe in lieu of 428A-21A Probe normally supplied, no extra charge.

MODEL 22 DC SERVO VOLTMETER

Multi-range, extremely accurate, large linear scale voltmeter

Advantages:

- 3 mv to 300 v, full scale, in 11 ranges
- All solid-state circuitry
- 14" mirror-backed linear scale
- Continuous electronic reference
- Module construction with rack and table adaptability

Uses:

- To drive output potentiometer, digitizer
- "On-line" component testing
- Operate external equipment at selected scale positions (when fitted with optional high-low limit switches)

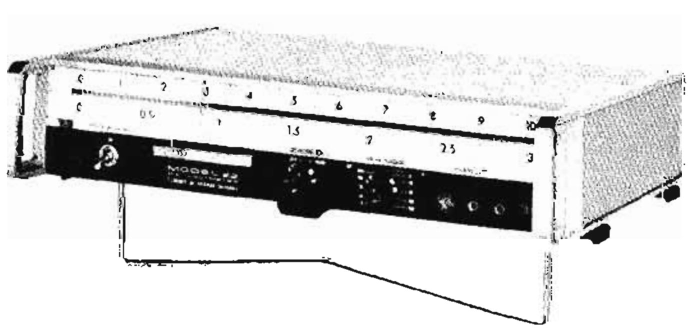
The Moseley Model 22 DC Voltmeter is a servo potentiometer type instrument with eleven calibrated ranges, instant zero-left or zero-center selection and easy-to-read 14 inch mirror-backed linear scale. Designed for general laboratory use, it has fast response, high accuracy, and its servo system may be used to drive a variety of instruments for process control and data reduction applications. Completely self-contained, the 22 Voltmeter is adaptable to either rack mounting or bench operation. A bar-type tilt stand permits horizontal or inclined orientation on the bench.

Module construction

Five easily serviced sub-assemblies are used in the complete unit. They consist of a Control Panel with input terminals, range and zero positioning selectors, power switch and indicator lamp; Input and Balance assembly which includes the attenuator, low-pass noise filter and precision summing resistors; Servo Drive assembly consisting of the dc servo motor, slidewire potentiometer, gear train and slip-clutch; Servo Amplifier which is all solid state with high gain and chopper input; Power Supply with zener-regulated section for servo-balancing potential.

Applications

Because a slip-clutch and full-scale stop feature prevents short-term over-scale voltages from damaging the pointer, the Model 22 is ideal for "on-line" component checking. When fitted with a proportional output potentiometer (Option 01.) the 22 may be used as a standard voltage source, a driftless dc amplifier, a dc-to-ac transducer of any frequency or waveform or a squaring device. Using the servo system to drive an output digitizer (extra cost), printers or other apparatus requiring digital input information may be operated directly. For driving external devices at selected scale positions, installed high-low limit switches (Option 02.) are available. For low current drain, potentiometric input may be established on the most sensitive range.



Model 22, illustrating tilt stand

Specifications

Indicator movement: servo-actuated drive; completely solid-state servo amplifier.

Balancing time: one second, maximum, for full scale.

Scale: linear, 14" long; large numbers and mirror-backed; instant selection of zero-left or zero-center.

DC voltage ranges: 11 steps, 0 to 3, 10, 30, 100, 300 mv, full scale; and 0 to 1, 3, 10, 30, 100, 300 v, full scale; input floating up to 500 v above ground.

Input resistance: 200,000 ohms/v, full scale, on all ranges through 30 v; 60,000 ohms/v, full scale, on 100 v range; 20,000 ohms/v, full scale, on 300 v range; removal of straps on input circuit permits potentiometric operation on most sensitive range with essentially zero current drain at null.

Accuracy: 0.2% of full scale on all ranges.

Standardization: continuous electronic reference, zener diode controlled.

Power: 115 or 230 volts, 50 to 60 cps, approximately 15 volt-amperes.

Dimensions: 17" wide, 3½" high, 12" deep (432 x 89 x 31 mm).

Price: Moseley 22 (standard instrument), $595.

Options:

01. With installed 5000-ohm retransmitting potentiometer, add $65.
02. With installed limit switches, add $105.

VOLTMETER ACCESSORIES

11018A Adapter

Connects hp 410 Series AC Probe to shielded dual banana plugs; hp 11018A, $35 each. (Refer to pages 128, 129.)

11021A Probe

1000:1 divider probe increases range of hp 425A DC Microvolt-Ammeter to 1000 volts; hp 11021A, $55 each. (Refer to page 135.)

11022A-11026A Probe Tips

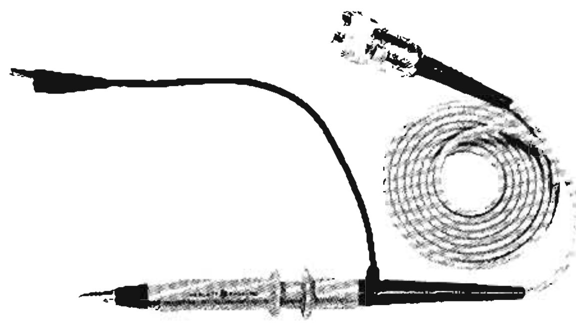
Assorted probes decrease input capacity of hp 411A RF Millivoltmeter; hp 11022A-hp 11027A, $25 to $40. (Refer to page 123.)

11028A Divider

100:1 divider probe increases range of hp 456A AC Current Probe up to 25 amps, depending upon the frequency of the ac current being measured; hp 11028A, $32 each. (Refer to page 140.)

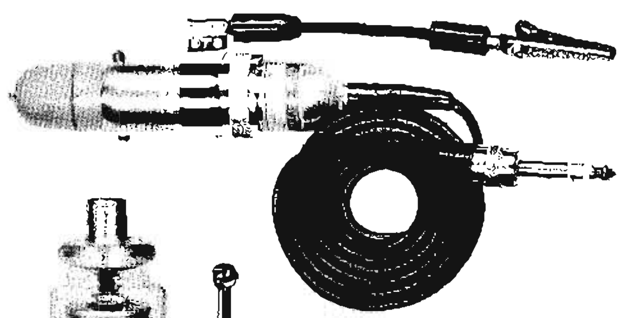
hp Instrument	Max. current	Max. voltage	Price
11029A	3 a	0.3 v	$35
11030A	1 a	1 v	$20
11031A	0.3 a	3 v	$20
11032A	0.1 a	10 v	$20
11033A	40 ma	25 v	$20
11034A	30 ma	30 v	$20

11018A (1/2 actual size)

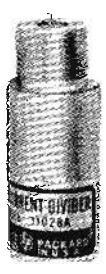


11021A (1/2 actual size)

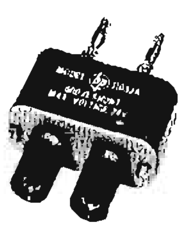
11022A-11027A (1/2 actual size)



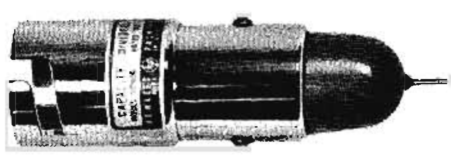
11036A (1/3 actual size)



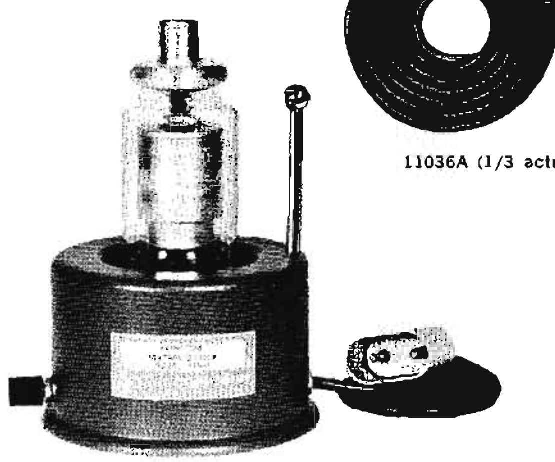
11028A (1/2 actual size)



11029A-11034A (1/2 actual size)



11040A (1/2 actual size)



11039A (1/3 actual size)

11039A Capacitive Voltage Divider

For 400 and 410 Series Voltmeters. Safely measures power voltages to 25 kv; accuracy ±3%. Division ratio, 1000:0. Input capacity, 15 pf ±1. Maximum voltage ratings (sea level) 60 cps, 25 kv; 100 kc, 22 kv; 1 mc, 20 kv; 10 mc, 15 kv; 20 mc, 7 kv. Useable for dielectric heating, power and ultrasonic voltages. Price,hp 11039A, $150 each. (Refer to pages 118-121, 128, 129.)

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, decreasing to 100 v at 400 mc; for frequencies 10 kc and above. Price, hp 11040A, $35 each. (Refer to pages 128, 129.)

11041A Capacitive Voltage Divider

For hp 400 Series Voltmeters. Safely measure power line, audio, ultrasonic and rf voltages; accuracy, ±3%. Division ratio, 100:1. Input impedance, 50 megohms resistive shunted with 2.75 pf capacity. Maximum voltage, 1500 v. Price,hp 11041A, $60 each. (Refer to pages 118-121.)

11042A Probe Coaxial "T" Connector

For hp 410 Series Voltmeters. Measures voltages between center conductor and sheath of 50-ohm transmission line. Maximum swr, 1.1 at 500 mc, 1.2 at 1 gc. Male and female Type N fittings. Price, hp 11042A, $40. (Refer to pages 128, 129.)

11043A Probe Coaxial "N" Connector

For hp 410 Series Voltmeters. Measures at open end of 50-ohm transmission line (no terminating resistor). Has male Type N fittings. Price, hp 11043A, $37.50. (Refer to pages 128, 129.)

11044A DC Voltage Divider

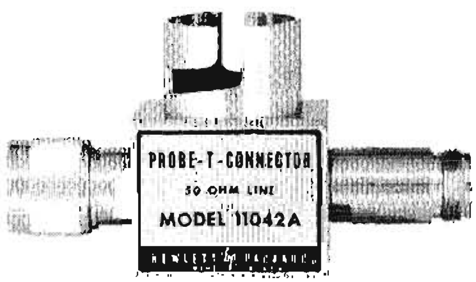
For hp 410B Voltmeter. Gives maximum safety and convenience for measuring high voltages as in television receivers, etc. Accuracy, ±5%; division ratio, 100:1. Input impedance, 12 megohms. Maximum voltage, 30 kv. Maximum current drain, 2.5 μamps. Price, hp 11044A, $50. (Refer to page 129.)

11045A Divider

Same as 11044A except input impedance, 10 megohms. Price,hp 11045A, $50.

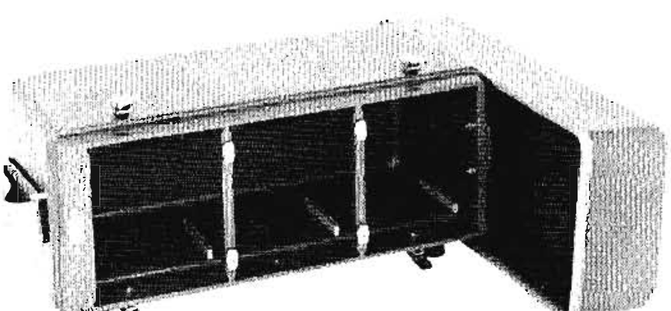
11046A Combining Case

Combining case houses 2 one-half and 3 one-third full rack width instruments. (Refer to pages 13 and 14.) Price, hp 11046A, $150 each.

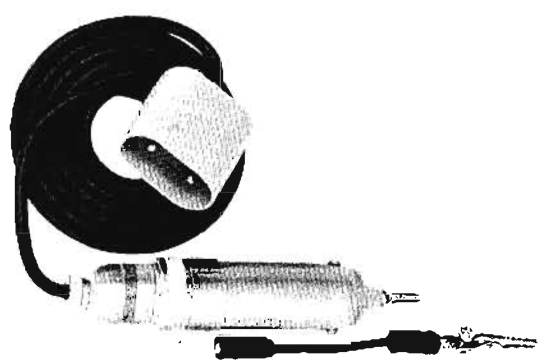


11041A (1/3 actual size)

11044A (1/4 actual size)



11046A (1/9 actual size)



11042A (1/2 actual size)

11043A (1/2 actual size)

200SR, 738BR, 739AR VTVM CALIBRATION SYSTEM
456A AC CURRENT PROBE

VTVM calibration system

The hp 200SR, 738BR, 739AR System calibrates vacuum tube voltmeters and oscilloscopes for both frequency response and voltage accuracy. The system combines three moderately priced basic hp instruments that calibrate for voltage levels from 300 microvolts to 300 volts in precise preselected steps and calibrate for frequency response from 5 cps to 10 mc.

The three instruments are available individually (hp 738BR Voltmeter Calibrator, hp 739AR Frequency Response Test Set, hp 200SR Oscillator) or in a single enclosure provided with rear-access door and power strip as the K02-738BR.

The 738BR is a highly stable precision voltage source, with drift less than 0.1% per week for dc voltage, less than 0.25% per week for ac voltage. The 739AR provides a convenient constant-amplitude reference voltage of a variable frequency, 300 kc to 10 mc. The 200SR combines with the 739AR to extend the range to frequencies as low as 5 cps.

Specifications, VTVM calibration system

738BR Voltmeter Calibrator

Voltage range: 300 μv to 300 v, dc or ac (rms and p-p, 400 cps.)

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 volt steps and 0.05 to 0.5 volts in 0.05 volt steps.

Accuracy: 300 v working voltage into attenuator, accurate within 0.1% dc and 0.2% ac, after a 30-minute warm-up.

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 volts ±10%, 50 to 60 cps, 350 watts.

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, $850 (rack mount).

739AR Frequency Response Test Set

Frequency range: 300 kc to 10 mc in 3 ranges (5 cps to 10 mc with 200SR Oscillator).

Frequency response of monitoring circuit: flat within ±0.5% from 10 cps to 5 mc; within +0.5%, 5 cps to 10 mc with meter reading kept at set level; monitoring circuit is average reading.

Power: 115 or 230 v ±10%, 50 to 1000 cps, 30 w.

Dimensions: 19" wide, 7" high, 8¾" deep behind panel (483 x 178 x 400 mm).

Weight: net 14 lbs (6.3 kg); shipping 24 lbs (10,8 kg).

Price: hp 739AR, $600 (rack mount).

200SR Oscillator

Frequency range: 5 cps to 600 kc in 5 ranges.

Output: at least 3 v rms into 50 ohms.

Dial accuracy: ±2%.

Frequency response: ±1 db, 1000 cps reference.

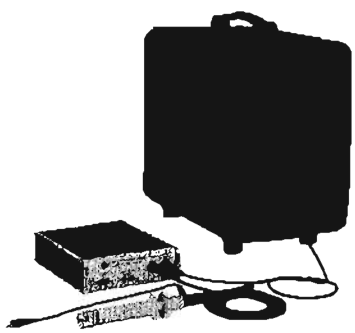
Power: 115 or 230 v ±10%, 50 to 1000 cps, 75 w.

Dimensions: rack mount: 19" wide, 7" high, 13⅛" deep behind panel (483 x 178 x 333 mm).

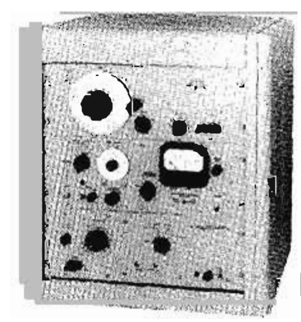
Weight: net 25 lbs (11,3 kg); shipping 37 lbs (16,8 kg) (rack mount).

Price: hp 200SR, $230 (rack mount).

Note: All three instruments are available in cabinet with single power cord and plug strip; specify K02-738BR, $1920.



hp 456A with hp 400H



NEW

Top to bottom
200SR, 739AR, 738BR

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 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 kc.

Frequency response: ±2%, 100 cps to 3 mc; ±5%, 60 cps to 4 mc; −3 db at 25 cps and greater than 20 mc.

Pulse response: rise time is <20 nsec, sag <16%/msec.

Maximum input: 1 amp rms, 1.5 amp peak; 100 ma above 5 mc.

Effect of dc current: no appreciable effect on sensitivity and distortion from dc current up to 0.5 amp.

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 in. of hookup wire).

Probe aperture: 5/32" (4 mm) diameter.

Probe shunt capacity: approx. 4 pf added from wire to ground.

Distortion at 1 kc: for 0.5 amp 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 kc; approximately +1 v dc component; should work into load of not less than 100,000 ohms shunted by approximately 25 pf.

Power: two Mallory Battery Co. TR 233R and one TR 234 batteries (1420-0005 and 1420-0006); battery life approximately 400 hours; ac power supply optional at extra cost, 115 or 230 v ±10% 50 to 1000 cps approx. 1 w.

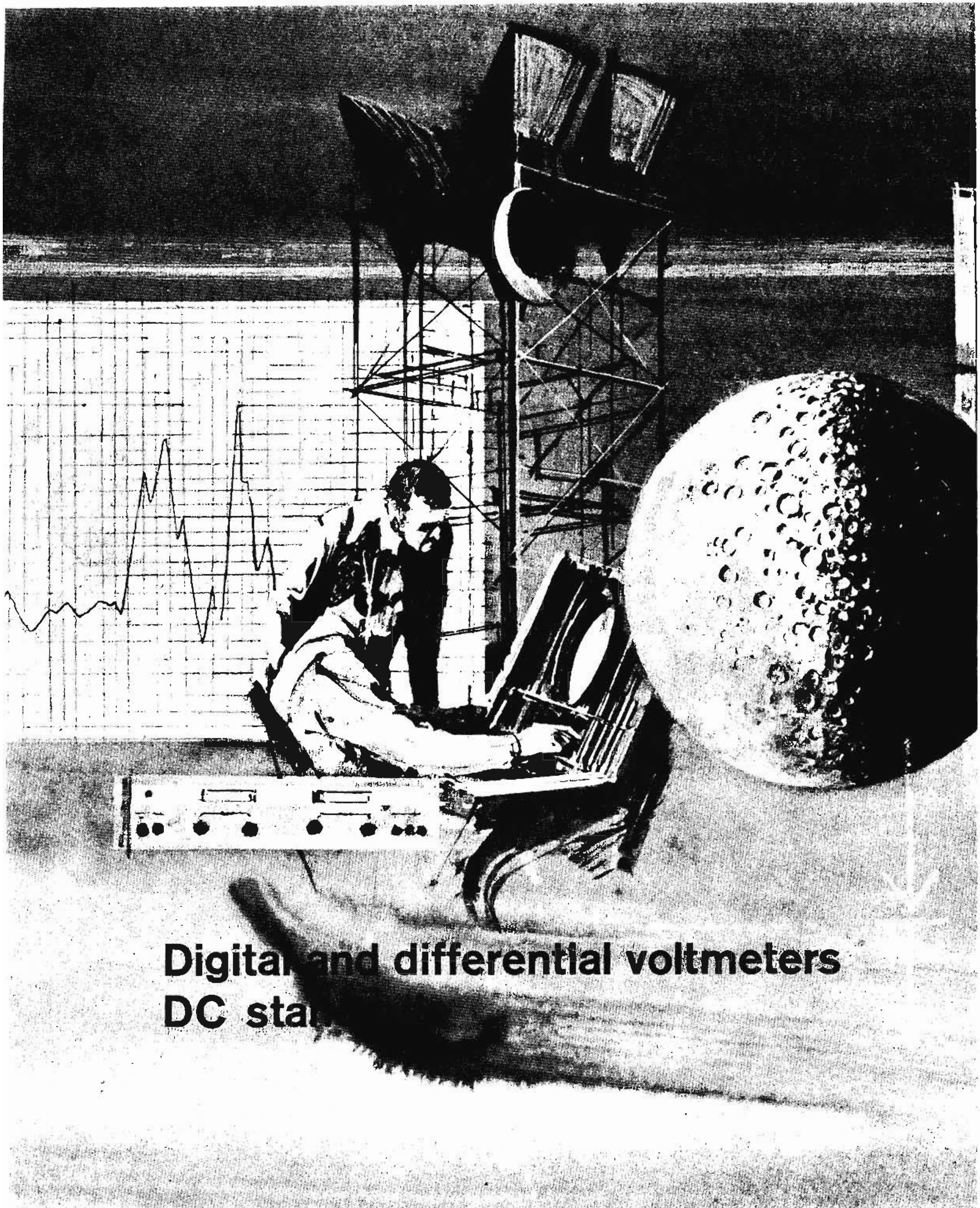
Weight: net 3 lbs (1,4 kg); shipping 4 lbs (1,8 kg).

Dimensions: 5" wide, 6" deep, 1½" high (127 x 152 x 38 mm); probe cable is 5 ft. long; 2 ft. output cable terminated with dual banana plug.

Accessory available: 456-11A AC Supply for field installation, $40.

Price: hp 456A with batteries, $190.

Option 01.: AC supply installed in lieu of batteries, add $20.



Digital and differential voltmeters
DC sta

DIGITAL, DIFFERENTIAL VOLTMETERS

Digital voltmeters

Digital voltmeters (DVM's) display measurement as discrete numerals, rather than as a pointer deflection on a continuous scale commonly used in analog devices.

Several advantages in DVM characteristics lead to selection of a DVM in preference to some analog measurement methods. 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 or reversed polarity. Measurement capabilities of ac voltages, dc currents and resistance are available. Permanent records of measurements are available with printers, card and tape punches, and by magnetic tape equipment. With data in digital form, it may be processed with no loss of accuracy.

Details of operation

The heart of a digital voltmeter is the circuitry which converts analog voltage to a digital form. Most digital voltmeters on the market today fit into one of five categories:

1. Successive-approximation
2. Continuous-balance
3. Ramp (voltage-to-time-interval)
4. Integrating
5. Integrating and potentiometric

The successive-approximation type of digital voltmeter converts the input voltage into digital form by a series of approximations and decisions. This type of voltmeter consists of a digital storage register (digital accumulator), a digital-to-analog converter, a comparison network (error detector), a precision voltage reference and control circuitry. The input voltage is compared first with the most significant bit. The actual comparisons are made successively in binary form. If the input voltage is less than the most significant bit of the reference, the most significant bit of the register is cleared, and the next lower bit is switched in for comparison. The process of switching in the next lower significant bit is continued until a decision is made on all digits.

At this point, the voltmeter has completed its measurement. The accuracy of this technique is limited by the comparator sensitivity, reference supply, digital-to-analog converter and the resolution of the instrument. Its advantages are speed, accuracy and fixed encoding time. However, the successive-approximation method has sensitivity and noise problems and lacks the ability to make accurate measurements in the presence of noise, without the use of filters.

The continuous-balance type of digital voltmeter performs a digital measurement by comparing the unknown voltage against a voltage derived from a stable reference supply. At the beginning of a measurement the unknown voltage is compared against the "full scale" reference. If a null is not reached, a voltage derived from the reference is reduced by an incremental value representing a unit of the least significant digit by automatically switching precision resistors. This process continues until null is achieved. However, when the input voltage varies because of superimposed noise, null is never reached, and the digital voltmeter hunts, never reaching an answer.

Ramp (voltage-to-time conversion) DVM

Hewlett-Packard has made notable contributions in digital voltmeters with three basic approaches in design. Each design was a pioneer at the time of its introduction to the field. The techniques will be discussed in order of their historical development.

The ramp category forms the economy class of digital voltmeters. The operating principle of the ramp digital voltmeter is to measure the length of time it takes for a linear ramp of voltage to become equal to the unknown input voltage after starting from a known level. 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. It requires an input filter if superimposed noise is present. A time-encoding technique is utilized in the hp 405B, 405C and hp 3440A Digital Voltmeters.

Voltage-to-time conversion

Conversion of a voltage to a time interval is illustrated by the timing diagram of 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.

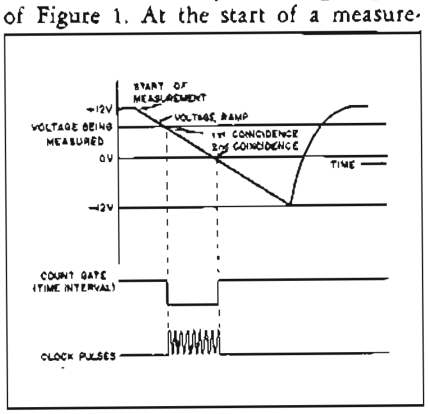


Figure 1. Voltage-to-time conversion.

It is readily seen that the time duration of the gate opening is proportional to the input voltage. The gate allows clock pulses to pass to totalizing circuits, and the number of pulses counted during the gating interval is a measure of the voltage. Choice of ramp slope and clock rate enables the totalizing circuit readout to read directly in millivolts (e.g., a slope of 400 v/sec and clock rate of 400 kc).

If the input were a negative voltage, coincidence with it would occur before zero coincidence. Circuitry senses which coincidence occurs first and switches the polarity indicator accordingly.

The virtue of the voltage-to-time conversion as a digitizing technique lies in its simplicity. Furthermore, slowly varying input voltages do not disturb the operation of the voltmeter, as often happens with null-seeking voltmeters which may continually hunt for, but never achieve a balance. The economical hp Model 405BR,CR and 3440A Digital Voltmeters use the voltage-to-time conversion technique.

A block diagram of the hp 3440A Digital Voltmeter (Figure 2) shows the basic parts of a system typical of time encoding. A voltage ramp is generated and compared with the unknown voltage and with zero voltage. Coincidence with either voltage starts the oscillator, and the electronic counter counts the cycles. Coincidence with the second comparator stops the oscillator. The elapsed time is proportional to the time the ramp takes to travel between the unknown voltage and zero volts, or vice versa. The order in which pulses come from the two comparators indicates the polarity of the unknown voltage. The accumulated reading in the counter can be used to control ranging circuits. The comparators used in the hp 3440A are of a unique solid-state circuit design, contributing to a sys-

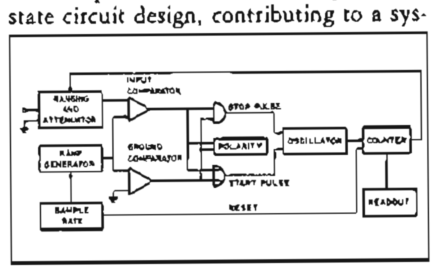


Figure 2. Block diagram hp 3440A Digital Voltmeter.

tem which is fast, economical and capable of great utility.

The system used in the 3440A DVM allows one to make an economical DVM with adequate speed and accuracy for a majority of production and bench test requirements. 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 (using the hp 3443A Plug-in Unit) and four-digit readout, make it the economical choice.

Integrating (voltage-to-frequency conversion) DVM

The next advancement in the state of digital voltmeter art was made by Hewlett-Packard's Dymec Division with the DY-2401C. It features integration of the input signal, guarding and remote operation. This integrating digital voltmeter measures the true average of the input voltage over a fixed encoding time, in contrast to the successive-approximation, continuous-balance and ramp types of digital voltmeters, which measure the voltage at the end of the encoding interval. Measurement at the end of the encoding interval can easily coincide with a burst of noise, thus creating a discrepancy in the DVM's indication.

Voltage-to-frequency conversion (integrating)

A voltage-to-frequency converter is shown in Figure 3. 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.

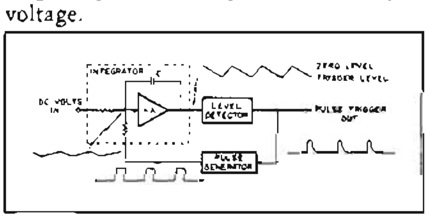


Figure 3. Voltage-to-frequency conversion.

A positive voltage at the input results in a negative-going ramp at the output of the integrator. The ramp continues until it reaches a voltage level that fires the level detector, which, in turn, triggers a pulse generator. The pulse generator produces a rectangular pulse with closely controlled width and amplitude just sufficient to draw enough charge from capacitor C to bring the input of the integrator back to the starting level. The cycle then repeats.

The ramp slope is proportional to the input voltage. A higher voltage at the input would result in a steeper slope, resulting in a shorter time duration for the ramp. Consequently, the pulse repetition rate would be higher. Since the pulse repetition rate is proportional to the input voltage, the pulses can be counted during a known time interval to derive a digital measure of the input voltage. While a voltage ramp is generated in this type of DVM, the amplitude is only a fraction of a volt, and the accuracy of the analog-to-digital conversion is determined not only by the characteristics of the ramp but also by the area of the feedback pulses.

The primary advantage of this type of analog-to-digital conversion is that the input is "integrated" over the sampling interval, and the reading represents a true average of the input voltage. The pulse repetition frequency "tracks" a slowly varying input voltage so closely that changes in the input voltage are accurately reflected as changes in pulse repetition rate. The total pulse count during a sampling interval therefore represents the average frequency, and thus, the average voltage. This is important when noisy signals are encountered. The noise is thereby averaged out during the measurement without requiring input filters that would slow the voltmeter response time. Furthermore, the voltmeter achieves essentially infinite rejection of power line hum, the most prevalent source of signal noise, when the measurement interval is an exact multiple of the hum waveform period.

A second advantage is that the pulse circuits provide a convenient means of coupling the information out of a guard circuit. The Dymec DY-2401C Integrating Digital Voltmeter has a floating input, and all of the voltage-to-frequency conversion circuitry is housed within a guard shield. Figure 4 shows a simplified block diagram of the technique used in the DY-2401C. The integrator, pulse generator and level detector generate a train of pulses. The total number of pulses over a specified period is directly proportional to the integral of the input signal over this same period of time. This arrangement makes it possible to transformer-couple the signal to the digital circuits outside the guard and thus enables complete isolation of the measuring circuit itself.

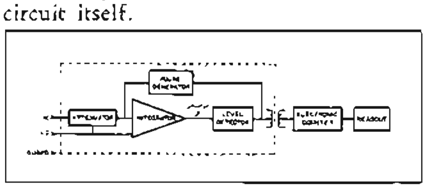


Figure 4. Block diagram DY-2401C DVM.

The DY-2401C Voltmeter applies especially to measurements of extremely noisy signals up to 100% of full-scale peak value. It is also capable of 1 μv resolution; full-scale readings down to 99.999 mv can be made without an accessory amplifier (9.9999 mv with DY-2411A). If high reading rates are required, the DY-2401C can take readings with three-digit resolution at rates up to 50/second. Speed is an outstanding feature of the optional auto-ranger for the 2401C; less than 34 msec are required to select the correct range. This speed, along with its complete remote control ability, makes it ideal for many system applications. Another unique feature of the DY-2401C is its ability to measure the volt-second integral of an arbitrary waveform. It also can be used as an electronic counter to measure frequency or period.

Potentiometric integrating DVM

A new high in DVM measurement accuracy obtained by a special analog-to-digital conversion technique is found in the hp solid-state Model 3460A Digital Voltmeter. The 3460A, in a sense an automated differential voltmeter, offers extremely high accuracy and resolution. Especially in comparison with non-integrating continuous-balance meters and with successive-approximation meters, the 3460A offers extreme accuracy and resolution, with superior noise immunity, while retaining speed and presenting a constant high input impedance. Beyond this, the 3460A features compactness and economical price.

By special techniques which utilize the best features of several existing systems, a totally new result has been achieved in the hp 3460A Digital Voltmeter. Besides being an integrating type voltmeter which continually measures the true average of the input voltage over a fixed encoding time, it also is a potentiometric type relying primarily on resistance ratios and a stable reference voltage to assure high accuracy.

A block diagram of the 3460A Integrating-Potentiometric Digital Voltmeter is shown in Figure 5. Note that the voltmeter is divided into three sections: a voltage-to-frequency (V/F) converter, a counter and a digital-to-analog (D/A) converter. The hp 3460A takes a reading in two steps.

First, the voltage-to-frequency converter generates a pulse train with a rate exactly proportional to the input voltage. This pulse train is gated for a precise time interval and is fed to the first four places in a 6-digit counter. The stored (undisplayed) count is transferred to the D/A converter, which produces a highly accurate dc voltage proportional to the stored count. This voltage is subtracted from the unknown voltage at the input to the V/F converter.

Next, the pulse train from the V/F converter is again gated—this time to the last two places in the 6-digit counter. At the end of the second gate period the total count is transferred to the 6 display tubes. The counter display is indicative of the integral of the input voltage.

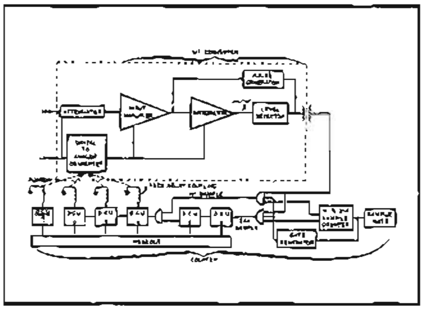


Figure 5. Block diagram hp 3460A DVM.

The hp 3460A should be chosen for applications which require extremely high accuracy ($\pm 0.005\%$) and high speed with high resolution. The 3460A takes up to 15 readings per second with more than 5-digit resolution (1.19999 full scale). These reading all can be made in the presence of large common mode signals. The 3460A is equipped to be ranged automatically or remotely, and to be triggered on command. A most useful degree of noise-averaging is obtained through use of the integrating technique. It can reject superimposed noise up to either 1% or 6% of the full-scale range, depending upon the chosen gate length. The integration feature also allows a maximum reading rate even with noisy signals, since no input filter is required.

Selecting a digital voltmeter

A knowledge of DVM operation principles aids in proper selection. The choice of a digital voltmeter is governed largely by the intended application. Relative cost also should be considered.

If the DVM is to be used with a data acquisition system, then binary-coded decimal (BCD) output and remote programming ability are necessities. Compatibility with related equipment should be determined.

When selecting a digital voltmeter to make accurate measurements in the presence of noise, the digital voltmeter must be able to discriminate the real signal from the noise appearing at its input terminals. Noise rejection by integration permits both high accuracy and speed in the presence of severe noise conditions. The integrating digital voltmeter reads the average value of the input signal and fits into an attractive price class.

Noise on the signal may also be reduced if the digital voltmeter has a passive input filter. Filtering can be employed without degrading voltmeter accuracy but it does impose a penalty on the speed of making measurements. Considerations of speed must be made if the digital voltmeter is to be used in data acquisition systems; however, the input filter type of DVM enters into an economical price class.

Common mode pickup, which is noise induced in the signal current by circulating ac ground currents, is frequently a severe measurement problem. Guarding, which virtually eliminates the effects of common mode noise, may therefore be of prime importance when selecting a digital voltmeter.

For production line and other operator-controlled measurements, automatic ranging may be of prime importance. The ability to track signals around zero may be needed, in which case inclusion of a bi-directional counter (DY-2401C and hp 3460A) may be desirable. Laboratory applications, on the other hand, may be more concerned with accuracy and resolution.

All of the Hewlett-Packard digital voltmeters described have been designed with the requirements of a maximum number of voltage measurements in mind. Each category of DVM uses a different system to convert analog voltage to digital information. These various techniques were chosen to maximize performance while minimizing cost. A Hewlett-Packard DVM is available to meet your specific application requirements.

Differential voltmeters

The basic concept of differential voltage measurements is to apply an unknown voltage against one that is accurately known and to measure the difference between the two on an indicating device. If the known voltage is adjusted to the exact potential of the unknown voltage, one can determine the unknown quantity being measured as accurately as the known voltage (reference standard).

A typical differential voltage measurement is shown in Figure 6. The null meter M_x indicates when the voltage e_{ac} at the potentiometer is equal to the unknown voltage e_x. From considerations of the ratio of resistance R_{ab} and R_{ac} in the potentiometer, the ratio of e_{ac} to the known reference voltage e_{ref} may be determined precisely.

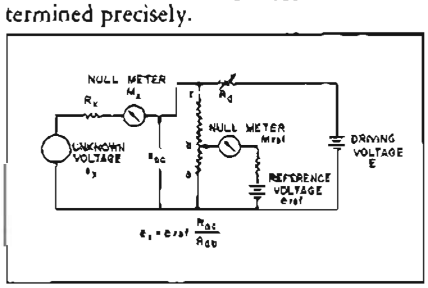


Figure 6. Potentiometer method of measuring unknown voltages.

The potentiometric method is highly accurate, since precise resistance ratios can be determined. No current is drawn from either the standard cell or the unknown voltage source *at null*. The source impedance R_x, therefore, does not affect measurement. The divider output tap (b) is adjusted to null e_{ref}.

$$\left(\text{Thereby } e_x = e_{ref} \frac{R_{ac}}{R_{ab}} \right)$$

Conventional differential voltmeter

Figure 7 illustrates a simplified, conventional differential voltmeter, where the potentiometer slidewire has been replaced by a Kelvin-Varley divider and the voltage E has been replaced by an accurate supply, E_s, referenced to the standard voltage. The null device is a solid-state voltmeter instead of a galvanometer. Using this method, a high voltage standard is required to measure high voltages. This need may be overcome by inserting a voltage divider between the source and the null meter, but this, in turn, provides relatively low input impedance for voltages higher than the reference standard. This low input impedance is undesirable, because accurate measurements cannot be obtained if current is drawn from the source that is being measured. Most differential voltmeters used today offer impedance approaching infinity only at a null condition, and then only if an input voltage divider is not used.

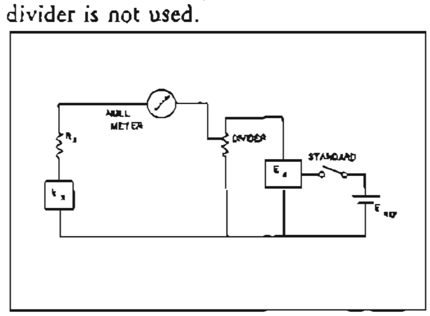


Figure 7. Simplified conventional differential voltmeter.

Isolation achieves high input impedance regardless of null

Hewlett-Packard has developed a system with an isolation stage and a precision amplifier that can be used to provide a high input impedance which eliminates loading the source. This approach used in the hp 740A and hp 741A results in a differential voltmeter whose input impedance is independent of both null condition and range.

Standard lab accuracy, versatility, ease of operation

Recently developed, the hp 740A and hp 741A combine a differential voltmeter (ΔVM) and a dc voltage standard into one package that provides several conveniences for making precision voltage measurements. Both instruments (740A, 741A) draw negligible current from the unknown voltage source whether or not the instrument is nulled. This simplifies the measurement, especially when the unknown voltage is drifting.

In addition to their function as △VM's, the hp differential voltmeter/standards provide calibrated voltages for external use. Furthermore, these instruments can perform extra service as precision voltmeters and dc amplifiers. The hp Model 741A also has an ac-dc converter that permits it to make differential measurements on ac voltages (by precise conversion of the unknown ac to an equivalent dc), and to serve as a precision ac voltmeter.

Circuit description

When a voltage to be measured is applied to the input terminals, the amplifier responds by recreating this voltage at the summing point and inherently balancing the system to achieve a constant high input impedance. The amplifier output is converted to a 1 volt level by means of a precision range divider switch for direct comparison with a 1 volt interval reference. The range switch performs two operations. It changes the overall feedback factor, and thus, the overall amplifier gain, and it selects the potentiometer tap on the range stick. Consequently, choice of the proper range enables any input voltage between 0 to 1000 volts to be represented by a proportional voltage between 0 and 1 volt at the tap connecting to the potentiometer. Figure 8 illustrates a simplified block diagram of both hp ac and dc differential voltmeters/dc standard.

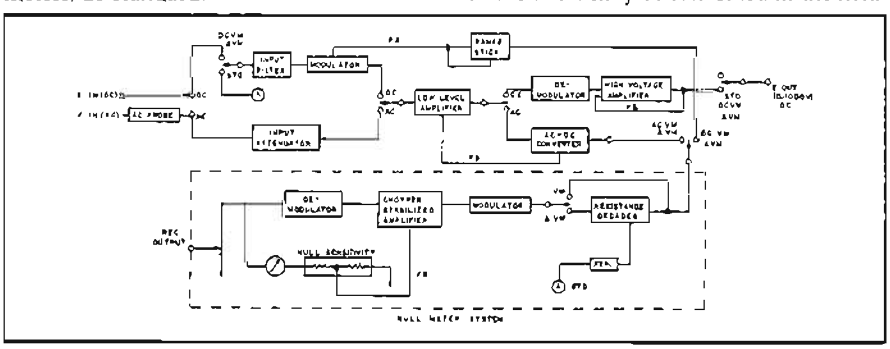


Figure 8. Hewlett-Packard ac/dc differential voltmeter/dc standard.

The isolation stage in the hp 740A and 741A consists of a series-connected pair of amplifiers, a low-level chopper-stabilized amplifier and a high-voltage amplifier. Overall feedback greater than 100 db assures gain accuracy and produces input impedance greater than 1000 megohms.

The high-level amplifier in the 740A and 741A is the key to obtaining a high voltage output using low-voltage power supplies and solid-state design. Voltage regulation is provided by pulse-width modulation of an internally generated square wave. This controls a transistor switch which drives a step-up transformer, a rectifier and filter circuit.

High sensitivity, stability and high input impedance are achieved in the meter circuits of hp differential voltmeters. These are acquired by careful design of the solid-state, chopper-stabilized, feedback amplifier. Null sensitivity is provided through decade pushbuttons, which select the proper amount of amplifier gain, and connect the decade dividers to the measuring circuit.

An adjustable recorder output supplies up to 1 volt at 1 ma for end-scale deflection of the meter. From input terminals to recorder output a maximum voltage gain of 120 db (740A) and 60 db (741A) is available.

The basic stability of the 740A and 741A is derived from the reference supply encased in a highly regulated proportionally controlled oven operated at 80°C. The reference supply maintains a stability better than 0.0015%/month (740A) or 0.005%/month (741A).

Most differential voltmeters use a Kelvin-Varley decade divider which provides a constant impedance to the reference supply. Such a divider uses 11 resistors per decade.

A binary technique developed by Hewlett-Packard (patent applied for) is electrically similar to the Kelvin-Varley divider but uses only 4 resistors per decade. This reduces initial cost, as well as calibration time. Greater accuracy and long-term stability are achieved by using hp-manufactured precision resistors.

An important feature of this new technique is the method by which the dividers in the 740A may be calibrated in the field. An internal multi-position switch connects the resistors of a decade in a bridge combination. The front-panel meter serves as a null indicator, so trimming resistors can be adjusted to establish resistor ratios to extreme accuracy.

741A achieves ac input capacity <5 pf

The foregoing has covered the basic technique of the 740A and 741A as a dc differential voltmeter. The block diagram in Figure 8 also shows the basic parts of the 741A used as an ac differential voltmeter. The outstanding contributions in ac measurement capability of the hp 741A are the very low input capacity (<5 pf) with the convenience of an ac probe and the extended bandwidth to 100 kc. This is obtained by an overall feedback scheme (patent applied for) in conjunction with the ac probe. The unknown ac signal is fed from the precision attenuator to the high-impedance, low-level amplifier. It is then amplified and applied to a diode bridge whose halfwave signal is averaged to produce a dc output. The dc output of the converter is measured in the same manner as the dc differential mode—by connecting the null meter decade divider system. Consequently, this ac measurement is made to a high degree of accuracy, since the ac signal is converted to dc and measured with the same precision dividers and reference standard used in dc operation. By this method, accuracy can approach that of the dc mode. The converter provides accurate ac measurements from 20 cps to 100 kc, and low input capacity allows measurements to be made at high frequencies and high voltage levels without drawing large reactive currents.

Either as a high-impedance ac voltmeter or as a high-impedance ac differential voltmeter, the hp 741A has an input impedance of 1 megohm shunted by less than 5 pf directly at the probe tip.

DC standard

The hp differential voltmeters previously discussed are converted by a front-panel switch to a dc standard. The same feedback amplifier and precision range stick are used. The internal reference supply now becomes the input to this amplifier. The input is automatically nulled against a feedback voltage which is determined by the range-switch setting and the output voltage at the sensing terminals. The vernier on the decade divider is mechanically linked to a voltage divider connected to the input of the null meter. This provides the 5th and 6th digits of resolution. Remote sensing is provided, as well as continuously adjustable current limiting. Both instruments used as a standard ac source have ranges from 1 volt to 1000 volts with six-place resolution on each range.

Multi-purpose field, lab standard

The ever-expanding usage of high-resolution, intermediate-accuracy ac and dc instruments have accentuated the need for devices having absolute accuracies and exhibiting extremely good stability for calibration of such instruments. This particular need for a variety of measurement requirements can be satisfied by Hewlett-Packard's 740A or 741A. Refer to pages 154 and 156 for specifications.

3460A DIGITAL VOLTMETER

Unique new performance at economical price

The new solid-state Hewlett-Packard 3460A Digital Voltmeter offers a broader measuring capability at moderate cost than any other DVM. High accuracy and resolution, rapid speed, with more than 5-digit readout and constant high input impedance are insured with the 3460A.

This guarded DVM permits automatic and remote controlled dc measurements from 1 volt to 1000 volts full scale. Low-level measurements of ±100 millivolts can be obtained with ±10 μv resolution. High accuracy of ±0.005% of reading ±2 counts makes the 3460A ideal for precision measurements. The hp 3460A provides 15 readings per second. As much as 20% overranging capability on all ranges offers full-scale display within specified accuracy up to 1000 volt range. Another feature includes constant 10 megohms input impedance on all ranges. An in-line digital tube display (and polarity indicator) provides voltage measuring capabilities to an accuracy of ±0.005% ±2 counts from 0.00001 to 1199.99 volts dc over a +10°C to +40°C temperature range (0.01% ±3 counts from 0°C to +10°C and +40°C to +50°C). Four input voltage ranges of 1.00000, 10.0000, 100.000, 1000.00 are selected by front-panel pushbuttons, with remote or automatic control left to the option of the operator. A lighted function symbol and decimal point are automatically positioned, so the display always reads directly in volts.

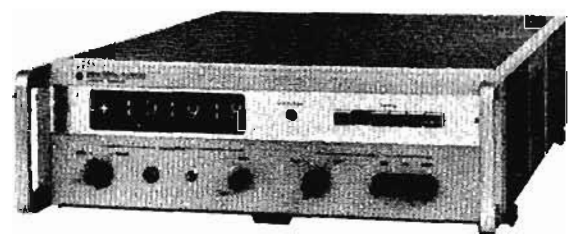
The hp 3460A is fully programmable. Permanent test records on all functions, including polarity, decimal function and overload, are available with accessory hp Model J76-562A Printer for a 1-2-4-8 code (Model J74-562A provides the same readout on a 1-2-2-4 code with 3460A, Option 01.). Accessory instruments include the guarded DY-2410B-M22 AC/Ohms Converter for ac voltage and resistance measuring capabilities (Option 02.).

Principles of operation

This new DVM is distinctly different from all other types of digital voltmeters. The hp 3460A combines potentiometric and integrating techniques and continually measures the true average of input voltage over a fixed encoding time. It attains ±0.005% accuracy largely as a result of the potentiometric principle which relies on resistance ratios and a stable reference voltage. It is used in combination with integration, producing much of the noise immunity of integrating DVM's while retaining potentiometric accuracy (refer to pages 143-145 for circuit description). The voltmeter, in one 5" high, 19" wide convenient rack mount unit, combines the extreme precision and measurement flexibility expected from laboratory standards with the programming and electronic output features necessary for automated systems.

Accurate measurements

The hp 3460A Digital Voltmeter relies primarily upon resistance ratios and an ultra-stable reference supply for its excellent accuracy and stability. Wire-wound resistance ratios establish the linearity of this new and different digital voltmeter. The stability of the reference supply exceeds 0.001%/month and consists of a breakdown reference diode in a temperature-controlled oven with temperature change of 0.2°C over a 0 to +50°C temperature range. The wire-wound resistance ratio and precision voltage reference have been the classic and most reliable sources of accurate voltage measurements in standards laboratories. While this historic technique is outstanding for achieving maximum accuracy, it can be used only for very stable voltages with no noise being present. This factor has affected the accuracy of successive-approximation and continu-



Triggering	Range	Speed
local	all	3 readings/sec; 1/5 sec
remote	1 v	7 readings/sec

Table 1. Measuring speed

Ranging

Voltages are measured in 4 ranges, from ±1 volt to ±1000 volts full scale. Ranges are selected automatically, manually or remotely on the 3460A. An important advantage of the 3460A is that up to 20% of full-scale overranging can be obtained on any range (1200 v dc on the 1000 v range). An overload condition is indicated on the front panel and the recording output when the input voltage is greater than 1.2 times of full scale on any range during manual operation or greater than 1200 v in automatic operation. If the overload condition persists, the cycle is repeated. Automatic selection of the appropriate input voltage range may be made by the front-panel selector or by an external circuit closure.

AC voltage and resistance measurements

AC voltages up to 750 volts peak and resistance to 10 megohms can be measured with the hp 3460A (Option 02.), in conjunction with a DY-2410B-M22 AC/Ohms Converter (pages 148, 149).

Systems applications

The 3460A forms the heart of a series of standard DY-2013 Digital Data Acquisition Systems available from Dymec.

Recording outputs

A 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 3460A output information can be obtained with a 562A,AR Digital Recorder (page 76).

Tentative specifications

Voltage accuracy: ±0.005% of reading ±2 digits from +10°C to +40°C on all ranges (±0.01% of reading ±3 digits from 0°C to +10°C and +40°C to +50°C).

Ranges: full-scale presentation of ±1.00000, ±10.0000, ±100.000, and ±1000.00 (up to 20% overranging).

Reading rate

Remote control mode: maximum of 15 independent readings/sec on 10, 100, 1000 v ranges, including range selection; maximum of 7 independent readings/sec on 1 volt range including range selection; two switch closures to ground of 100 ohms or less, plus external triggering.

Local control mode: maximum of 3 independent readings/sec to a minimum of 1 independent reading/5 sec, including range selection; manual trigger provided.

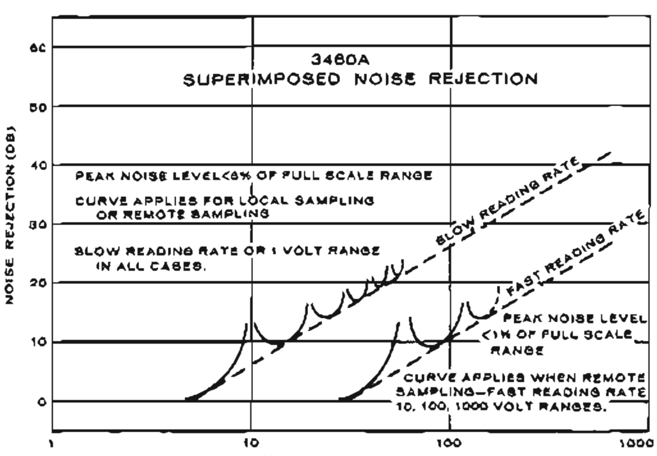
Input impedance: constant 10 megohms ±0.03% (to dc) all ranges.

Polarity selection: automatic

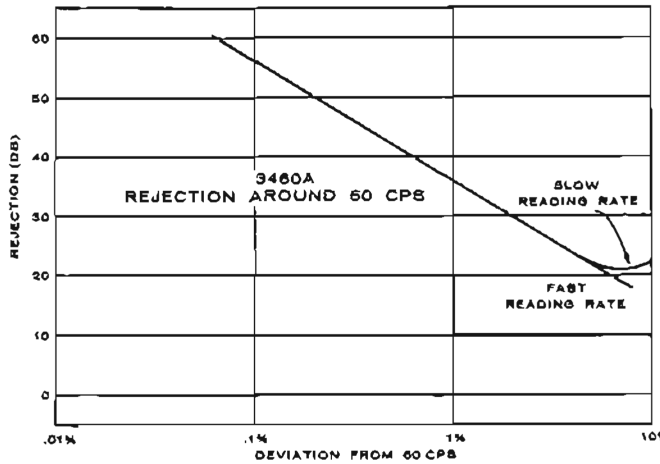
Range selection: automatic: pushbutton selector or a switch closure to ground with impedance <100 ohms provides autorange operation, 33 msec is required per range change (100 msec max.); remote: a switch closure to ground with impedance <100 ohms for a period >100 µsec selects range desired; manual: pushbutton selector.

Common mode rejection: common mode rejection (ratio of common mode signal to its effect on digital display) 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 up to 60 cps under the same conditions.

Superimposed noise rejection:



Superimposed Noise Rejection by Integration



Rejection around 60 cps

External read command:

Trigger	Open ckt voltage	Triggering level	Duration	Current
Positive-going, direct-coupled	—10 v	+10 to +30 v dc	100 µsec to 30 msec	2.5 ma at +10 v, 6 ma at +30 v
Negative-going, direct-coupled	+10 v	—10 to —30 v dc	100 µsec to 30 msec	2 ma at —10 v, 5 ma at —30 v
AC-coupled (either polarity)		20 v p-p with rise-time 10 µsec	100 µsec to 30 msec	6 K ohms load 25 pf

Trigger hold-off: hold-off level is +3 to +10 volts with a maximum current of 6.3 ma (provided by 562A Digital Recorder).

Print command: dc-coupled; print level, —1 volt with 2 K ohm source resistance; print hold-off level, —17 volts with 2 K ohm source resistance (minimum load resistance is 15 K ohms).

BCD outputs: 4-line BCD (1-2-4-8) 9 columns consisting of Polarity, Decimal Location and Overload and 6 digits of Data.

state	voltage	source resistance
0	—24	100 K
1	—1	100 K
Ref. levels	**voltage**	**source resistance**
Positive	—4 v	380 ohms
Negative	—21 v	900 ohms
4-line BCD (1-2-2-4) available (Option 01.)		

General

Inputs: floated and guarded signal pair (binding post on front panel or connector on rear panel is selected by front-panel switch); guard may be operated up to ±500 v above chassis ground (350 v rms); low may be operated up to ±50 v above guard (50 v rms).

Power: 115 or 230 volts ±10%, 50 to 60 cps, approx. 60 watts; 50 to 1000 cps available on special order.

Dimensions: 5" high, 16" wide, 21⅜" deep (127 x 406 x 543 mm); rack mount kit furnished with instrument.

Weight: net 38 lbs (16 kg); shipping 43 lbs (19,6 kg).

Accessory available: 11065A 6' rear input cable, guarding preserved, terminated end mates with 3460A, $10.

Accessory furnished: rack mounting kit includes 3 printed circuit extender boards.

Price: hp 3460A, $3600.

Options

01. 1-2-2-4 BCD output, no additional charge.
02. replacement printed circuit board and digital indicating tube for ac voltage and resistance measurements using Dymec DY-2410B-M22 AC/Ohms Converter; function symbol (digital indicating tube) indicates all modes of operation, add $250.

* 1-2-2-4 available with 3460A, Option 01.

DY-2401C INTEGRATING DIGITAL VOLTMETER

Precise measurements, even in the presence of severe noise

The DY-2401C Integrating Digital Voltmeter combines the precision and measurement flexibility of a laboratory instrument with the programming and electrical output features necessary for systems use.

Design features virtually eliminate measurement errors due to extraneous noise 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. Controls and input/output features of the DY-2401C permit maximum versatility of application in an instrument that is simple to use. Programming of the DY-2401C (for digital systems applications) requires only external circuit closures to ground and does not affect noise rejection properties.

The DY-2401C measures the average value of the applied voltage over one of three fixed crystal-controlled sample periods (0.01, 0.1 and 1 second), selected manually or remotely. Accuracy is 0.01% of reading +0.005% of full scale + 1 digit (at 25°C). Reversing counter circuits permit signals to be integrated around zero with full instrument accuracy. The 6-place display ensures that resolution will not limit a reading.

DC voltages are measured in five ranges from ±0.1 v to ±1000 v full scale. Range selection is manual, remote or (optionally) automatic. Overranging to 300% of full scale is permissible (all ranges except 1000 v) providing additional resolution and accuracy on the commonly used 1-to-3 readings. Overloads beyond this point switch the input attenuator to the 1000 v range. Overload is indicated in the front-panel display and recording output.

Operation of the optional auto-ranger is extremely fast—34 msec maximum range change time. The DY-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.

A precision internal standard with stability of ±0.006% per 6 months (independent of measurement circuit) is included for calibration. An additional mode of operation permits the DY-2401C to be used for direct frequency measurements up to 300,000 cps. Crystal-controlled gate times of 0.01, 0.1 or 1 second can be selected; alternatively, the gate can be opened and closed manually or remotely. An option extends the frequency range to 1.2 mc. For increased accuracy on low-frequency measurements optional period average measurements of 1, 10 or 100 periods of the signal frequency can be made. Measurements are displayed directly in milliseconds.

The DY-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 DY-2401C is guarded, all remote control lines and electrical outputs are referred to chassis ground and do not interfere with the guard. BCD voltages for use with output recorders are produced for each measured digit, for measurement function, voltage range and polarity.

Millivolt measurements

A full-scale range of ±10 mv, with overranging to ±30 mv, is obtained by adding a DY-2411A Guarded Data Amplifier to the DY-2401C. This amplifier provides an input impedance of 10,000 megohms, and features a guarded input/output which preserves the voltmeter common mode rejection characteristics. The 30 mv input range and high noise rejection provided by the DY-2411A/2401C combination is particularly useful in strain gage and thermocouple measurements, where resolution to better than 1 µv is desirable.

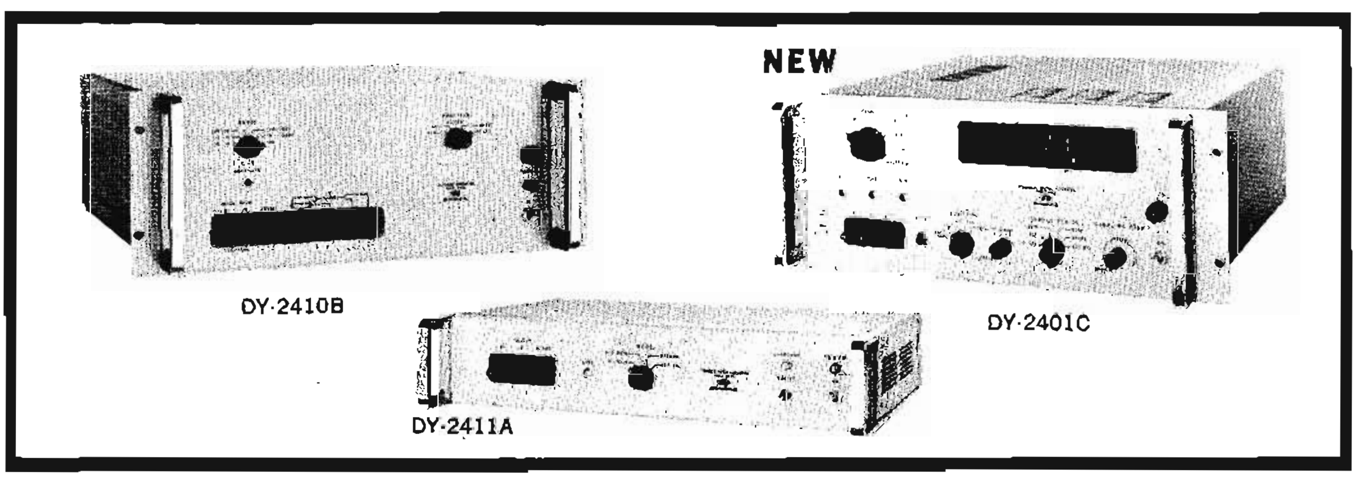
The DY-2401C accepts logic cards (furnished with the DY-2411A), which assures proper decimal point indication when the amplifier gain of 10 is used. The DY-2401C auto-ranger also selects the appropriate amplifier gain when the two instruments are used together, providing six automatically selected ranges, 10 mv to 1000 v full scale.

AC voltage and resistance measurements

AC voltages to 750 v peak, and resistances to 10 megohms can be measured with the DY-2401C by adding a DY-2410B AC/Ohms Converter. This instrument features a guarded measurement circuit similar to that of the 2401, and is suitable for programmed systems applications. The DY-2401C auto-ranger will select appropriate range for ac and ohms operation. Appropriate measurement units are indicated in the display window of the voltmeter when it is used with the converter.

System applications

The DY-2401C forms the heart of a series of standard digital data acquisition systems (DY-2010) available from Dymec. These systems feature a choice of input scanners, signal conditioners, auxiliary devices and output couplers for recording on a variety of output media. (See pages 82-85 for descriptions of this equipment.)



Specifications, DY-2401C

DC voltage measurements

Noise rejection: overall effective common mode rejection: 140 db at all frequencies, 160 db at dc (0.1 sec sample period); common mode rejection: 120 db at 60 cps, 160 db at dc, with 1000 ohms between low side of source and low side of input (resistances up to 10 K); superimposed noise rejection: more than 20 db at 55 cps for 0.1 sec 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 v 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 M on 1, 100, 1000 v ranges, 1 M on 1 v range, 100 K on 0.1 v range, <150 pf all ranges.

Accuracy: 0.01% of reading ±0.005% f.s. ±1 digit at 25°C; temperature coefficient 0.001% of reading per °C (calibrated at temperature) 0.0015% of reading, 10 to 50°C.

Internal calibration source: ±1 volt standard for self-calibration; stability ±0.006% per 6 months at 25°C, temperature coefficient ±0.001% per °C; reference derived from specially selected temperature-stabilized zener diode.

Measurement speed: fixed sample periods of 0.01, 0.1 or 1 sec 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); also selects appropriate gain setting (X1 or X10) when DY-2401C is used with DY-2411A Amplifier; range change points: up-ranges at 310% f.s., down-ranges at 30% f.s.; range select time: 6 msec (nominal) for each range change, max. time from receipt of read command to start of sample period, 34 msec.

DC voltage integration: Input signal is integrated over selected sample period; using fixed sample period, integral is average of input, readout in volts; sample period may be started/stopped manually or remotely, display reads in mv-sec or v-sec.

Frequency measurements

Range: 5 cps to 300 kc, optionally to 1.2 mc; gate time 0.01, 0.1, 1 sec or manual; accuracy: ±1 count ± time base accuracy; time base: stability at constant temperature (±°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 or will accept neg. pulses; impedance: 1 M shunted by 100 pf.

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.

Frequency output: internal 100 kc frequency standard available.

External programming: may be completely programmed by external 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 cps, 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 70 lbs (33.5 kg).

Price: Dymec DY-2401C, $3950.

Specifications, DY-2410B

(used with DY-2401C)

AC voltage measurements

Common mode noise rejection: 110 db at 60 cps, with 1000 ohms between low side of source and low side of input.

Input circuit: frequency range: 50 cps to 100 kc; voltage ranges: 5 from 0.1 v to 1000 v rms f.s., 1000 v range usable to 750 v peak; overranging: to 300% f.s. on all ranges except 1000 v; input impedance: 1 M shunted by 100 pf.

Output circuit: output voltage: 1 v dc f.s. into 1 M load impedance, for all input ranges; output resistance 60 K; response: for frequencies below 400 cps output settles to within 0.2% of final value in 500 msec, frequencies above 400 cps output settles to within 0.2% in 200 msec.

Accuracy (for +10 to 50°C; ±10% line voltage change, and includes 30-day stability): 50 cps to 10 kc, ±0.05% of f.s. ±0.2% of reading; 10 kc to 30 kc, ±0.05% of f.s. ±0.4% of reading; 30 kc to 100 kc, ±0.1% of f.s. ±0.6% of reading.

Resistance measurements

Noise rejection: resistance measurement circuit enclosed in same guard as ac converter; ac common mode pickup on resistance measurements eliminated by connecting guard to grounded end of test resistance; double-shielded cable allows extension of guard to test resistance.

Input circuit: type: guarded, modified 4-terminal circuit; ranges: 0.1 K, 1 K, 10 K, 100 K, 1 M, 10 M f.s.; overranging: to 300% of f.s. on all ranges except 10 M.

Output circuit: output: 1 v dc full scale into 1 M load impedance for all ranges; output resistance less than 10 ohms on all ranges except 10 M, where it is 100 K; response: output settles to 99.99% of final value in 100 msec (for 100 ft. of Dymec resistance measurement cable).

Accuracy (for ±10% line voltage change, and includes 30-day calibration stability): constant temp. (25°C): ±0.015% of f.s. ±0.025% of reading; change per °C: ±0.001% of f.s. ±0.004% of reading.

General

External programming: measurement mode (Ohms, DC, AC Normal, AC Fast) and range selected by external circuit closures to ground; commands for DY-2401C applied to 2410B.

Programming outputs: contact closures representing measurement mode and range supplied by DY-2410B used to program the DY-2401C.

Operating conditions: specifications apply for operating temperature to +50°C; relative humidity to 95% at 40°C.

Power: 115 or 230 v ±10%, 60 cps, 110 w (50 cps optional).

Dimensions: 19″ wide, 7″ high, 17¼″ deep behind panel (483 x 177 x 438 mm).

Weight: net 43 lbs (19.4 kg); shipping 60 lbs (27 kg).

Price: Dymec DY-2410B, $2250; ac only, $1850; ohms only $1650.

Specifications, DY-2411A

(used with DY-2401C)

Noise rejection: reduces common mode rejection of DY-2401C by <6 db.

Gain settings: +1 and +10 (non-inverting); bypass mode permits use to 1000 v; gain accuracy (into 100 K or 1 M): +1, ±0.002%; +10, ±0.007%; temp. coeff. <0.0005% of reading per °C; linearity: ±0.0005% of full scale.

Zero drift: <1 µv per week, <0.5 µv per °C.

Noise: ±2 µv for 2401C 1 sec sample, ±5 µv for 0.1 sec sample.

Input circuit: input resistance: 10^{10} ohms, for relative humidity to 95% at 40°C; input capacitance: 180 pf nominal; full-scale input: ±10.5 v for +1 gain, ±1.05 v for +10 gain ±1000 v in bypass mode; amplifier automatically switches to bypass when input exceeds these values.

Output circuit: output resistance: <1.5 ohms; min. load impedance: 10 K; max. output: ±10.5 v.

Absolute accuracy: (10 mv range, 1 sec. gate) 0.015% of reading ±0.03% f.s. at 25°C; temp. coefficient 0.0015% of reading per °C (calibrated at temperature) 0.002% of reading, 10 to 50°C.

Settling error: <1 count (0.001% of f.s.on 1 sec. gate)with simultaneous application of signal and encode command.

Programming: range: selected by external contact closures to ground, selections take <6 msec; programming output: commands from system scanner routed to voltmeter; generates contact-closures to ground when switched to +10 for correct decimal indication on DY-2401C.

Operating conditions: 10 to 50°C ambient temperature range; up to 95% relative humidity at 40°C.

Power: 115 to 230 v ±10%, 50 to 1000 cps, 16 w.

Dimensions: 16¾″ wide, 3½″ high, 11⅛″ deep behind panel (425 x 88 x 286 mm); hardware furnished to convert to 19″ wide rack mount.

Weight: net 17 lbs (7.7 kg); shipping 26 lbs (11.7 kg).

Price: Dymec DY-2411A, $1150.

3440A DIGITAL VOLTMETER

Interchangeable plug-ins increase versatility

The hp 3440A Digital Voltmeter is a compact, accurate, rapid and multiple-function digital voltmeter. The choice of automatic ranging, remote and manual operation is obtained by using the 3441A, 3442A, 3443A, 3444A or 3445A plug-ins, which are interchangeable with any 3440A. The basic voltmeter is solid-state with easy-to-service plug-in circuit cards mounted in the Hewlett-Packard modular enclosure.

Figure 1 illustrates the features obtained by using the 3441A, 3442A, 3443A, 3444A or 3445A plug-ins with any 3440A.

Plug-in function					
Plug in	3441A	3442A	3443A	3444A	3445A
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	✓	✓	✓	✓	✓
Printer output	✓	✓	✓	✓	✓
Remote ranging		✓	✓		✓
Remote triggering	✓	✓	✓	✓	✓

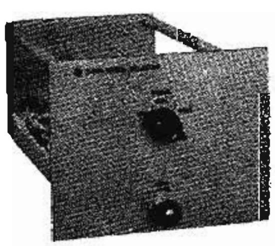
*True rms measurements: 1 mv to 300 v (10 cps to 10 mc), using hp 3400A

Figure 1.

Accuracy and speed

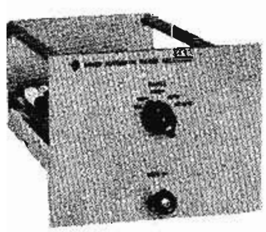
The 3440A Digital Voltmeter has a dc accuracy of better than ±0.05% of reading ±1 digit over the ambient temperature of +15°C to +40°C with a line voltage variation of ±10%. In addition, specified accuracy is retained to 5% beyond full scale, a feature that permits 5-digit resolution at the decade range change points. The ac input filter has a rejection of 30 db at 60 cps, and the response time to a step change is 450 msec to read 99.95% of final value without a range change. The input signal pair may be floated at up to 500 volts 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.

Use of the 3440A with the hp 3445A AC/DC Range Unit permits ac and dc measurement capabilities in one plug-in. The ac conversion circuits of the 3445A produces a dc output voltage proportional to the average value of the applied ac voltage and is calibrated in rms. Three full-scale ranges: 10 v, 100 v and 1 kv are displayed to an accuracy of ±0.1% of reading ±2 digits from 50 cps to 20 kc; ±0.1% of full scale ±2 digits from 20 kc to 50 kc; ±0.1% of full scale ±2 digits to ±0.3% of full scale ±2 digits from 50 kc to 100 kc. Resolution is 1 mv on the 10 volt ac range.

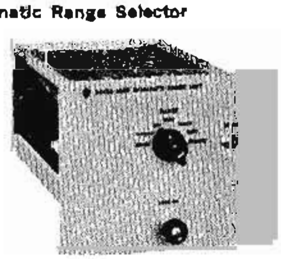


3441A Range Selector

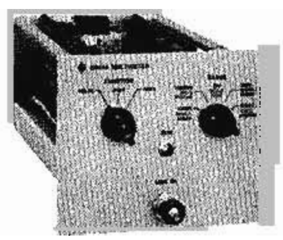
3440A/3445A AC/DC Range Unit



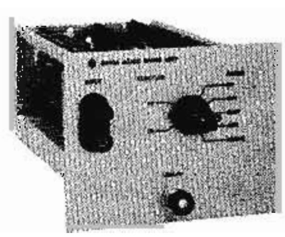
3442A Automatic Range Selector



3443A High Gain/Auto Range Unit



3444A DC Multi-Function Unit



3445A AC/DC Range Unit

AC voltage measurement, average

Average-responding, rms calibrated, measurements from 50 cps to 500 kc can be obtained by use of the hp 457A AC-to-DC-Converter with the 3440A (page 153).

The operator can instantly verify the accuracy of his 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 volt ranges with 0.03% linearity full scale for the 100 mv and 1000 mv range. The stability of readings is approximately ±1 count.

Specifications, 3440A

Available plug-in units (3440A requires a plug-in to operate): 3441A Range Selector; 3442A Automatic Range Selector; 3443A High Gain/Auto Range; 3444A DC Multi-Function Unit; 3445 AC/DC Range Unit.

Sample rate: 5 samples per sec to 1 per 5 sec with storage during samples and "Hold"; in "Hold", a sample may be initiated by applying a +10-v pulse 20 μsec wide or greater (ac-coupled), or by contact closure.

DC Isolation: signal common may be floated up to 500 v dc from chassis ground.

Polarity: automatic indication.

BCD output

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) available on special order.

Impedance: 120 K maximum, each line; "0" state level, −24 volts; "1" state level, −1 volt.

Reference levels: positive: approx. −2.5 volts, 330 ohms source impedance; negative: approx. −27 volts, 920 ohms source impedance.

Print command: generated internally, hold-off level, −12 v dc; print level, −2 v dc from 100-ohm source.

Hold-off requirements: anywhere from +6 volts to +15 volts max. from source impedance less than 2000 ohms (provided by 562A Digital Recorder, page 76).

Power: 115 or 230 v ±10%, 50 to 1000 cps, approx. 20 w, depending upon plug-in.

Weight: net 18 lbs (8 kg); shipping 29 lbs (13 kg).

Accessories available:

KOI-3440A Plug-in Extender, $45.

J74-562A,AR: digital recorder for use with 3440A accepting 1-2-2-4 BCD code (floating operation); includes special print wheel, 6 BCD column boards, input connector assembly with cable; cabinet, $1693; rack, $1668.

Data	Function	Logic 1-2-2-4	Logic 1-2-4-8	Std.	562A Print wheel J75-562A J77-562A	562A Print wheel 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	*	**

J75-562A,AR: same as J74-562A,AR, except for single character function symbol; cabinet, $1673; rack, $1648.

J76-562A,AR: digital recorder for use with 3440A accepting 1-2-4-8 BCD code (floating operation); includes special print wheel, 6 BCD column boards, input connector assembly with cable; cabinet, $1693; rack, $1668.

J77-562A,AR: same as J76-562A,AR except for single-character function symbol; cabinet, $1673; rack, $1648.

Price: hp 3440A Digital Voltmeter (requires a plug-in), $1160.

The hp 3441A Range Selector is a plug-in unit with a range switch to select manually one of three voltage ranges, 9.999, 99.99 or 999.9 volts.

The hp 3442A Automatic Range Selector retains the manual range selection of the 3440A/3441A combination and adds automatic and remote range features. Ten per cent hysteresis is built into the automatic ranging function of the 3442A. The hysteresis prevents continual changing of ranges because of small voltage variations when measuring voltages that are close to the decade range change points. The voltmeter up-ranges at the decade point but does not down-range unless the voltage falls below 90% of the next lower range. When a need for range change is sensed, the voltmeter sample rate is automatically increased if the sample is not already at its maximum rate. During this brief period, the correct range is selected and the printout is inhibited until the voltage at the input filter reaches its final value.

The hp 3443A High Gain/Auto Range Unit features automatic or remote range selection from 100 mv to 1000 v full scale. A front-panel zero offset control enables the operator to obtain a zero indication at the dvm to compensate for the thermocouple voltages of external connections. The 3443A has the same ranging capabilities as the 3442A with the additional features of two additional ranges and 10 μv resolution, making it ideal for thermocouple and transducer measurements. For current measurement, where it is not practical to break the circuit, a 428B Clip-on Milliammeter (page 138) may be used and the output measured on the 3440A with a 3443A High Gain/Auto Range Unit.

The hp 3444A DC Multi-Function Unit offers voltage, current and resistance measurement capabilities in one plug-in module. This plug-in is a manual-ranging dc voltmeter, dc ammeter and ohmmeter. Full-scale ranges of 100 mv to 1000 volts 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 nanoamps. Five resistance ranges of 1000 ohms to 10 megohms are provided. Permanent test records on all functions including polarity, decimal, function and overload are available with accessory hp Model J74-562A Printer for a 1-2-2-4 code. (Model J76-562A provides the same readout on a 1-2-4-8 code, page 76.) Analog record is available when used with the hp 580A Digital-to-Analog Converter (page 79) and Moseley 680 Strip Chart Recorder (pages 360, 361).

The hp Model 3445A AC/DC Range Unit offers ac and dc measurement capabilities in one plug-in. The ac conversion circuits of the 3445A produces a dc output voltage proportional to the average value of the applied ac voltage and is calibrated in rms. This solid-state converter/range unit has three full-scale ranges—ac or dc, from 10 to 1000 volts. Both ac and dc voltages may be measured with the 3440A/3445A by direct connection to the 3445A plug-in.

Specifications, 3440A Plug-ins

Full scale ranges (with 5% overrange capability)	Accuracy	Range selection	Input impedance	Input filter characteristics (to a step function to within 99.95% of final value without a range change)	Input filter ac rejection	Weight
dc voltage: 4 digit presentation of 9.999, 99.99 and 999.9 volts	dc volts: ±0.05% of reading ±1 digit with line voltage variations of ±10% from nominal; front-panel adjustment on the 3440A insures accuracy 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	manual	constant 10.2 megohms — all ranges	response time: less than 450 msec	30 db at 60 cps, increasing 12 db/octave on all ranges	net 1 lb (0,45 kg); ping 3 lbs (1,5 kg
dc voltage: 4 digit presentation of 9.999, 99.99 and 999.9 volts	dc volts: ±0.05% of reading ±1 digit with line voltage variations of ±10% from nominal; front-panel adjustment on the 3440A insures accuracy 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	manual automatic and remote; rate change speed: automatic, (max.) achieves accurate reading in <1 sec after new voltage is applied; remote (max.) will change range within 40 msec	constant 10.2 megohms — all ranges	response time: less than 450 msec	30 db at 60 cps, increasing 12 db/octave on all ranges	net 1.5 lbs (0,7 shipping 3.5 lbs (1,
4 digit presentation of 99.99 mv, 999.9 mv, 9.999 v, 99.99 v and 999.9 v	dc volts (9.999 v to 999.9 v) same as 3441A; dc volts (99.99 mv and 999.9 mv): ±0.1% of reading ±1 digit with line voltage variations of ±10% from nominal, front-panel adjustment insures accuracy 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	manual automatic and remote; rate change speed: automatic, (max.) achieves accurate reading in <1.5 sec after new voltage is applied; remote (max.) will change range within 40 msec	constant 10.2 megohms — all ranges	10, 100, 1000 v dc ranges: response time <450 msec; 100, 1000 mv ranges: less than one sec	10, 100, 1000 volt ranges: 30 db at 60 cps, increasing 12 db/octave; 100, 1000 mv ranges: max. of 40 mv and 400 mv p-p respectively at 60 cps for <0.1% of full-scale error, increasing 6 db/octave	net 3 lbs (1,3 kg); ping 6.5 lbs (2,9
dc voltage: same as 3443A; dc current: 4-digit presentation of 99.99 μa, 999.9 μa, 9.999 ma, 99.99 ma and 999.9 ma; resistance: 4-digit presentation of 999.9 ohms, 9.999 K, 99.99 K, 999.9 K, 9.999 megohms	dc voltage: same as 3443A; dc current: ±0.2% of reading ±1 digit with line voltage variations of ±10% from nominal; resistance: (999.9 ohms to 999.9 K) ±0.3% of reading ±1 digit; resistance: (9.999 megohm) ±1% of reading ±1 digit	manual	constant 10.2 megohms all dc voltage ranges; ammeter: 0.4 ohm to 1 K, depending on range; ohmmeter max. current 0.1 μa-1 ma	dc voltage: same as 3443A; current: <1 sec for a full-scale step function on all ranges; resistance: (1 K to 1 megohm) <1 sec (10 megohms) <5 sec	voltage: same as 3443A; current: p-p ripple current may be up to 40% of full-scale range at 60 cps for <0.1% of full-scale error; increasing 6 db/octave	net 3 lbs (1,4 kg); ping 6.5 lbs (2,9
ac and dc voltage; 4-digit presentation of 9.999, 99.99 and 999.9 volts full scale; ac voltage calibrated in rms volts	dc voltage same as 3442A; ac voltage from +20°C to +30°C with line voltage variations of ±10% from nominal (±2 digits) ±0.1% of reading from 50 cps to 20 kc; ±0.1% of f.s. from 20 kc to 50 kc; ±0.5% 50 kc; 50 kc to 100 kc derates linearly from ±0.1% of full scale at 50 kc to ±0.3% of full scale at 100 kc; ±0.005%/°C TC applies from 0°C to +20°C (use +20°C as zero TC reference point) and from +30°C to +50°C (use +30°C as zero TC reference point)	dc same as 3442A, except achieves accurate reading within 3 sec after new voltage is applied; ac: manual, automatic and remote; range change speed: automatic; (max.) achieves proper range within 2 sec following a sample; remote, (max.) will change range within 40 msec; response speed: achieves accurate reading within 3 sec when on proper range; allow extra sec for amplifier recovery when over-loaded	dc: same as 3442A; ac 10 megohms shunted by 20 pf nominal on all ranges	dc: same as 3442A; ac: not applicable	dc: same as 3442A; ac: not applicable	net 2.8 lbs (1,2 shipping 5.2 lbs (2,

405BR,CR DIGITAL VOLTMETERS; 457A AC-DC CONVERTER

Touch-and-read dc voltmeters; converter for ac to 500 kc

Remarkable simplicity of use is an outstanding feature of the hp 405BR,CR Digital Voltmeters. Just touch the probe to the voltage to be measured, and the 405BR,CR automatically zero-sets itself and chooses the proper range and polarity.

Three-digit resolution on all voltages between 1 and 1000 volts allows the observation of very small changes, and accuracy is held to ±0.2% of the reading on all ranges ±1 count. For maximum usability in various environments, the input is isolated from ground (allowing voltage difference measurements), dc input impedance is 11 megohms on all ranges, and ac rejection reaches the 3 db point at 1.5 cps.

For systems applications, the hp 405CR is offered. This instrument is similar to 405BR but has provision for an external sampling command and recording outputs both in ten-line decimal code and one-line staircase code, as well as a print command for operating hp 560A and 561B Digital Recorders (page 77).

Specifications, 405BR,CR

Range: 0.001 to 999 volts, dc.

Presentation: 3 illuminated figures, with decimal and polarity sign.

Accuracy: within ±0.2% of reading ±1 count.

Floating Input: permits measurement of systems operating within ±500 volts dc of power line ground.

Range, polarity selection: automatic; hold control disables automatic range selection and permits manual range choice.

Ranging time: 0.2 sec to 2 sec, depending on range change required.

Input impedance: 11 megohms to dc on all ranges.

Sample rate: internal: max. between 4 and 5 per sec, min. one every 5 sec; external (405CR only): controlled by 20 v positive pulse, max. rate five per sec.

Input filter response time: < 1 sec to step function.

Input filter ac rejection: 3 db at 1.5 cps, nominally 44 db at 60 cps.

Output (405CR only)

(1) 10-line decimal code for operating 561B Digital Recorder or K05-405A remote indicator.

(2) Single-line voltage coded decimal (staircase), for operating 560A Digital Recorder, with use of the 405A-95C adapter.

(3) A print command for hp digital recorders is issued after every sample, except when the 405CR is ranging.

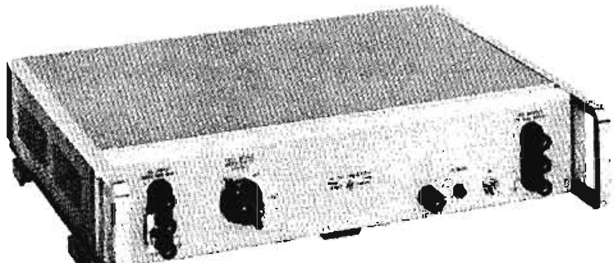
Power: 115 or 230 volts ±10%, 50 to 60 cps, 180 watts.

Dimensions: 7" high, 19" wide, 13⅞" deep behind panel (178 x 483 x 327 mm).

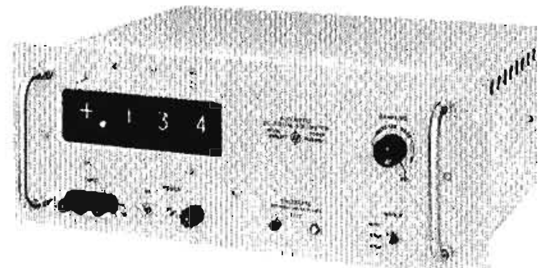
Weight: net 31 lbs (13,9 kg); shipping 46 lbs (20,7 kg).

Accessories available: 457A AC-to-DC Converter.

Price: hp 405BR, $890; hp 405CR, $960.



457A



405CR

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 cps to 500 kc is covered with conversion accuracy of ±0.75% of full scale ±1 mv. Even greater accuracy is obtained for signals under 50 kc. When hp 457A is used with 405BR,CR Digital Voltmeters, ac voltage measurements can be made with three-digit resolution and overall accuracy of 1% ±2 counts from 50 kc to 500 kc. From 50 cps to 50 kc accuracy is 0.5% ±2 counts.

When the 3440A Digital Voltmeter and one of its associated plug-ins (pages 150-152) are used with the 457A, ac voltage measurements can be made with 4-digit resolution and overall accuracy of ±0.8% ±2 counts from 50 kc to 500 kc. From 50 cps to 50 kc accuracy is ±0.35% ±2 counts.

Specifications, 457A

Input range: 100 μv 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 cps to 500 kc.

Accuracy: ±0.3% 1 mv from 50 cps to 50 kc; ±0.75% ±1 mv from 50 kc to 500 kc.

Floating Input: permits measurement of ac voltages at dc potentials of ±500 v above power line ground.

Output: 0 to 1 v dc, 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 1000 cps, approx. 31 w.

Dimensions: 16¾" wide, 3¼" 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, $17.50; 11000A Cable, $4.50; 11001A Cable, $5.50.

Price: hp 457A, $450.

740A DC STANDARD, DIFFERENTIAL VOLTMETER

Never before so much instrument to perform so many tasks so well at so great a value

DC standard	Differential voltmeter	High-impedance electronic voltmeter	Amplifier
*±0.01% accuracy; floating and guarded output; 1, 10, 100, 1000 v ranges, 1 ppm resolution at full scale	*±0.01% absolute accuracy ±1 μv; floating and guarded input, 1μv to 1000 v null ranges; 2 ppm resolution at full scale	2% accuracy end scale; floating and guarded input; 1 μv to 1000 v end scale	accuracy: ±0.01%; 50 ma output (25 watts max.) up to 60 db of voltage gain (gain depends on range)
stability greater than 0.001%/day, 0.0015%/mo; regulation better than ±0.001% ±25 μv line or load	stability better than 0.001%/day, 0.0015%/mo.		stability: 0.001%
50 ma output (25 watts max.), continuously adjustable current limiter from 5 to 50 ma (nominal)	high input impedance: >10⁹ ohms resistance on most ranges; independent of null condition on all ranges	high input impedance: >10⁹ on most ranges	recorder amplifier: recorder output voltage directly proportional to meter deflection (120 db max. gain depends on range); 1 v nominal into 1 K load
temperature coefficient <2 ppm/°C	temperature coefficient <2 ppm/°C		
6-digit resolution; readout with 4 in-line display tubes, plus individually calibrated taut-band meter	6-digit resolution readout with 4 in-line display tubes, plus individually calibrated taut-band meter	individually calibrated taut-band meter	
all solid-state circuitry, rugged and reliable	isolated recorder output	isolated recorder output	

* 0.005% accuracy available on special order

The 740A DC Standard, Differential Voltmeter is a precision ±0.01% dc standard that provides a standard source, a differential voltmeter, a high-impedance electronic voltmeter, a voltage amplifier and a power amplifier for a wide variety of measurements. Stability is greater than 0.001% per day or 0.0015% per month. Repeatability is better than 0.001%. Continually adjustable dc voltages with 6-digit resolution simplify the calibration of digital voltmeters. The guarded 0 to 1000 volt dc Δvm offers extremely high input impedance off null, which makes the 740A ideal for drift measurements where null conditions cannot be maintained. The user need only select the desired degree of sensitivity, thereby eliminating the necessity for nulling all ranges. In addition, extra features such as in-line digital readout, plus taut-band meter, pushbutton range selection, overload indicator and recorder output terminals make the instrument easy to use.

Used as a dc standard — The hp 740A DC Standard is designed to deliver accurate dc voltages from 0 to 1000 volts at currents up to 50 ma (25 watts maximum). A front-panel current-limit control continuously adjusts maximum output current between 5 and 50 ma to protect test circuits from damage. A 6-terminal cable is provided for output sensing, guard and ground terminals. This floating output allows either positive or negative ground (−500 volts max.) with remote sensing. The 740A DC Standard output voltage is accurate to 0.01% of the indicated setting and stable to within 0.001% per day or 0.0015% per month. The output is completely isolated from chassis and power grounds. Voltage setting is indicated by 4 digital display tubes, providing the first four digits, with the remainder of the reading indicated on the front-panel meter. The decimal point is automatically located. Output voltage resolution is better than 1 ppm at full scale on any range, directly readable on the front panel.

Used as a differential voltmeter — As a differential voltmeter, the hp 740A measures dc voltages from 0 to 1000 volts in seven ranges with an accuracy of 0.01% ±1 μv. Input impedance is greater than 10^9 ohms on most ranges, independent of null, as opposed to conventional differential techniques, where the input impedance is low and varies except at null. The high input impedance off null makes the 740A ideal for drift measurements where null conditions cannot be maintained. Accuracy is maintained independent of null conditions.

Used as an amplifier — As a ±0.01% amplifier up to 60 db voltage gain is available. Stability is better than 0.001%/day and output up to 50 ma (25 watts max.) is available at the output terminals. Up to 120 db gain is available at the recorder terminals (voltage output directly proportional to meter deflection). Maximum output is 1 volt nominal into 1 K load.

Used as a high-impedance voltmeter — The Model 740A is also a ±2% floating and guarded voltmeter with ranges from 1 μv to 1000 volts. Input impedance is $>10^9$ ohms on the 0.1 volt to 1000 volt range, $>10^8$ ohms on the 10 mv range and $>10^7$ ohms on the 1 μv to 1 mv ranges.

Circuit guard system

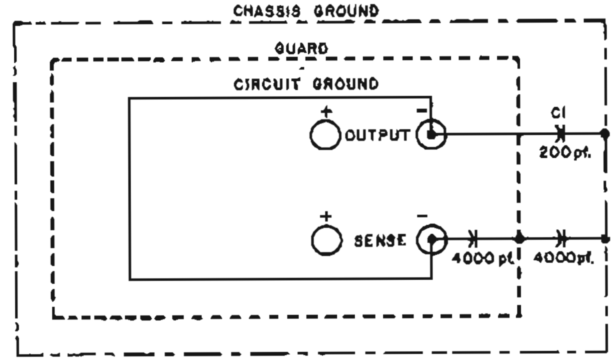
The 740A features a shield or guard which isolates the floating output and measuring circuits from the chassis. Induced ac ground currents, usually at the power line frequency, can generate a potential of several volts between the signal source ground and the chassis ground. Unless shunted, these currents will cause a voltage to appear at the input or output which can be larger than the signal itself, resulting in an erroneous reading or output voltage. This effect is known as common mode ac insertion.

With the 740A guard operated at the ground potential of the signal source, the common mode rejection (defined as the ratio between the common mode signal and the spurious voltage it causes to be superimposed on the output signal or signal to be measured) exceeds 120 db at 60 cps. The figure below illustrates the 740A guard system and the capacitance between the output and measuring circuits to chassis, insuring high ac common mode rejection.

The guard system also is useful in reducing dc leakage currents when making measurements above ground such as intercomparison of resistors in a precision resistive divider. The guard system of the 740A may be operated as much as ±500 v dc with respect to ground.

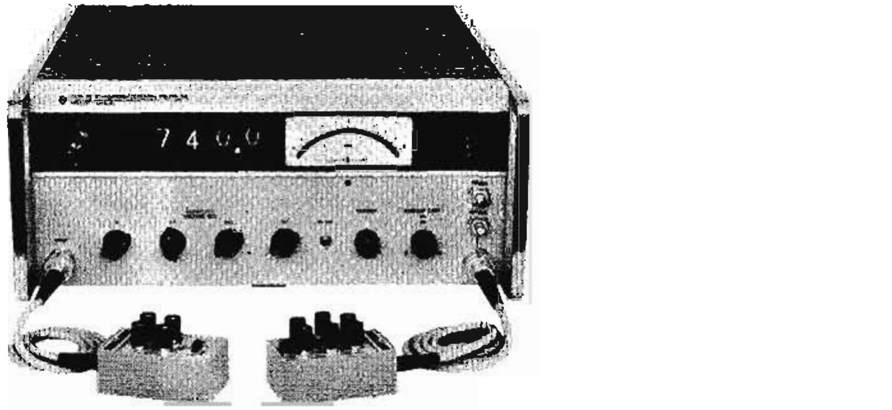
Rapid calibration

The only external equipment required for a complete field calibration of the 740A is a standard cell. An internal bridging arrange-



CI EFFECTIVE GUARDED CAPACITY: LESS THAN 200 pf.

NEW



ment is used to ratio match the binary-coded decade resistive dividers* and critical range resistors. In a matter of a few minutes a complete field calibration is accomplished.

The reference supply consists of a zener diode with associated control circuitry in a constant temperature proportionally controlled oven. The reference supply can be compared with a standard cell and measured differentially with the 740A.

The overload indicator on the front panel indicates when the 740A is overloaded or in current limit. When the overload indicator is not lighted, the operator is assured that the instrument is within its specified accuracy.

Specifications

DC standard

Ranges: 0 to 1 v, 0 to 10 v, 0 to 100 v, 0 to 1000 v; continuously adjustable on all ranges (6-digit resolution).

Accuracy: ±0.01% of indicated setting or ±0.001% of full scale.

Temperature coefficient: < 2 ppm/°C from +10°C to +40°C.

Resolution: 1 ppm at full scale.

Stability: better than 0.001% per day; 0.0015% per month.

Output current: 5 to 50 ma nominal (25 w max.); output current limiter continuously variable from 5 to 50 ma nominal.

Line regulation: <±0.001% change for ±10% line voltage change.

Remote sensing: permits output regulation at the point of application.

Load regulation: <±0.001%, ±25 μv, no load to full load.

Operating temperature: 0°C to +50°C.

Noise and hum: dc to 1 cps, −120 db below full scale; 1 cps to 10 kc, −100 db below full scale or 150 μv; >10 kc, −100 db below full scale or 200 μv or whichever is greater.

Output: floating and guarded.

Readout: 4-digit in-line tubes, individually calibrated taut-band meter.

Output terminals: 6 banana jacks mounted on a terminal box with 3' cable (accessory 11055A), 1 furnished with instrument, having positive and negative output terminals, positive and negative remote sense terminals, circuit guard shield and chassis ground; a max. of 500 v dc may be connected between chassis ground guard or circuit ground.

Differential voltmeter

Input voltage ranges: 1 mv to 1000 v full scale, with null ranges full scale, 1 μv to 1000 v.

Accuracy: ±0.01% of reading or ±0.001% of full scale from 0 to 1000 v dc, ±1 μv.

Temperature coefficient: <2 ppm/°C from +10°C to +40°C.

Voltage resolution: 0.0002% of full scale.

Repeatability: better than 0.001% on all ranges.

Stability: better than 0.001%/day; 0.0015%/month.

Line regulation: <±0.001% change for ±10% line voltage change.

Operating temperature: 0°C to +50°C.

Input impedance: $>10^9$ ohms above 10 mv; $>10^8$ ohms, 1 mv to 10 mv; $>10^7$ ohms, 1 μv to 1 mv, independent of null; slide switch on input terminal box shunts input with 2 megohms.

Input: floating and guarded.

AC common mode rejection: >120 db at 60 cps.

Superimposed ac noise-rejection: <0.005% change for 100% superimposed ac noise above 100 cps on dc signal (25 v ac max.); <0.005% change for 25% superimposed ac noise above 50 cps on dc signal (25 v ac max.).

Input terminals: four banana jacks mounted on a terminal box with 3 ft cable (accessory 110054A), one furnished with instrument, having positive and negative input terminals, circuit guard shield and chassis ground; a maximum of 500 v may be connected between chassis ground and guard or circuit ground.

Readout: 4-digit in-line tubes, plus individually calibrated taut-band meter.

High-impedance voltmeter

Accuracy: ±2% end scale.

Input voltage ranges: 1 μv full scale to 1000 v dc full scale.

Input impedance: $>10^9$ ohms above 10 mv; $>10^8$ ohms, 1 mv to 10 mv; $>10^7$ ohms, 1 μv to 1 mv.

Operating temperature: 0°C to +50°C.

Amplifier

Accuracy: ±0.01%.

Output: 50 ma nominal (25 watts max.).

Voltage gain: 60 db at 1 mv max. input; 40 db at 10 mv max. input; 20 db at 100 mv max. input; unity above 100 mv.

Stability: better than 0.001%/day after warm-up.

Bandwidth: dc to 0.1 cps.

AC common mode rejection: same as Δvm.

Load regulation: same as dc standard.

Line regulation: same as dc standard.

Superimposed ac noise rejection: same as Δvm.

Input impedance: same as Δvm.

Noise: dc to 1 cps: <0.1 μv referred to the input at 60 db; <0.2 μv referred to the input at 40 db; <2 μv referred to the input at 20 db; at unity gain (1 v range and above) same as dc standard; greater than 1 cps: same as dc standard 1 v range and above (constant 1 v range and below).

Recorder amplifier: recorder output voltage directly proportional to meter deflection, 120 db gain (max.), depends on range; 1 v nominal with 1 K load.

General

Power: 115 or 230 v ±10%, 50 to 1000 cps, 125 w max.

Dimensions: 7" high, 16¾" wide, 18¾" long (178 x 425 x 527 mm); rack mount kit (5060-0776) furnished with instrument.

Weight: net 47¼ lbs (19 kg); shipping, 60 lbs (27 kg).

Accessories furnished: 11055A, output terminal box with cable; 11054A, input terminal box with cable.

Price: hp 740A, $2350. (hp 740A with accuracy of 0.005% available on special order at additional cost.)

* Patent applied for

741A AC-DC DIFFERENTIAL VOLTMETER, DC STANDARD

Never before so much instrument to perform so many tasks so well at so great a value

Advantages:

- AC differential voltmeter
- DC differential voltmeter
- DC standard
- AC/high-impedance voltmeter
- DC/high-impedance voltmeter
- Power amplifier, voltage amplifier
- 6-digit resolution
- Recorder output
- Floating input and output
- Overload indicator
- Solid state
- Rugged and reliable

The hp Model 741A AC-DC Differential Voltmeter/DC Standard is a precision ±0.02% dc standard that provides a dc standard source, an ac and dc differential voltmeter, a high-impedance ac and dc electronic voltmeter and a dc voltage and power amplifier. Used as a dc standard, the 741A provides adjustable dc voltages with 6-digit resolution which simplifies the calibration of digital voltmeters.

The 0 to 1000 volt dc differential voltmeter offers a high input impedance independent of null, which makes the 741A ideal for drift measurements when null conditions cannot be maintained. The 0 to 1000 volt ac differential voltmeter offers exceptionally low input capacity, which makes the 741A ideal for ac circuit measurements where capacitance loading is critical. The user need only select a desired degree of sensitivity, thereby eliminating the necessity for nulling all ranges. In addition, extra features such as taut-band meter, pushbutton range selection, overload indicator and recorder output terminals make the instrument easier to use.

Used as an ac differential voltmeter

As an ac differential voltmeter the hp 741A measures ac voltages from 50 mv to 1000 volts with an accuracy better than ±0.05% of reading +0.01% end scale. (Refer to specifications for accuracies between 1 mv and 50 mv.) A low-capacitance probe (less than 5 pf) allows measurements to be made in circuits where capacitance loading is critical. The extremely low input capacitance makes the hp 714A Differential Voltmeter ideal for ac circuit measurements where oscillations or instability of measurements become a problem. It also is ideal when measuring high ac voltages, since the source is not required to supply high reactive currents. Accuracy is maintained independent of null conditions. The decimal point is located automatically with the range switch. Stability is better than 0.02%/day. A recorder output makes the 741A ideal for drift regulation measurements on oscillators and ac sources.

Used as a dc differential voltmeter

As a dc differential voltmeter the hp 741A measures dc voltages from 0 to 1000 volts in 7 ranges with an accuracy of ±0.02% ±10 μv, and $>10^9$ ohms input impedance on all ranges independent of null, as opposed to conventional differential techniques where the input impedance is low and varies except at null.

Extremely high input impedance off null makes the 741A Differential Voltmeter ideal for drift measurements where null conditions cannot be maintained. Accuracy is maintained independent of null conditions. The decimal point is located automatically with the range switch. Stability is 0.003%/day and 0.005%/month.

Used as a dc standard

The hp 741A DC Standard will deliver accurate dc voltages from 0 to 1000 volts at currents up to 20 ma. A front-panel current limit control continuously adjusts maximum output current nominally between 4 and 20 ma to protect external circuits from damage. A floating output allows either positive or negative ground with remote sensing.

The 741A calibrated dc voltage is accurate to 0.02% of the indicated setting ±10 μv and stable to within 0.003%/day or 0.005%/month. Voltage setting is indicated by 4 digits, with the remainder of the reading indicated on the front-panel meter. The decimal point is located automatically with the range switch. Output voltage resolution is 1 ppm on any range, directly readable on the front panel.

Used as a high-impedance ac or dc voltmeter

The Model 741A is a ±2% floating dc voltmeter with ranges from 1 mv to 1000 volts. It is also a ±2% floating ac voltmeter from 10 mv to 1000 volts. Input impedance (dc) is greater than 10^9 ohms on all ranges. The low-capacity probe provides a high input impedance (1 megohm shunted by <5 pf) on all ranges in ac operation.

Reference supply

The reference supply consists of a temperature-controlled zener diode and maintains a stability better than 0.003%/day or 0.005%/month. The reference supply can be compared with a standard cell and measured differentially with the 741A.

Used as a voltage amplifier

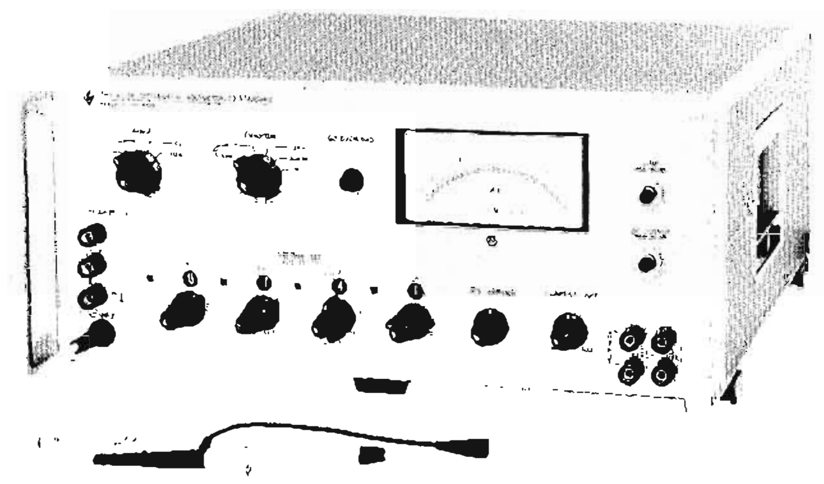
As a voltage amplifier up to 60 db gain is available at the recorder terminals. (Voltage output is directly proportional to meter deflection.) Maximum output is 1 volt nominal into 1 K load.

Used as a power amplifier

As a ±0.02% power amplifier, the hp 741A provides unity voltage gain from 0 to 1000 volts. Stability is better than 0.002%/day, and an output up to 20 ma (20 watts maximum) is available.

Input-output terminals

The ac input terminals consist of a low-capacitance probe which allows measurements to be made in circuits where capacitive loading is critical. The dc input terminals allow the instrument to be used as a two-terminal device. The instrument can be used as a floating or grounded device in ac and dc modes.



NEW

Specifications

AC differential voltmeter

Input voltage ranges: 1, 10, 100, 1000 volts end scale; with null ranges end scale, 1 mv to 1000 volts.

Accuracy (% of reading)	50 mv-1 kv	1 mv-50 mv	5 mv-50 mv
0.05% +0.01% end scale	100 cps-10 kc		
0.1% +0.01% end scale	50 cps-50 kc	50 cps-20 kc	
0.15% +0.01% end scale	30 cps-50 cps		
0.2% +0.01% end scale	20 cps-30 cps 50 kc-100 kc		
0.2% +0.02% end scale			30 cps-50 cps 20 kc-40 kc

Voltage resolution: 0.005% end scale.
Repeatability: better than 0.01% on all ranges.
Stability: better than 0.02%/day after 1 hr. warm-up.
Line regulation: <±0.01% change for ±10% line voltage change.
Temperature coefficient: <40 ppm/°C from 20 cps to 50 kc; <60 ppm/°C from 50 kc to 100 kc; between 0°C and 50°C.
Input impedance: 1 megohm shunted by less than 5 pf.
Input: floating (up to 500 v dc).

High-impedance ac voltmeter

Accuracy (end scale)	50 mv-1 kv	1 mv-50 mv	5 mv-50 mv
2%	20 cps-100 kc		
2% +100 μv		50 cps-20 kc	
2% + 150 μv			20 cps-50 cps 20 kc-50 kc

Input voltage ranges: 1 mv to 1000 v ac end scale.
Input impedance: 1 megohm shunted by <5 pf.

DC differential voltmeter

Input voltage ranges: 1 v to 1000 v end scale, with null ranges end scale, 1 mv to 1000 v.
Accuracy: ±0.02% of reading from 0 to 1000 v dc, ±10 μv.
Voltage resolution: 0.002% end scale.
Repeatability: better than 0.001% on all ranges.
Stability: better than 0.003%/day; 0.005%/month after 1 hr. warm-up.
Line regulation: ±0.002% change for ±10% line voltage change.
Temperature coefficient: <3 ppm/°C from +0°C to +50°C.
Input impedance: >10⁹ ohms on all ranges (independent of null).
Input: floating (up to 500 v dc).
Superimposed ac noise rejection: <0.01% error (above 50 cps) rms, 50% of input or 25 v rms, whichever is less.

High-impedance dc voltmeter

Input voltage ranges: 1 mv to 1000 v.
Accuracy: ±2% of end scale, all ranges.
Input impedance: $>10^9$ ohms, all ranges.
Superimposed ac noise rejection: same as differential voltmeter.

DC standard

Ranges: 0 to 1 v, 0 to 10 v, 0 to 100 v, 0 to 1000 v continuously adjustable on all ranges (6-digit resolution).
Accuracy: ±0.02% of indicated setting ±10 μv.
Resolution: 1 ppm.
Stability: better than 0.003%/day; 0.005%/month after 1 hr. warm-up.
Output current: 0 to 20 ma, output current limiter continuously variable from 4 to 20 ma (nominal).
Line regulation: <±0.002% for ±10% line voltage change.
Remote sensing: permits output regulation at the point of application.
Load regulation: <±0.002% or ±50 μv, whichever is greater, no load to full load.
Temperature coefficient: <3 ppm/°C from +0 to +50°C.
Noise and hum: dc to 1 cps, 100 db below full scale; 1 cps to 1 mc, −100 db below full scale or 200 μv, whichever is greater.
Output: floating (up to 500 v).
Readout: 4 digits, plus individually calibrated taut-band meter.

Power amplifier

Accuracy: ±0.02%.
Output current: same as dc standard.
Voltage gain: unity 0 to 1 kv.
Stability: better than 0.002%/day after 1 hr. warm-up.
Bandwidth: dc to 0.1 cps.
Line and load regulation: same as dc standard.
Input impedance: same as ΔVM.
Superimposed ac noise rejection: same as dc ΔVM.
Noise: same as dc standard.

General

Recorder output: available for all modes of operation.
Recorder amplifier: recorder voltage output directly proportional to meter deflection, 60 db gain (max), 1 ma into 1 k load.
Power: 115 or 230 volts ±10%, 50 cps to 1000 cps, 125 watts maximum.
Weight: net 46 lbs (20,7 kg); shipping 60 lbs (27 kg).
Price: hp 741A, $1475.

DY-2212A VOLTAGE-TO-FREQUENCY CONVERTER

Accurate low-level dc voltage-to-frequency conversion

The Dymec DY-2212A is a compact voltage-to-frequency converter which is particularly well suited to low-level signal applications. Low input drift and high common mode rejection (120 db at dc) have been achieved without a chopper by means of differential circuits. Internal feedback circuits provide an output pulse train with a pulse rate directly proportional to the magnitude of an applied dc voltage. The output pulse rate rises linearily and instantaneously from 0 to 100,000 pulses per second as the dc input level is increased from zero to full scale. These techniques combine to provide outstanding linearity, stability and noise immunity.

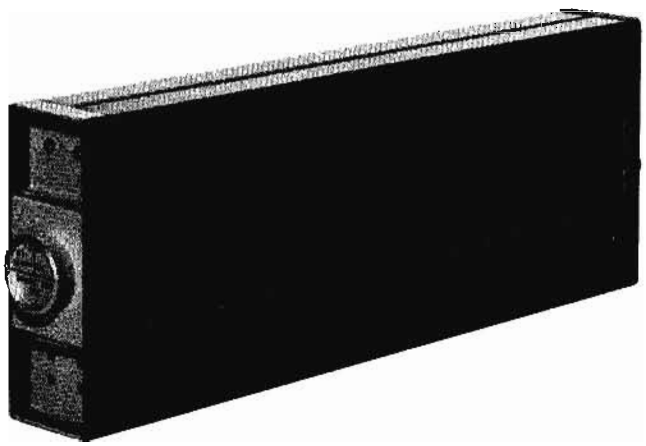
The output of the DY-2212A, when connected to a Hewlett-Packard electronic counter provides a convenient method of making digital measurements of dc voltages. The converter also provides a polarity indication. The combination of DY-2212A and hp counter can be connected directly to a digital printer or through Dymec couplers to digital recording devices. Computer processing or storage on punched card, punched tape or magnetic tape can then be accomplished.

The converter-counter combination provides integration of dc voltages over any period of time and can therefore be used to read the average of the input over the selected sample period and provide accurate dc measurements in the presence of noise superimposed on the signal. The instrument is applicable, for example, to high-accuracy FM telemetry systems, gas chromatographs, and wide-range coulometric analysis.

The unique 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 standard 19" rack panel space.

Other voltage-to-frequency converters are available from Dymec to satisfy a variety of speed, accuracy and resolution requirements. Ask for information on the DY-2210, DY-2211 and DY-5207-1 Converters.

AVAILABLE MID-1965



Specifications

(Unless noted, all specifications apply after a 30-minute warm-up at 25°C ambient, 1 K ohm source resistance, any unbalance)

Input: dc voltage ranges: 0 to 10 mv, 100 mv, 1 v; up to 150% overranging; optionally 0 to 10 mv, 30 mv, 100 mv, 300 mv, 1 v; other ranges between 10 mv and 1 v available, up to 6 positions.

Range accuracy (relative to calibrated range): ±0.02% of reading at 25°C ±0.005% per month.

Scale factor: stability at constant temperature: ±0.01% of reading per day; temperature coefficient: ±0.004% of reading per degree C.

Zero (referred to input): stability at constant temperature: ±5 μv ±0.5 na ±0.002% of full scale per day; temperature coefficient: ±2 μv ±0.2 na ±0.001% of full scale per degree C.

Linearity: ±0.01% of full scale (0.01% of reading in overrange) measured from straight line through 0 and full scale.

Input impedance: 1000 megohms min. shunted by 5 pf max.

Maximum input signal: ±11 volts, signal + common-mode.

Common mode rejection: 120 db, dc to 60 cps.

Settling time: 100 μsec to within 0.01% of final value.

Overload recovery: settling time +100 μsec for differential inputs of 10 times full scale or less, less than 1 millisec for inputs up to 20 volts.

Output: frequency, 0 to 100 kc full scale; overrange to 150 kc.

Polarity signal: electrical and visual indication.

Operating conditions: 10 to 55°C ambient temperature range, up to 95% relative humidity at 40°C.

Power: 115 or 230 volts ±10%, 50 to 400 cps, 5 watts.

Dimensions: 1⅝" wide, 4-27/32" high, 15" deep (41 x 123 x 381 mm).

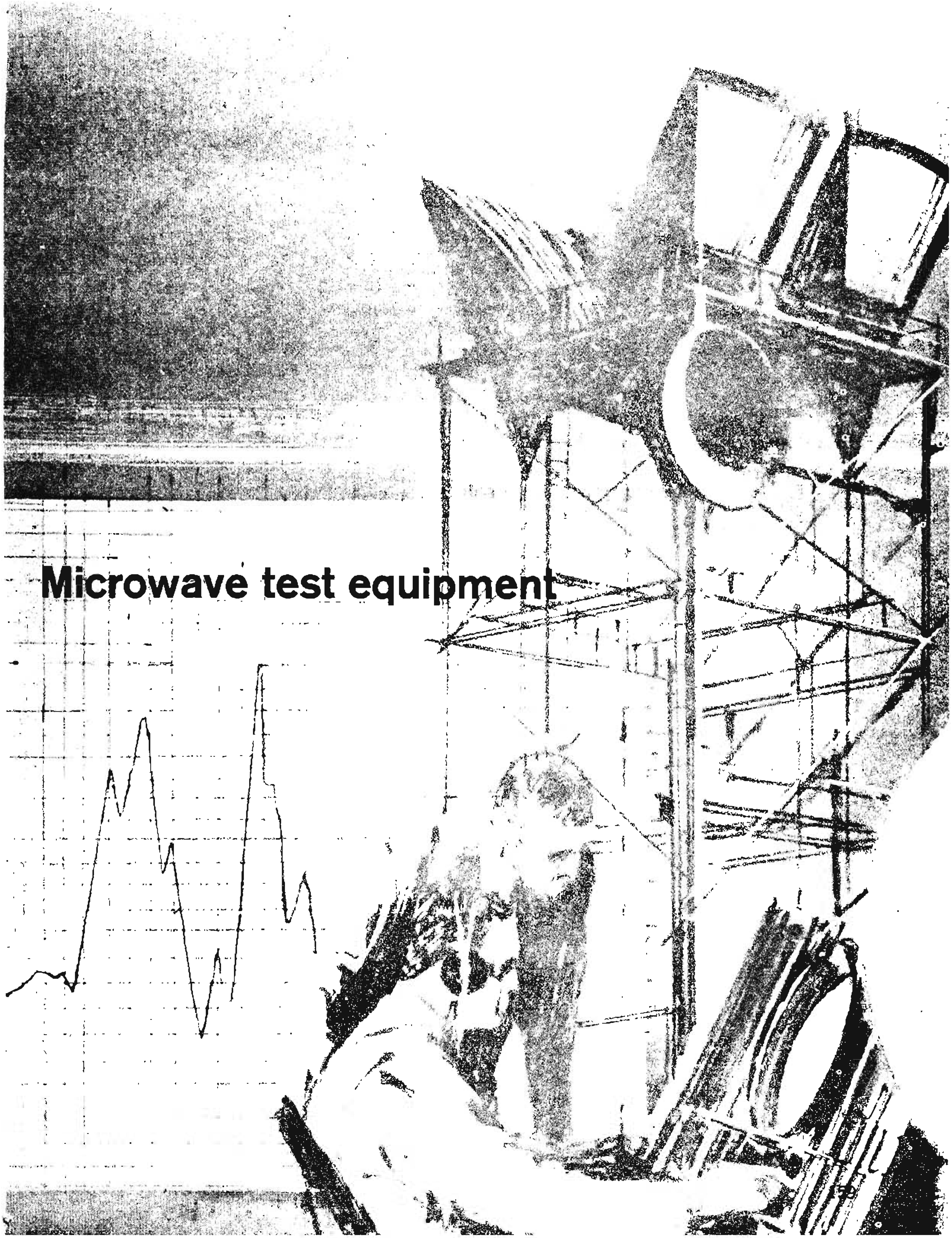
Weight: net 4 lbs (1,8 kg); shipping 6 lbs (2,7 kg).

Accessories available: combining case contains up to 10 instruments in 5¼" of standard 19" rack space (mating connectors furnished with amplifier); bench stand, holds one VFC upright and includes input/output connectors, power switch, pilot light, power cord; mating rear connector with power cord, input/output cables.

Optional modifications: special voltage ranges; internal calibration source.

Price: DY-2212A, price on request.

Microwave test equipment



MICROWAVE TEST EQUIPMENT

Hewlett-Packard microwave test equipment includes a wide range of high-quality, low-cost instruments for measurement of virtually all microwave parameters. Accurate determination of such major characteristics as power, impedance, frequency, attenuation and noise figure is performed quickly and easily with Hewlett-Packard microwave instruments. In the sections that follow, detailed information is presented on hp coaxial and waveguide instruments, microwave signal-generating equipment (including signal sources, sweep oscillators, microwave amplifiers and modulators), instruments for power measurement, noise figure meters and an important new spectrum analyzer. Also presented is information on frequency stabilizing equipment offered by the Dymec Division of hp, plus the wide and versatile array of vhf and uhf equipment produced by the Boonton Division. Each of the major product sections is preceded by technical information discussing major applications, measurement techniques and general accuracy considerations.

In using microwave test equipment, an engineer relies heavily on the manufacturer's specifications to assure performance of his test system. He cannot afford tedious and complex pre-testing before using the microwave equipment. Hewlett-Packard has always been keenly aware of the reliance that the using engineer places on the instrument's specifications, and has therefore continually employed the most advanced test and measurement techniques to ensure that all hp microwave equipment meets or exceeds specifications. The engineer using hp microwave instruments can, therefore, put complete confidence in the equipment's accuracy and performance, whether the operating locale be a development or standards laboratory, a production or manufacturing test installation, or even a field operational site.

Calibration and certification

The Hewlett-Packard Standards Laboratory devotes full time to advancing the art of standards measurements and has received wide recognition throughout the industry for its contributions in microwave measurement techniques. Continuing correlation of the Hewlett-Packard house standards with the available certification services of the National Bureau of Standards assures that high accuracy is built into all hp microwave equipment. Traceability to the national standards wherever this certification service is available, can be supplied for the applicable hp microwave instruments. In addition, there are many types of hp microwave instruments whose usefulness can be considerably enhanced for certain applications by having them calibrated by the Hewlett-Packard Standards Laboratory at specific frequencies. Such calibrations can be made to a much higher accuracy than those specified on a broadband basis in this catalog. Your hp field engineer will be pleased to provide detailed information on this service as it applies to your particular requirements.

Microwave measuring techniques

There are two basic types of microwave measuring techniques—(1) fixed frequency and (2) swept frequency.

Fixed frequency techniques offer the highest precision attainable for individual measurements, because the small inherent mismatch ambiguities which must be tolerated on a broad-frequency sweep basis may be individually tuned out. Consequently, fixed frequency techniques are widely used in "standards" measurements and in applications where the system under test is operating either at a single frequency or within a very narrow band. To meet requirements for fixed frequency measurements, Hewlett-Packard offers a complete line of both coaxial and waveguide slotted sections and tuners.

Swept-frequency techniques are used to obtain measurements quickly and easily over a range of frequencies. Important parameters such as swr, directivity, attenuation, noise figure, etc., can be ascertained on a swept frequency basis, and the user can quickly determine if there is a narrow-band phenomenon, such as a resonance, in the device being tested. Recent hp product developments (such as leveled sweep oscillators and signal generators, extremely flat crystal detectors and high-directivity directional couplers), together with refinements in the actual techniques, now permit very accurate measurements to be made on a broadband basis, thereby giving the microwave engineer a powerful new tool for analyzing system characteristics.

Swept-frequency measurements

The basic set-up for making swept frequency measurements is shown in Figure 1 (the arrangement depicted is for swr measurements). This is the hp-developed "Improved Reflectometer" system which materially reduces the calibration errors that were present in earlier reflectometer set-ups. The standard attenuator in the secondary arm of the reverse coupler is used to calibrate the system so that most of the sources of error found in earlier reflectometers are automatically included in the initial system calibrations made in this new improved set-up. A typical swr plot made with this improved swept frequency reflectometer is shown in Figure 2. You will find additional information on swept frequency reflectometers, as well as other

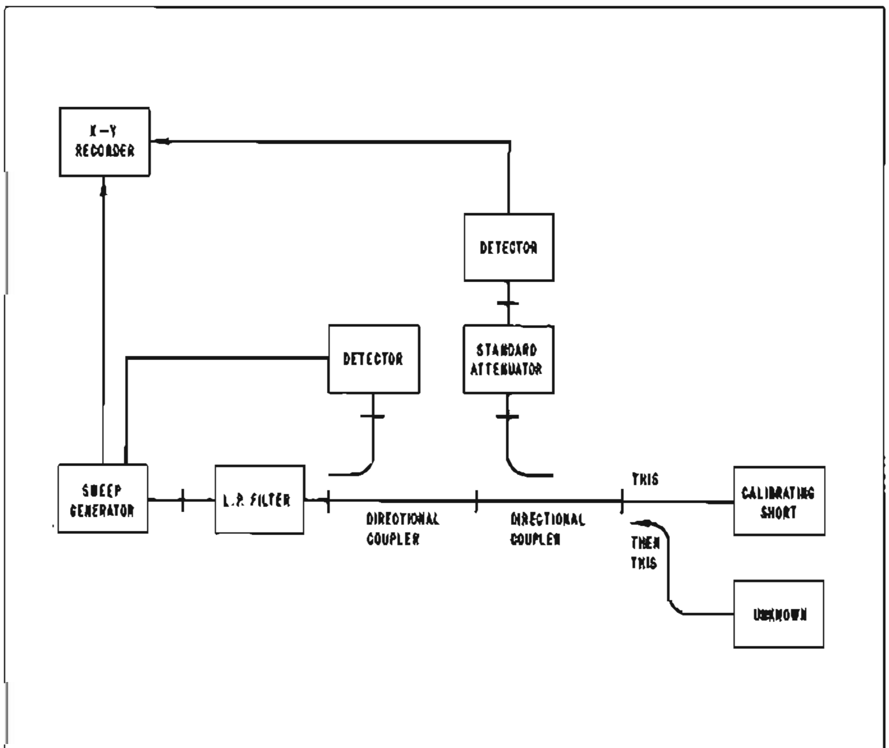


Figure 1. Improved set-up for sweep frequency swr measurements.

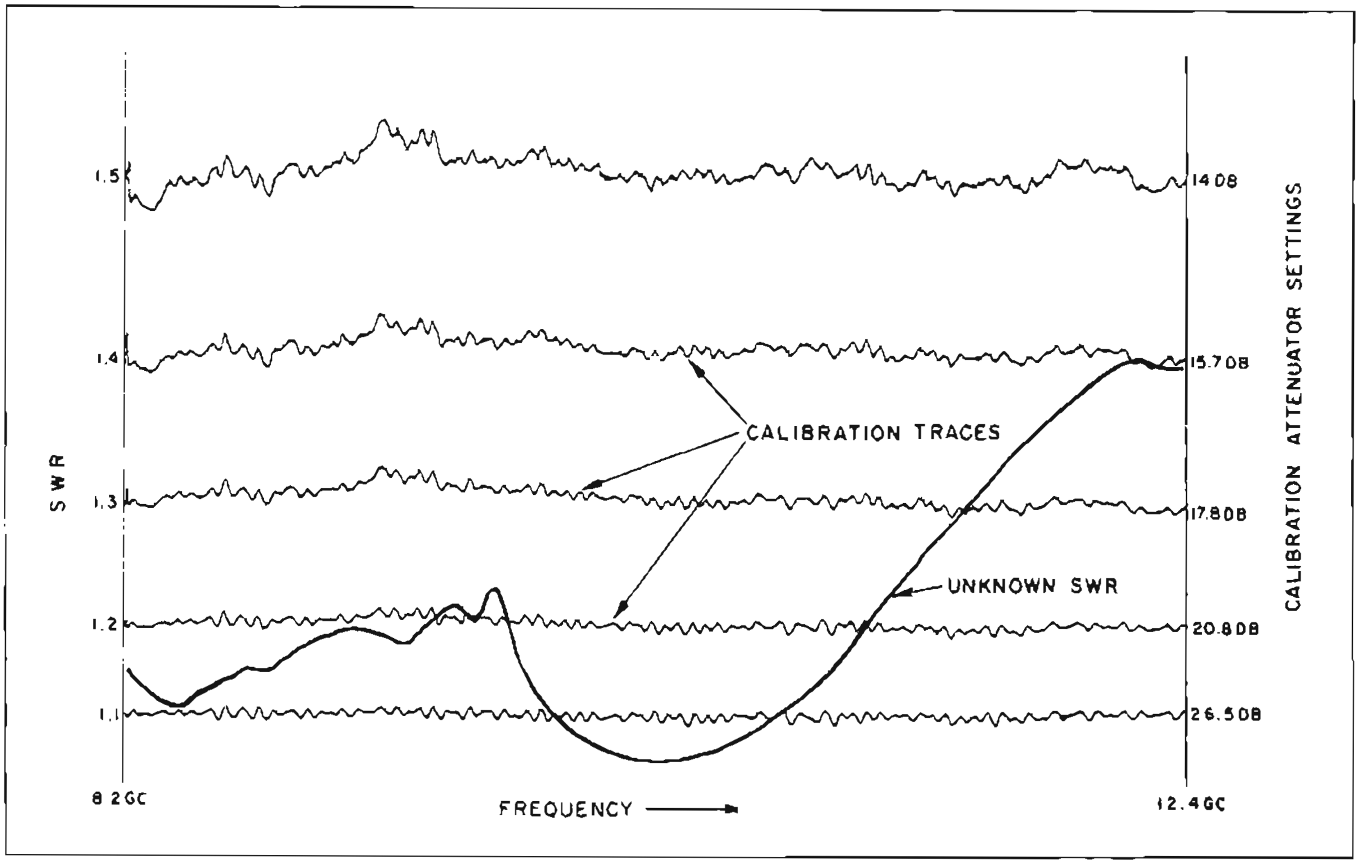


Figure 2. Typical swr plot.

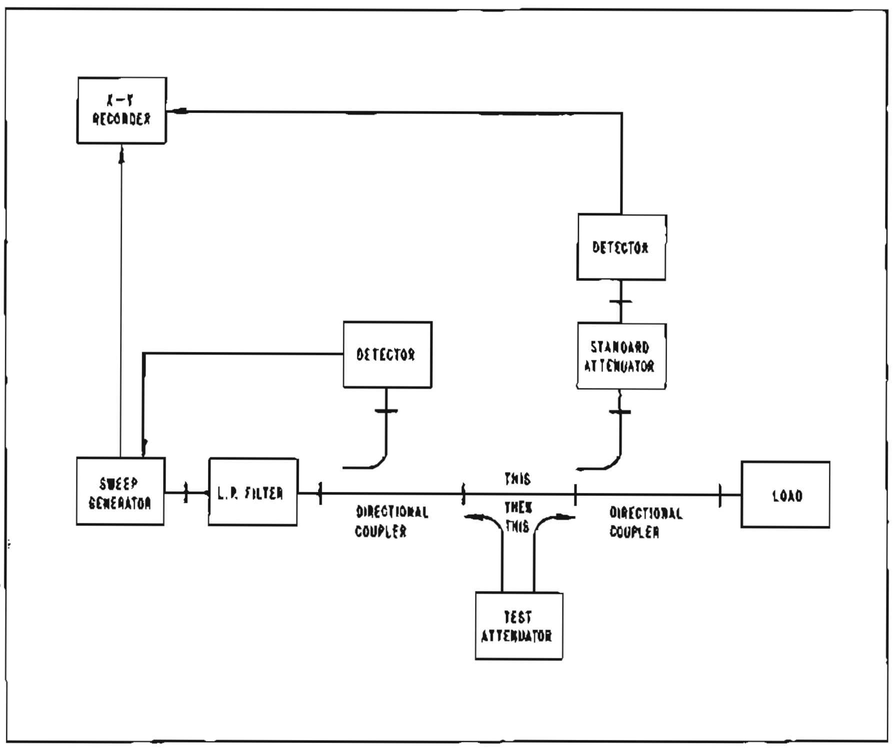


Figure 3. Set-up for accurate swept frequency attenuation measurements.

impedance measuring techniques, in the technical information section on microwave impedance measurement, pages 230 and 231 of this catalog.

A set-up for swept frequency attenuation measurements is shown in Figure 3. Here, what had been the "reflected" channel in the reflectometer from Figure 1 becomes the "transmission" channel because the coupler-detector is placed in the forward direction. Attenuation characteristics of a flap attenuator, measured in this set-up, are shown in Figure 4.

In many swept frequency set-ups, an oscilloscope display of the measurement results is desirable, particularly when the device under test is being adjusted for best broadband characteristics. The new hp 1416A Swept Frequency Indicator for the hp 140A Oscilloscope (page 277-279) is expressly designed for microwave swept measurement systems employing leveled sweep oscillators, flat detectors and high directivity couplers. The accurate, high sensitivity, logarithmic display of the 1416A permits rapid measurement of swr (oscilloscope readout is in db of "Return Loss"), using the reflectometer set-up in Figure 1 with the 140A/1416A used in place of the x-y recorder. Likewise, the oscilloscope can be used in swept measurements of attenuation similar to the arrangement shown in Figure 3.

Attenuation measurement

Attenuation measurements are made by a number of different methods such as power ratio or either rf or IF substitution.

In the power ratio method, the signal source is connected to a detector mount through a length of lossless transmission line—in whose place the unknown attenuator may be substituted. A reading is obtained on the output indicator with a section of lossless line in the circuit. The lossless line is then replaced by the attenuator being measured. The power reduction at the output indicator is a measure of the attenuation. This measurement requires, first, that the law of the detector is known over the complete frequency range of the measurement, and, second, that reflection effects in the system are essentially the same both with and without the attenuator.

Impedance matching is important to eliminate effects of reflections between generator and attenuator, and attenuator and load. Well matched pads are often used to achieve isolation. Closed-loop leveling arrangements employing high-directivity directional couplers, flat detectors and high-gain leveling amplifiers result in excellent generator match; the source match is essentially equivalent to the directivity of the coupler used.

The type of detecting equipment used will depend on the range of the attenuation measurement. A range of attenuation measurement up to 20 or 30 db can be achieved with a detector mount employing a barretter and an hp 415 Series Standing Wave Indicator (high sensitivity tuned voltmeter). In this case, the signal source must be modulated, and the rf power level must be kept below 200 microwatts for square law detector characteristics. The 415D, with its 2.5 db steps and 0.02 db tracking accuracy, is most useful for these measurements.

RF substitution depends on substituting an attenuator of known characteristic for the unknown. For instance, a signal generator attenuator may be used. When this method is used, the output of the signal generator is fed to the detection system without the unknown attenuator, and the setting of the signal generator attenuator is noted. Then the unknown attenuator is inserted, and the signal generator output is adjusted to obtain the same reading from the detection system as before. The difference between the signal generator attenuator settings is the attenuation of the unknown in db. Since the detector is always operated at the same level, detector law is no problem. The attenuator measurement may be performed in a similar manner with an hp 382 Series Precision Attenuator and a signal source.

The IF substitution method offers the widest dynamic range in attenuation measurements, since a linear detector is used. The power change caused by removing the unknown rf attenuator is replaced by change of the precision IF cutoff attenuator in the IF stage of the detecting microwave receiver.

Other microwave measurements

General information on microwave power measurements, including discussion of techniques, accuracy considerations, and measurement equipment is presented on pages 218 and 219. Noise figure measurements are described on page 228, and microwave impedance measurements are discussed on pages 230 and 231.

An essential element in microwave measurement systems is the signal source; information on types of sources and their pertinent characteristics begins on page 175. The discussion also covers signal source modulation, amplification leveling, frequency stabilizing, etc.; in short, the many techniques available to the microwave engineer to permit him to make the most meaningful measurements possible.

Important new applications involving microwave spectrum analysis are described on pages 214 and 215.

Application Notes

The current index of hp Application Notes (available from your hp field sales office) lists many articles of interest and value to microwave engineers. Subjects include swept-frequency measurements and accuracy considerations, microwave power measurements, mismatch error analysis and noise figure fundamentals. The hp Application Notes are further evidence of Hewlett-Packard's desire to keep measurement people abreast of the newest and most accurate techniques. This additionally assures the user of hp test equipment that he is receiving maximum performance from his instruments.

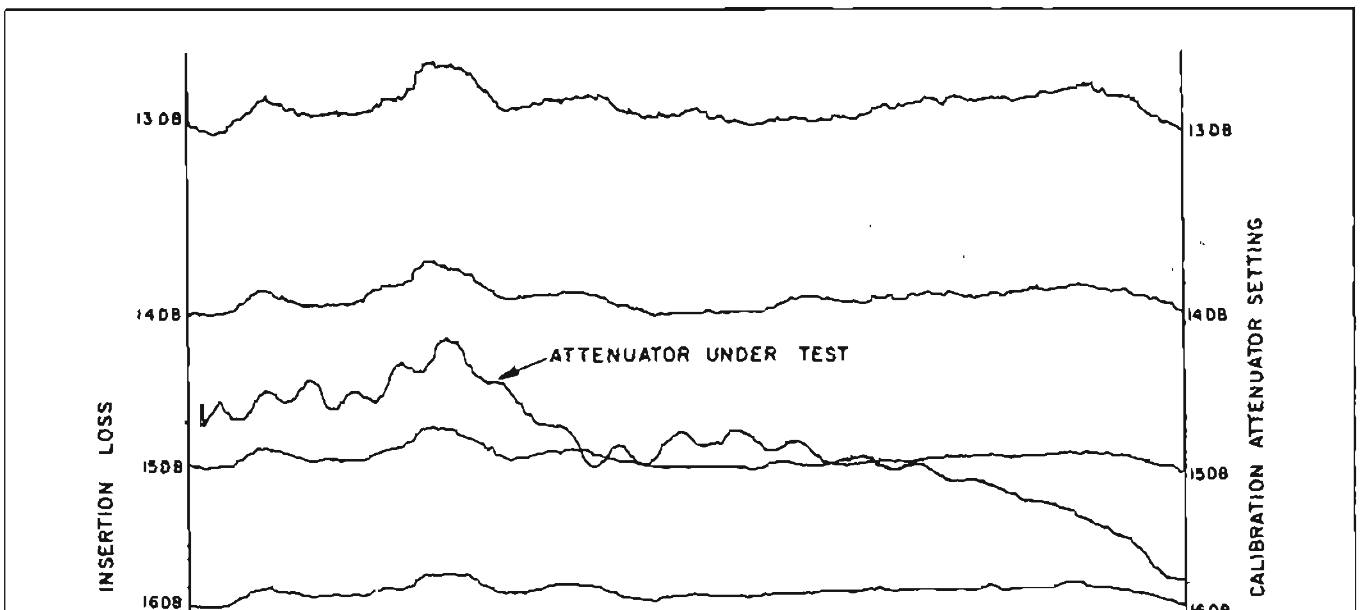


Figure 4. Attenuation characteristics of a flap attenuator.

COAXIAL INSTRUMENTATION

Hewlett-Packard offers an extensive line of instruments for coaxial systems operating to 12.4 gc. The table indicates the frequency range and major uses of these various instruments. Additional information will be found on the pages referenced in the table.

Frequency coverage by model (dc, 10 mc, 55 mc, 215 mc, 450 mc, 500 mc, 940 mc, 1 gc, 2 gc, 3 gc, 4 gc, 10 gc, 12.4 gc)	Page	Instrument name	Uses
281A Series	174	Waveguide-to-coax adapters	
360A 360B 360C 360D	213	Low-pass filters	Spectrum analyzer preselectors; elimination of harmonics from signal source output
8430A 8431A 8432A 8433A 8434A 8435A 8436A		Bandpass filters	
355C 355D 393A 394A	227	Attenuators	Measurement of reflection coefficient, insertion loss, transfer characteristics by rf substitution method
420A 420B 423A 440A 476A	235 242 233	Detectors	RF detection; reflection coefficient, attenuation measurements
477B 478A	222 220	Thermistor mounts	Power measurements with hp 430C (477B) and hp 431B (478A)
536A	246	Frequency meter	Frequency measurement
774D 775D 776D 777D	238	Dual directional couplers	Reflectometer measurements; *optimizing transmission* characteristics of rf systems
X781A 786D 787D 788C 789C	238	Directional detectors	Closed-loop leveling of signal sources; monitoring power
796D 797D 798C	238	Directional couplers	Power measurements; power leveling
417A 803A	112	VHF detector VHF bridge	Measurement of impedance magnitude and phase
805C 805D 806B	244 242	Slotted lines	Measurement of swr, wavelength, impedance, system flatness
872A	244	Slide screw tuner	Impedance matching
906A 908A	245	Terminations	Termination of 50-ohm systems
X8440A	236	Reflection coefficient bridge	Precise reflection coefficient measurements with swept frequency techniques

Many hp coaxial instruments are now offered with the newly introduced GPC-7 series precision coaxial connectors, thereby extending the range for practical coaxial measurements as high as 18 gc. See pages 240, 241 for additional information.

WAVEGUIDE INSTRUMENTATION

Hewlett-Packard offers a wide range of waveguide instrumentation in nine frequency bands between 2.6 and 40 gc. This instrumentation is tabulated by frequency band on the following pages for quick, easy reference. Included in the tables are the most pertinent specifications plus reference to other catalog pages where more complete information is available. Photographs illustrating the wide range of measurement possibilities with hp equipment accompany the tables. In general, the set-up shown for one band can be duplicated in other bands.

Letter designations

Model numbers of hp waveguide components are normally preceded by a prefix letter which designates the waveguide size and frequency band. Standard waveguide specifications for these bands are shown in the chart below.

In the case of fixed attenuators and directional couplers, the suffix letter indicates specific attenuation or coupling, as follows:

A	3 db	D	20 db
B	6 db	E	30 db
C	10 db		

Thus, the 20 db coupling version of the hp 750 Directional Coupler built for 1" x ½" waveguide (8.2 to 12.4 gc) is designated X750D.

Construction

Hewlett-Packard waveguide instruments are divided into two categories according to their construction: fabricated and cast. Fabricated instruments are constructed using standard waveguide tubing with brass flanges and other constructional details hard-soldered together. Instruments typifying this group are those which involve complicated construction such as multi-hole directional couplers.

The second category of instruments are cast aluminum. Most of the newer Hewlett-Packard instruments are cast aluminum to take advantage of the increased dimensional stability and production uniformity. In X-band waveguide tubing, for example, typical tolerances on the internal dimensions are ±0.003", whereas a precision broaching process can be used on aluminum castings to control internal dimensions to ±0.001" or less. A broach is a long cutting bar with teeth all around (somewhat similar to a file), and it is pulled through the casting. A linear cutting stroke, broaching eliminates even the minor surface irregularities inherent with milling cutters.

The broaching process is particularly important for instruments in which precise control of the guide wavelength is critical, for guide wavelength is directly dependent upon guide dimensions. Such instruments are slotted lines, high directivity directional couplers, sliding loads and sliding shorts. Many other instruments also are broached, although they are not highly dependent upon guide wavelength.

Fabricated waveguide instruments are silver plated internally and on the flange surface. They are generally treated with a copper flash to prepare the surface, followed by the silver plating and, sometimes, a layer of nickel. Finally, a rhodium flash protects the surface from tarnishing. The cast aluminum instruments are unfinished on the interiors and flange surfaces.

Flanges

Every flange is machine-lapped after an initial sanding belt preparation of the surface. This machine lapping process is unique and results in a flange surface which is slightly convex, 20 microinches per inch maximum, so that the innermost area of the mating flanges makes contact. Thus, discontinuities at the flange joint are eliminated. Leakage also is low; these flanges have better leakage characteristics than flange joints painted with silver paint.

An additional benefit of the lapping process is an extremely smooth flange surface, on the order of 30 microinches rms of surface ripple. The smooth surface adds considerably to the excellent mating and low leakage characteristics.

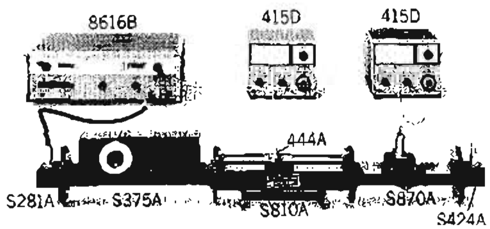
Testing techniques

Hewlett-Packard subjects all waveguide instruments to comprehensive tests to insure quality and conformance to published specifications. Of particular importance is the concept of full-range testing, pioneered by Hewlett-Packard, which makes maximum use of swept-frequency techniques. As opposed to spot checking, swept-frequency testing provides a record which is continuous over the entire range of an instrument and eliminates the possibility of holes and discontinuities.

Virtually every piece of hp waveguide equipment has at least one swept-frequency test performed on it, as determined by the basic accuracy of the test itself and the required specification to be tested. Spot tests are made where the required accuracy is greater than can be achieved using swept-frequency techniques, such as in attenuation where accuracies to ±0.1 db are required. Typical of such tests are the coupling tests on the 752 Series Directional Couplers; coupling is measured and logged at five specific frequencies. Nevertheless, the 752 Couplers are swept-frequency tested to insure smooth operation across their respective bands.

	Designations		Dimensions	TE_{10} operating range			Freespace wavelength	Theoretical attenuation db/100 ft.	Theoretical pk power rating megawatts
hp	EIA	JAN	Nominal OD (inches)	frequency (gc)	wavelength (cm)	cutoff freq. (gc)	(cm)	low to high freq.	low to high freq.
S	WR 284	RG-48/U	3 x 1½	2.60 - 3.95	19.18 - 8.92	2.078	11.53 - 7.59	1.478 - 1.008	2.2 - 3.2
G	WR 187	RG-49/U	2 x 1	3.95 - 5.85	12.59 - 6.08	3.152	7.59 - 5.12	2.79 - 1.93	0.94 - 1.32
J	WR 137	RG-50/U	1½ x ¾	5.30 - 8.20	9.68 - 4.29	4.301	5.66 - 3.66	4.61 - 3.08	0.56 - 0.71
H	WR 112	RG-51/U	1¼ x ⅝	7.05 - 10.0	6.39 - 3.52	5.259	4.25 - 3.00	5.51 - 4.31	0.35 - 0.46
X	WR 90	RG-52/U	1 x ½	8.20 - 12.4	6.09 - 2.85	6.557	3.66 - 2.42	8.64 - 6.02	0.20 - 0.29
M	WR 75	———	0.850 x 0.475	10.0 - 15.0	4.86 - 2.35	7.868	3.00 - 2.00	10.07 - 7.03	0.17 - 0.23
P	WR 62	RG-91/U	0.702 x 0.391	12.4 - 18.0	3.75 - 1.96	9.487	2.42 - 1.67	12.76 - 11.15	0.12 - 0.16
N	WR 51	———	0.590 x 0.335	15.0 - 22.0	3.11 - 1.60	11.571	2.00 - 1.36	17.3 - 12.6	0.08 - 0.107
K	WR 42	RG-66/U	½ x ¼	18.0 - 26.5	2.66 - 1.33	14.048	1.67 - 1.13	13.3 - 9.5	0.043 - 0.058
R	WR 28	RG-96/U	0.360 x 0.220	26.5 - 40.0	1.87 - 0.88	21.075	1.13 - 0.749	21.9 - 15.0	0.022 - 0.031

S-band 2.60 to 3.95 gc



Illustrated is a typical S-band fixed-frequency set-up, in which the S870A Slide-Screw Tuner is used to tune the S424A Crystal Detector to unity; the S810A Slotted Section facilitates this tuning. The device to be tested can then be inserted between the slotted section and tuner, and its insertion loss and swr measured.

Complementary equipment

hp Instrument	Frequency range, (gc)	Page	Price
616B Signal Generator	1.8 to 4.2	193	$1950 $1970(R)*
8616A Signal Generator	1.8 to 4.5	188, 189	$2100
8616B Signal Source	1.8 to 4.5	188, 189	$1450
692A Sweep Oscillator	2 to 4	199 - 201	$3000
692B Sweep Oscillator	2 to 4	199 - 201	$3350
491C Microwave Amplifier	2 to 4	202	$2250
8732A PIN Modulator	1.8 to 4.5	190, 191	$300
8732B PIN Modulator	1.8 to 4.5	190, 191	$500

*Rack mount.

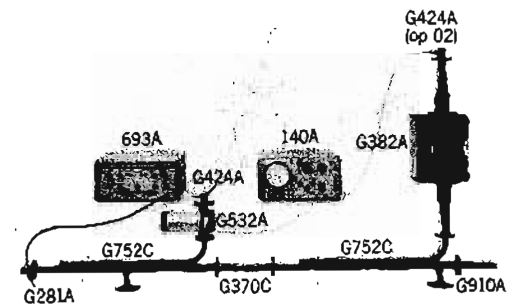
S-band equipment

hp Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
S281A	Adapter, waveguide-to-coax			1.25		3	76	174	$50
S347A	Noise source, waveguide	±0.5 db	15.1 db	1.2		22½	572	228, 229	$390
S370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	12	305	226	$100
S372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	2	46	1168	226	$425
S375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	2	14-⅛	359	226	$165
S382B	Attenuator, precision variable	±1% or 0.1 db to 50 db; ±2% above 50 db	0 to 60 db	1.2 below 3 gc; 1.15 above 3 gc	10	25¼	641	225	$650
S382C	Same as S382B except for degrees-of-rotation dial calibrated in 100'ths, as opposed to 10'ths on the S382B							225	$700
S424A	Crystal detector	response: ±0.2 db	sensitivity: >0.4 mv/μw	1.35		2-7/16	62	235	$175
S486A	Thermistor mount, compensated		0.001 to 10 mw	1.35		3	76	220, 221	$195
S487B	Thermistor mount, broadband		0.01 to 10 mw	1.35		2⅜	60	222	$105
S750	Directional couplers, cross-guide	±1.7 db	20, 30 db			9 x 9	229 x 229	236, 237	$150
S752A S752C S752D	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)	50¼ 48 48	1276 1219 1219	236, 237	$450
S810A (444A)	Slotted-section, waveguide and carriage (detector probe for S810A)			1.01		12¾	324	242, 243	$450 ($55)
S870A	Tuner, slide screw	insertion loss: <2 db to 20:1 swr	corrects swr of 20			11	279	244	$250
S910A	Termination, low power			1.04	2	10¼	260	245	$75
S914A	Moving load	load reflection: <0.5%	>½ wavelength	1.01	2	31	787	245	$125
S920A	Adjustable short		>½ wavelength			10-7/16	265	245	$150
S25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

G- AND J-BANDS, 3.95 TO 8.2 GC

G-band 3.95 to 5.85 gc

The swept-frequency system illustrated on the right permits rapid measurement of attenuation (in this example the G370C is being calibrated). The transmission characteristics of the system are accounted for in the initial calibration which is based on the G382A Attenuator. This same technique can be used in conjunction with a Moseley x-y recorder when permanent records are desired.



Complementary equipment

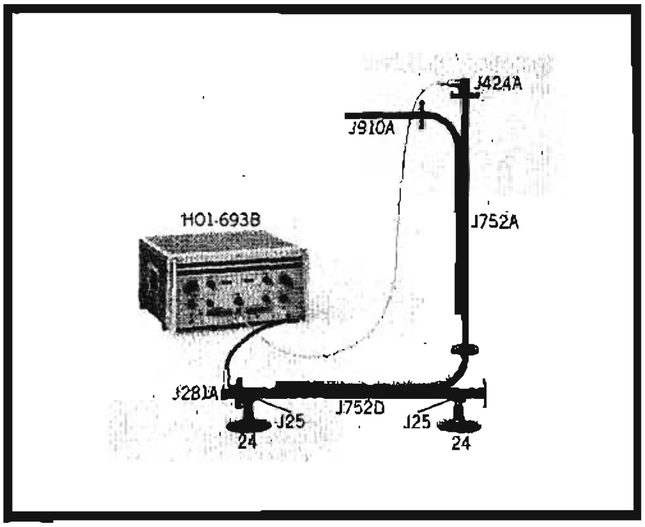
hp Instrument	Frequency range, gc	Page	Price
618B Signal Generator	3.8 to 7.6	194, 195	$2250 $2270(R)*
620A Signal Generator	7 to 11	194, 195	$2250 $2270(R)*
693A Sweep Oscillator	4 to 8	199-201	$3000
H01-693A Sweep Oscillator	3.7 to 8.3	199-201	$3300
693B Sweep Oscillator	4 to 8	199-201	$3350
H01-693B Sweep Oscillator	3.7 to 8.3	199-201	$3650
493A Microwave Amplifier	4 to 8	202	$2600
8733A PIN Modulator	3.7 to 8.3	190, 191	$300
8733B PIN Modulator	3.7 to 8.3	190, 191	$500

* Rack mount

G-band equipment

hp Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
G281A	Adapter, waveguide-to-coax			1.25		2⅛	54	174	$40
G347A	Noise source, waveguide	±0.5 db	15.2 db	1.2		19	483	228, 229	$310
G370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	10⅛	257	226	$95
G372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	2	30	762	226	$300
G375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	2	13	330	226	$145
G382A	Attenuator, precision variable	±2% of reading or 0.1 db whichever is greater	0 to 50 db	1.15	15	31⅝	803	225	$500
G424A	Crystal detector	response: ±0.2 db	sensitivity >0.4 mv/μw	1.35		2-1/16	52	235	$165
G485B	Detector mount (less detector)			with barretter 1.25		9-5/16	237	233	$120
G486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		4	102	220, 221	$180
G487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		2⅛	54	222	$95
G532A	Freq. meter, direct reading	dial: ±0.033% overall: ±0.065%				6¼	159	246	$375
G750	Directional couplers, cross-guide	±1.7 db	20, 30 db			6 x 6	152 x 152	236, 237	$120
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)	34⅝ 33 33	880 838 838	236, 237	$300
G810B (809B) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242, 243	$140 ($175) ($55)
G870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			8¼	210	244	$200
G910A	Termination, low power			1.04	2	6⅝	168	245	$65
G914A	Moving load	load reflection: <0.5%	>½ wavelength	1.01	2	20½	521	245	$95
G920A	Adjustable short		>½ wavelength			7-13/16	199	245	$125
G25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

J-band 5.30 to 8.20 gc



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.

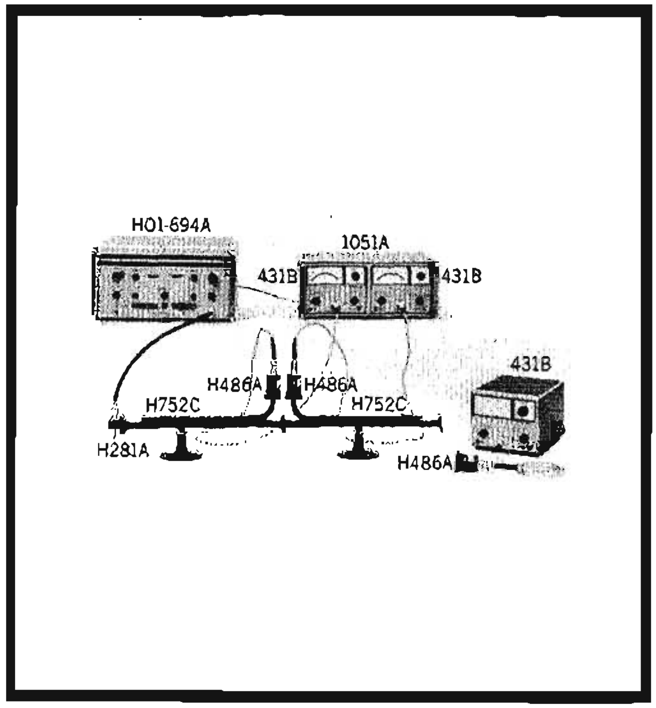
J-band equipment

hp Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length		Page reference	Price
						(in)	(mm)		
J281A	Adapter, waveguide-to-coax			1.25 (1.3 from 5.3 to 5.5 gc)		2	51	174	$35
J347A	Noise source, waveguide	±0.5 db	15.2 db	1.2		19	483	228, 229	$300
J370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	8⅛	206	226	$85
J372	Attenuators, precision fixed	±0.5 db (5.85 to 8.2 gc)	10, 20 db	1.05	1	21¾	553	226	$190
J375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	2	13	330	225	$135
J382A	Attenuator, precision variable	±2% of reading or 0.1 db which- ever is greater	0 to 50 db	1.15	10	25⅛	638	225	$375
J424A	Crystal detector	response: ±0.2 db	sensitivity >0.4 mv/μw	1.35		1⅞	48	235	$165
J485B	Detector mount (less detector)			with barretter 1.25 (5.85 to 8.2 gc) 1.5 overall		8¼	210	233	$105
J486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		3⅜	86	220	$170
J487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		1¾	45	222	$90
J532A	Frequency meter, direct reading	dial: ±0.033% overall: ±0.065%				6¼	159	246	$350
J750	Directional couplers, cross-guide	±1.7 db	20, 30 db			5 x 5	127 x 127	236, 237	$100
J752A J752C J752D	Directional couplers, multi-hole	mean: ±0.4 db variation: ±0.5 db (5.85 to 8.2 gc)	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	236, 237	$220
J810B (809B) (444A)	Slotted section, waveguide (carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242, 243	$125 ($175) ($55)
J870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			7⅝	194	244	$165
J885A	Waveguide phase shifter	lesser of 3° or 10%	−360° to +360°	1.35	10	25⅛	638	246	$550
J910A	Termination, low power			1.02	1	8⅛	206	245	$55
J914A	Moving load	load reflection: <0.5%	>½ wavelength	1.01	2	15½	394	245	$85
J920A	Adjustable short		>½ wavelength			6¼	159	245	$100
J25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

H- AND X-BANDS, 7.05 TO 12.4 GC

H-band 7.05 to 10 gc

The figure illustrates a swept-frequency system employing power meter leveling, in which the system is arranged to provide leveled net forward power at the mainline output of the right-hand H752C Directional Coupler. Both the incident and reflected powers are monitored, with the recorder outputs of the two 431B Power Meters connected in such a manner that the resultant voltage fed back to the sweep oscillator is related to the power actually absorbed by the load. Typical applications for this type of leveling include measurement of thermistor mount efficiency and antenna radiation characteristics.



Complementary equipment

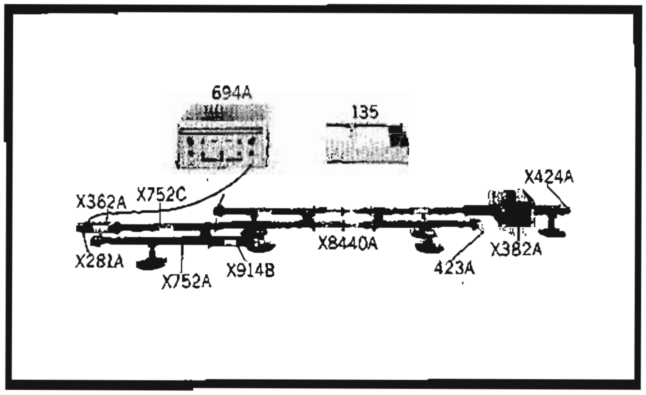
hp Instrument	Frequency range, gc	Page	Price
620A Signal Generator	7 to 11	194, 195	$2250 $2270(R)*
694A Sweep Oscillator	8 to 12.4	199 - 201	$3100
H01-694A Sweep Oscillator	7 to 12.4	199 - 201	$3400
694B Sweep Oscillator	8 to 12.4	199 - 201	$3450
H01-694B Sweep Oscillator	7 to 12.4	199 - 201	$3750
495A Microwave Amplifier	7 to 12.4	202	$2600
8734A PIN Modulator	7 to 12.4	190, 191	$300
8734B PIN Modulator	7 to 12.4	190, 191	$500

* Rack mount

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	174	$30
HX292B	Adapter, waveguide-to-waveguide		8.2 to 10 gc	1.05		1½	38	174	$25
H347A	Noise source, waveguide	±0.5 db	15.7 db	1.2		16	406	228, 229	$275
H370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	6⅜	162	226	$75
H372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	1	20⅞	530	226	$135
H375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	2	8¼	210	226	$125
H382A	Attenuator, precision variable	±2% of reading, or 0.1 db, whichever is greater	0 to 50 db	1.15	10	9-15/16	507	225	$350
H424A	Crystal detector	response: ±0.2 db	sensitivity >0.4 mv/μw	1.35		1-9/16	40	235	$155
H485B	Detector mount (less detector)			with barretter 1.25		6⅝	168	233	$85
H486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		3⅜	86	220, 221	$165
H487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		1-5/16	33	222	$80
H532A	Frequency meter, direct reading	dial: ±0.040% overall: ±0.075%				6¼	159	246	$300
H750	Directional couplers, cross-guide	±1.7 db	20, 30 db			4 x 4	102 x 102	236, 237	$75
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)	18⅜ 17½ 17½	473 445 445	236, 237	$150
H810B (809B) (444A)	Slotted sections, waveguide (Carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242, 243	$110 ($175) ($55)
H870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			6	152	244	$140
H910A	Termination, low power			1.02	1	5-9/16	141	245	$45
H914A	Moving load	load reflection: <0.5%	>½ wavelength	1.015	1	11½	267	245	$70
H920A	Adjustable short		>½ wavelength			4⅞	124	245	$85
H25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

X-band 8.2 to 12.4 gc



Accurate determination of reflection characteristics of Type N coaxial devices through the entire X-band range (8.2 to 12.4 gc) is achieved rapidly through use of the new hp X8440A Reflection Coefficient Bridge. Here, the 423A Crystal Detector is being examined, with the x-y recorder providing a permanent plot of the results.

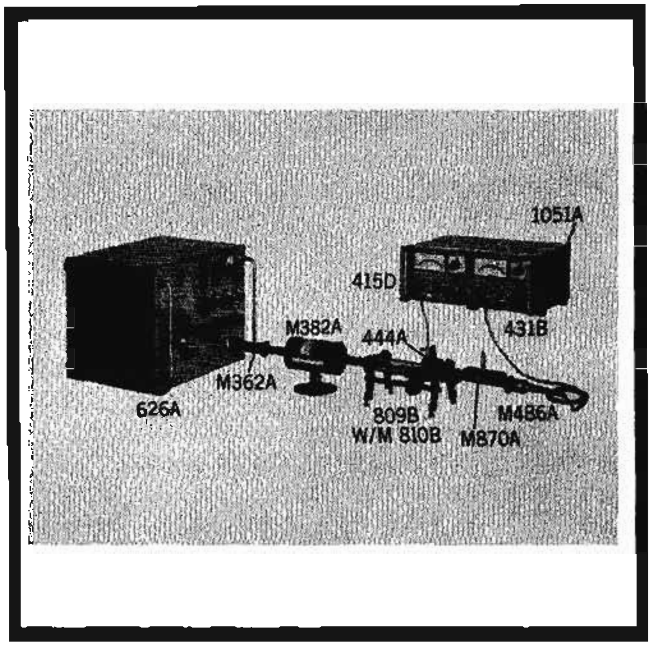
X-band equipment

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	174	$25
HX292B	Adapter, waveguide-to-waveguide		8.2 to 10 gc	1.05		1½	38	174	$25
MX292B	Adapter, waveguide-to-waveguide		10 to 12.4 gc	1.05		2⅜	60	174	$40
X347A	Noise source, waveguide	±0.5 db	15.9 db	1.2		14¾	375	228	$225
X362A	Low-pass filter	insertion loss, passband: <1 db stopband: >40 db	passband: 8.2 to 12.4 gc stopband: 16 to 37.5 gc	passband 1.5		5-11/32	136	213	$325
X370A	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	5¼	133	226	$65
X372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	1	19⅛	486	226	$110
X375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	2	7-3/16	183	226	$100
X382A	Attenuator, precision variable	±2% of reading or 0.1 db whichever is greater	0 to 50 db	1.15	10	15⅝	397	225	$275
X424A	Crystal detector	response: ±0.3 db	sensitivity >0.4 mv/μw	1.35		1⅜	35	235	$135
X485B	Detector mount (less detector)			with barretter 1.25		6-7/16	164	233	$75
X486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		2⅛	54	220,221	$145
X487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		1-3/16	30	222	$75
X532B	Frequency meter, direct reading	dial: ±0.05% overall: ±0.08%				4½	114	246	$200
X750	Directional couplers, cross-guide	±1.7 db	20, 30 db			3 x 3	76 x 76	236,237	$60
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	236,237	$125
X810B (809B) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242,243	$90 ($175) ($55)
X870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			5½	140	244	$130
X880A	E-H tuner	insertion loss: 3 db at 20:1 swr	corrects swr of 20			3½	89	244	$130
X885A	Waveguide phase shifter	<2° at 8.2 to 10 gc or 10% <3° at 10 to 12.4 gc or 10%	−360° to +360°	1.35	10	15⅝	397	246	$425
X910B	Termination, low power			1.015	1	6⅝	168	245	$35
X913A	Termination, high power			1.05	500	9½	241	174	$100
X914B	Moving load	load reflection: <0.5%	>½ wavelength	1.005	1	10⅛	257	245	$60
X916B	Standard reflection	coefficient: ±0.0025	nom. reflect. coeff.: 0.05			10¼	260	245	$125
X916C	Standard reflection	coefficient: ±0.0035	nom. reflect. coeff.: 0.1			10¼	260	245	$125
X916D	Standard reflection	coefficient: ±0.0045	nom. reflect. coeff.: 0.15			10¼	260	245	$125
X916E	Standard reflection	coefficient: ±0.007	nom. reflect. coeff.: 0.2			10¼	260	245	$125
X920A	Adjustable short		>½ wavelength			4⅞	124	245	$75
X930A	Waveguide shorting switch	insertion loss "Open": <0.05 db		"Open": 1.02 "Shorted": >125		3-11/16	94	174	$160
8735A	PIN modulator		35 db	1.7 (min. atten.) 2 (max. atten.)	1	6¾	171	190,191	$300
8735B	PIN modulator		80 db	1.9 (min. atten.) 2.2 (max. atten.)	1	10½	267	190,191	$500
11504A	Flexible waveguide					12	305		$35
X25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

M- AND P-BANDS, 10.0 TO 18.0 GC

M-band 10 to 15 gc

Illustrated here is a typical fixed-frequency measurement system for M-band. The M870A Slide Screw Tuner tunes the M486A Thermistor Mount to unity swr for improved power measurement accuracy. Note the portable microwave lab composed of the 431B Power Meter and 415D SWR Meter installed in the 1051A Combining Case. Both instruments are available with optional rechargeable batteries, making them especially useful in field measurement applications.



Complementary equipment

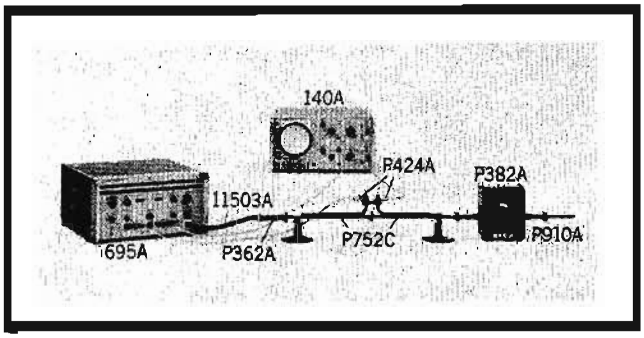
hp Instrument	Frequency range, gc	Page	Price
626A Signal Generator	10 to 15.5	196, 197	$3400 $3420(R)*
628A Signal Generator	15 to 21	196, 197	$3400 $3420(R)*
694A Sweep Oscillator	8 to 12.4	199 - 201	$3100
694B Sweep Oscillator	8 to 12.4	199 - 201	$3450
695A Sweep Oscillator	12.4 to 18	199 - 201	$3500
716B Klystron Power Supply		331	$875

*Rack mount.

M-band equipment

hp Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
MX292B	Adapter, waveguide-to-waveguide		10 to 12.4 gc	1.05		2⅜	60	174	$40
MP292B	Adapter, waveguide-to-waveguide		12.4 to 15 gc	1.05		2⅜	60	174	$40
M362A	Low-pass filter	insertion loss passband: <1 db stopband: >40 db	pass: 10 to 15.5 gc stop: 19 to 47 gc	passband 1.5		4-15/32	114	213	$350
M375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	1	6¼	159	226	$190
M382A	Attenuator, variable precision	±2% of reading or 0.1 db whichever is greater	0 to 50 db	1.15	10	13-7/32	336	225	$650
M424A	Crystal detector	response: ±0.5 db	sensitivity >0.3 mv/μw	1.5		1	25	235	$250
M486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		3	76	220	$195
M487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		15/16	24	222	$110
M532A	Frequency meter, direct reading	dial: ±0.053% overall: ±0.085%				4½	114	246	$300
M752A M752C M752D	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)	16-5/16 15-11/16 15-11/16	414 399 399	236, 237	$225
M810B (809B) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242, 243	$175 ($175) ($55)
M870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			5⅞	149	244	$170
M914A	Moving load	load reflection: <0.5%	>½ wavelength	<1.01	1	10	254	245	$85
M920A	Adjustable short		>½ wavelength			4-13/16	122	245	$125
M25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

P-Band 12.4 to 18.0 gc



The conventional swept-frequency reflectometer in the illustration is being used to examine the reflection characteristics of the P328A 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. Further discussion of swept-frequency measurement techniques will be found in Application Note 61.

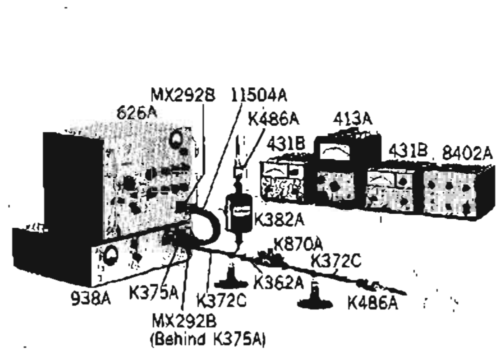
P-band equipment

hp Model	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
MP292B	Adapter, waveguide-to-waveguide		12.4 to 15 gc	1.05		2⅜	60	174	$40
NP292A	Adapter, waveguide-to-waveguide		15 to 18 gc	1.05		2⅜	60	174	$40
P347A	Noise source, waveguide	±0.5 db	16 db			14¾	375	228	$275
P362A	Low-pass filter	Insertion loss, pass-band: <1 db stopband: >40 db	pass: 12.4 to 18 gc stop: 23 to 54 gc	passband 1.5		3-11/16	94	213	$350
P370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	1	4⅛	105	226	$80
P372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	1	15½	394	226	$125
P375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	1	7¼	184	226	$135
P382A	Attenuator, precision variable	±2% of reading or 0.1 db, whichever is greater	0 to 50 db	1.15	5	12½	318	225	$300
P424A	Crystal detector	response: ±0.5 db	sensitivity >0.3 mv/μw	1.5		15/16	24	235	$175
P486A	Thermistor mount, compensated		0.001 to 10 mw	1.5		2½	64	220, 221	$195
P487B	Thermistor mount, broadband		0.01 to 10 mw	1.5		13/16	21	222	$110
P532A	Frequency meter, direct reading	dial: ±0.068% overall: ±0.1%				4½	114	246	$275
P752A P752C P752D	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	236, 237	$150
P810B (809B) (444A)	Slotted section, waveguide (Carriage for 810B) (Detector probe for 809B)			1.01		10¼	260	242, 243	$110 ($175) ($55)
P870A	Tuner, slide screw	insertion loss: <2 db at 20:1 swr	corrects swr of 20			5	127	244	$140
P880B	E-H tuner	insertion loss: 3 db at 20:1 swr	corrects swr of 20			2¼	57	244	$150
P885A	Waveguide phase shifter	lesser of 4° or 10%	−360° to +360°	1.35	5	12-5/16	312	246	$600
P910A	Termination, low power			1.02	1	4⅜	111	245	$40
P914A	Moving load	load reflection: <0.5%	>½ wavelength	1.02	0.5	9¾	248	245	$70
P920B	Adjustable short		>½ wavelength			5¾	146	245	$125
P932A	Harmonic mixer				0.1			63	$250
P25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3
11503A	Flexible waveguide, P-band					12	305		$48

K- AND R-BANDS, 18 TO 40 GC

K-band 18.0 to 26.5 gc

The Hewlett-Packard system illustrated on the right permits accurate determination of low values of insertion loss (the K362A Filter is the item under test in this photo). The high directivity of the K752C Directional Coupler provides excellent source match while the combination of the K870A Slide Screw Tuner and K372C Attenuator presents extremely low load swr, thereby minimizing mismatch ambiguities. The high stability of the 431B Power Meter/K486A Thermistor Mount makes the overall measurement simple and reliable.



Complementary equipment

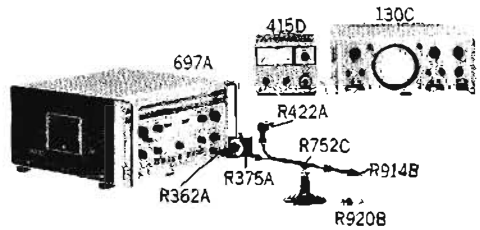
hp Instrument	Frequency range, gc	Page	Price
626A Signal Generator and 938A Frequency Doubler Set	20 to 26.5	626A: 196 938A: 198	\$3400 \$1700
696A Sweep Oscillator	18 to 26.5	199 - 201	\$4500

K-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 gc stop: 31 to 80 gc	passband 1.5		2½	64	213	\$385
K370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	0.5	3¼	83	226	\$115
K372	Attenuators, precision fixed	±0.5 db	10, 20 db	1.05	0.5	11½	292	226	\$240
K375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	0.5	4½	114	226	\$185
K382A	Attenuator, precision variable	±2% of reading or 0.1 db, whichever is greater	0 to 50 db	1.15	2	7⅝	194	225	\$475
K422A	Crystal detector	freq. resp.: ±2 db sens: 0.1 v dc/mw cw		2.5		2	51	235	\$250 \$540 (matched pair)
K486A	Thermistor mount, compensated		0.001 to 10 mw	2		2⅞	73	220	\$300
K487C	Thermistor mount, broadband		0.01 to 10 mw	2		1⅝	41	222	\$225
K532A	Frequency meter, direct reading	dial: ±0.077% overall: ±0.11%				4½	114	246	\$350
K752A K752C K752D	Directional couplers, multi-hole	mean: ±0.7 db variation: ±0.5 db	3 db 10 db 20 db	1.1 1.05 1.05	0.5 (in aux. guide)	10⅜ 9-15/16 9-15/16	264 252 252	236, 237	\$200
K815B (814B) (446B)	Slotted section, waveguide (Carriage for 815B) (Detector probe for 814B)			1.01		7-9/16	192	242, 243	\$265 (\$225) (\$145)
K870A	Tuner, slide screw	insertion loss: <3 db at 20:1 swr	corrects swr of 20			4¼	108	244	\$250
K914B	Moving load	load reflection: <0.5%	>½ wavelength	1.01	0.5	6⅛	156	245	\$250
K920B	Adjustable short		>½ wavelength			5½	140	245	\$155
K25	Waveguide clamp							174	\$2.50
24	Waveguide stand							174	\$3

*Circular flange adapter (UG-425/U) 11515A, \$35 each.

R-band 26.5 to 40 gc



The set-up illustrated on the left permits rapid measurement of reflection characteristics on a swept basis. The hp 415D SWR Meter is serving as a preamplifier for the 1000 cps modulation signal displayed on the oscilloscope. This technique is especially useful when adjustments must be made to the component under test to optimize its performance.

Complementary equipment

hp Instrument	Frequency range, gc	Page	Price
626A Signal Generator and 940A Frequency Doubler Set	26.5 to 31	626A: 196 940A: 198	$3400 $1700
628A Signal Generator and 940A Frequency Doubler Set	30 to 40	628A: 196 940A: 198	$3400 $1700
697A Sweep Oscillator	26.5 to 40	199 - 201	$6500

R-band equipment

hp Model*	Description	Accuracy	Range	SWR (max.)	Power (watts)	Length (in)	Length (mm)	Page reference	Price
R362A	Low-pass filter	insertion loss, passband: <2 db, stop-band rej.: >35 db	pass: 26.5 to 40 gc stop: 47 to 120 gc	passband 1.8		1-21/32	42	213	$385
R370	Attenuators, fixed	±20%	3, 6, 10, 20 db	1.15	0.5	3	76	226	$125
R372	Attenuators, precision fixed	±0.5 db (±0.6 db R372D)	10, 20 db	1.05	0.5	10	254	226	$275
R375A	Attenuator, flap	±1 db at <10 db ±2 db at >10 db	0 to 20 db	1.15	0.5	4⅜	111	226	$200
R382A	Attenuator, precision variable	±2% of reading or 0.1 db, whichever is greater	0 to 50 db	1.15	1	6-7/16	164	225	$500
R422A	Crystal detector	freq. resp.: ±2 db sens: 0.1 v dc/mw cw		3		2	51	235	$250 $540 (matched pair)
R486A	Thermistor mount, compensated		0.001 to 10 mw	2		3	76	220	$375
R487B	Thermistor mount, broadband		0.01 to 10 mw	2		1⅜	35	222	$275
R532A	Frequency meter, direct reading	dial: ±0.083% overall: ±0.12%				4½	114	246	$400
R752A R752C R752D	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)	11⅝ 8⅝ 8-23/32	295 219 222	236, 237	$250
R815B (814B) (446B)	Slotted section, waveguide *(Carriage for 815B)* *(Detector probe for 814B)*			1.01		7-9/16	192	242, 243	$265 ($225) ($145)
R870A	Tuner, slide screw	insertion loss: <3 db at 20:1 swr	corrects swr of 20			4⅜	111	244	$300
R914B	Moving load	load reflec.: <0.5%	>½ wavelength	1.01	0.5	5⅛	130	245	$250
R920B	Adjustable short		>½ wavelength			4½	114	245	$155
R25	Waveguide clamp							174	$2.50
24	Waveguide stand							174	$3

* Circular flange adapter (UG-381/U) hp 11516A, $40 each.

ADAPTERS, WAVEGUIDE STAND AND CLAMPS, HIGH-POWER TERMINATIONS, WAVEGUIDE SHORTING SWITCH

Increase flexibility of microwave measurements

281A, 292A,B Adapters

Fitted with a standard Type N female connector and a plain AN flange, hp 281A Waveguide-to-Coaxial Adapters use a probe with a low-loss dielectric sheath to transform waveguide impedance into coaxial impedance. Power may be transmitted in either direction, and each adapter covers the full frequency range of its waveguide band with swr less than 1.25.

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

hp Model	Maximum swr	Frequency range (gc)	Fits waveguide size OD (in.)	Fits waveguide size (EIA)	Price
S281A	1.25	2.60 to 3.95	3 x 1½	WR284	$50
G281A	1.25	3.95 to 5.85	2 x 1	WR187	$40
J281A	1.25*	5.30 to 8.20	1½ x ¾	WR137	$35
H281A	1.25	7.05 to 10.0	1¼ x ⅝	WR112	$30
X281A	1.25	8.20 to 12.4	1 x ½	WR 90	$25

*1.3 from 5.3 to 5.5 gc.

Specifications, 292A,B

hp Model	SWR	Length (in.)	Length (mm)	Frequency range (gc)	Price
HX292B	1.05	1½	38	8.20 to 10.0	$25
MX292B	1.05	2⅜	60	10.0 to 12.4	$40
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

X913A Termination

The X913A is a high-power termination which does not require cumbersome water connections. The unit will dissipate 500 watts average, 100 kw peak, and its swr over the full 8.2 to 12.4 gc range is less than 1.05. Price: X913A, $100.

X930A Shorting Switch

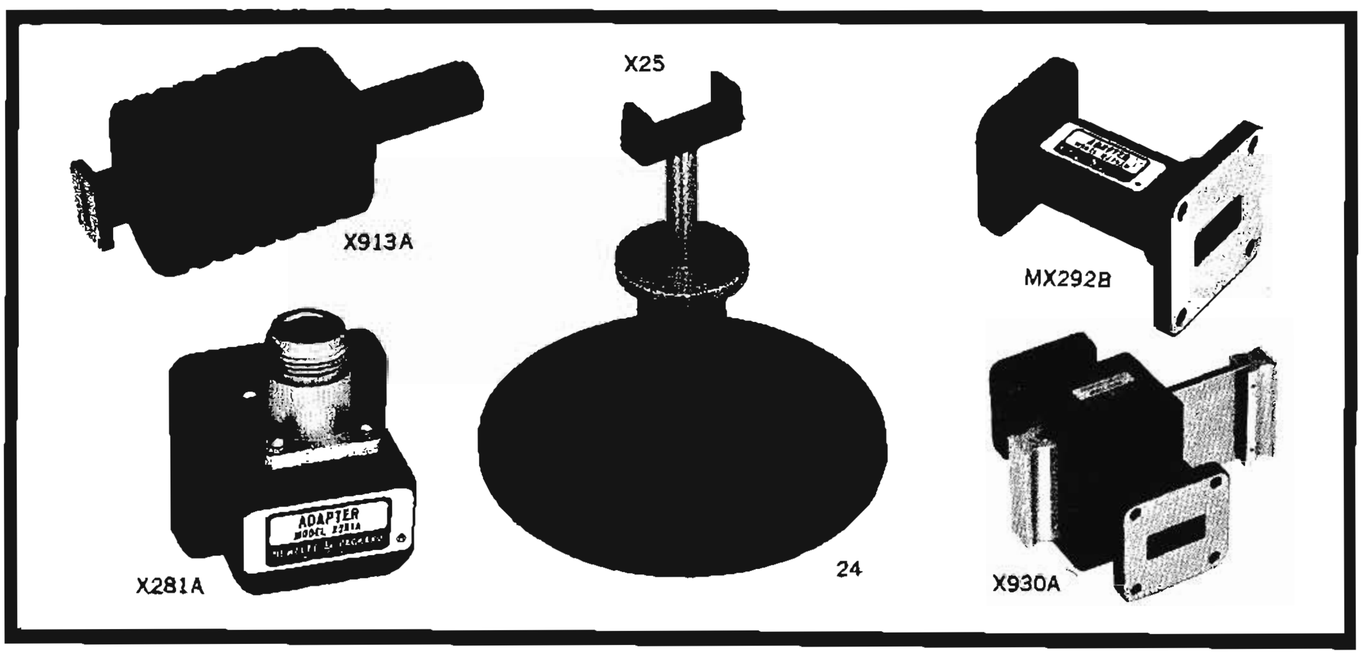
Model X930A, 8.2 to 12.4 gc, provides a removable short in a waveguide circuit. SWR is less than 1.02 in the "open" position, greater than 125 in the "short" position. Price: hp X930A, $160.

24 Waveguide Stand, 25 Waveguide Clamps

Cast and machined from zinc alloy, the hp 24 Waveguide Stand locks the hp 25 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: hp 24, $3. The hp 25 Waveguide Clamps are offered in nine sizes to fit waveguide equipment covering frequencies from 2.6 to 40 gc. They consist of a molded plastic cradle with a center rod. Price: hp 25: $2.50.

Specifications, 25

hp Model	Waveguide size (outside dimensions, in.)	Waveguide size EIA
S25	3 x 1½	WR284
G25	2 x 1	WR187
J25	1½ x ¾	WR137
H25	1¼ x ⅝	WR112
X25	1 x ½	WR 90
M25	0.850 x 0.475	WR 75
P25	0.702 x 0.391	WR 62
K25	½ x ¼	WR 42
R25	0.360 x 0.220	WR 28



SIGNAL GENERATORS

Essential to practically all microwave measurement applications is signal generating equipment. This section describes the wide variety of Hewlett-Packard instruments—signal generators and sources, sweep oscillators, microwave amplifiers, modulators, frequency stabilizing equipment and special-purpose instruments—available for use in the most exacting requirements.

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 kc and 40 gc. Each 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 assures 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 for driving bridges, slotted lines, filter networks, etc.

Table 1 lists the individual Hewlett-Packard signal generators and their major characteristics.

LF to uhf signal generators

These signal generators, including hp 606A, 608C, 608D and 612A, collectively cover frequencies from 50 kc to 1.23 gc and are characterized by extremely low drift and incidental frequency modulation. All may be amplitude (sine, square, pulse) modulated. A feedback loop in the 606A keeps its output and per cent modulation constant as frequency is varied. For very high on-off ratios, pulses may be applied directly to the oscillator of the 612A, which also may be used to simulate positive or negative tv transmissions.

UHF to shf signal generators and sources

This group of instruments, covering 800 mc to 21 gc, features extremely simple operation. The 614A, 616B, 618B, 620A, 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 pushbuttons permit fast, easy selection of function (cw, leveled output, square-wave modulation or external amplitude, pulse or frequency modulation). In addition, each unit contains a unique PIN diode modulator which permits such a wide range

Table 1

hp Model	Frequency range	Characteristics	Page
606A Signal Generator	50 kc to 65 mc	output 3 v to 0.1 μv, mod. BW dc to 20 kc, low drift and noise, low incidental FM, low distortion	180
608C Signal Generator	10 to 480 mc	output 1 v to 0.1 μv, into 50-ohm load; AM, pulse modulation, direct calibration	182
608D Signal Generator	10 to 420 mc	output 0.5 v to 0.1 μv into 50 ohms, amplitude, pulse modulation, direct calibration, low incidental FM and drift	182
612A Signal Generator	450 to 1230 mc	output 0.5 v to 0.1 μv into 50-ohm load; AM, pulse or square-wave modulation, direct calibration	187
614A Signal Generator	0.8 to 2.1 gc	output at least 0.5 mw to —127 dbm (0.1 μv) into 50 ohms, pulse or frequency modulation, direct calibration	193
8614A Signal Generator	0.8 to 2.4 gc	output +10 to —127 dbm into 50 ohms, leveled below 0 dbm; internal square-wave, external pulse, AM and FM; auxiliary rf output	188
8614B Signal Source	0.8 to 2.4 gc	output 15 mw; precision attenuator 130 db range; internal square-wave, external pulse and FM; auxiliary rf output	188
616B Signal Generator	1.8 to 4.2 gc	output 1 mw to —127 dbm (0.1 μv) into 50-ohm load, pulse or frequency modulation, direct calibration	193
8616A Signal Generator	1.8 to 4.5 gc	output +3 to —127 dbm into 50 ohms, leveled below 0 dbm; internal square-wave, external pulse, AM and FM; auxiliary rf output	188
8616B Signal Source	1.8 to 4.5 gc	output 3 mw; precision attenuator 130 db range; internal square-wave, external pulse and FM; auxiliary rf output	188
618B Signal Generator	3.8 to 7.6 gc	output 1 mw to —127 dbm (0.1 μv) into 50 ohms, pulse, frequency or square-wave modulation, direct calibration	194
620A Signal Generator	7 to 11 gc	output 1 mw to —127 dbm (0.1 μv) into 50 ohms, pulse, frequency or square-wave modulation, direct calibration	194
626A Signal Generator	10 to 15.5 gc	output +10 dbm to —90 dbm; pulse, frequency or square-wave modulation, direct calibration	196
628A Signal Generator	15 to 21 gc	output +10 dbm to —90 dbm; pulse, frequency or square-wave modulation, direct calibration	196
938A Frequency Doubler	18 to 26.5 gc	driven by 9 to 13.25 gc source, hp 626A, 694A,B or klystrons; 100 db precision attenuator	198
940A Frequency Doubler	26.5 to 40 gc	driven by 13.25 to 20 gc source, hp 628A, 695A or klystrons; 100 db precision attenuator	198

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 gc range. Designed to be driven by signal sources in the 9 to 20 gc 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.

In addition to the hp models listed here, the Dymec Division manufactures several rf test sets; each one consists of a signal generator, frequency meter and power meter. Thus, a complete testing system is available in one unit for checking communication and radar systems. Details are given on page 203.

Stabilized microwave signal generation

Absolute control of reflex klystron oscillator frequencies is possible using Dymec synchronizing instruments such as the DY-2650A Oscillator Synchronizer and DY-2654A Frequency Standard Synchronizer. Both instruments employ automatic phase control techniques to provide signal stability essentially equal to that of an internal or external crystal reference. Applications requiring extremely stable signals include doppler systems, radio astronomy receivers, microwave spectroscopy and parametric amplifier pumps.

The DY-2650A incorporates an internal reference oscillator, while the DY-2654A works in conjunction with a packaged quartz oscillator such as the hp 107BR (page 100). Both synchronizers are fully compatible with hp 8614A,B and 8616A,B Signal Generators. Dymec synchronizers introduce no frequency error. Standard instruments will stabilize most reflex klystrons, 1 to 12.4 gc, with complete elimination of klystron drift and minimization of incidental FM caused by klystron noise, power supply ripple and mechanical shock. Modified versions and cascaded instruments allow operation from 0.1 to 40 gc.

Figure 1 shows the functional diagram of the DY-2650A. The DY-2654A is similar, the major variations being in the rf and IF reference section to accommodate the external reference, and the elimination of the VFO.

DY-2650A is essentially a crystal-controlled superheterodyne receiver terminating in a phase comparator. Sample of the signal frequency is mixed with harmonics of the rf reference to produce an intermediate frequency of 30 mc, which is compared in phase with the 30 mc reference. For stabilizing a klystron, the resultant phase error voltage is added in series with the klystron reflector power supply voltage.

The rf reference frequency is controlled by a quartz crystal, oven-mounted for temperature stabilization, operating at a frequency between 100 and 120 mc. The harmonics of the internal reference are spaced between 200 and 240 mc apart, depending on the crystal selected. For each harmonic there are two "lock" frequencies, one 30 mc above the harmonic and the other 30 mc below. A number of lock points are therefore available for a given crystal. As an example, a 100 mc crystal produces 42 available lock frequencies between 8.2 and 12.4 gc (X-band).

The signal frequencies at which locking will occur with a particular crystal are given by the formula:

$F_{signal} = 2NF_{xtal} \pm F_{if}$

Where F_{xtal} = 100 to 120 mc (as specified)

F_{if} = 30 mc (fixed) or 29 to 31 mc (variable)

N = harmonic number (5 through 62)

Detailed specifications of the DY-2650A and DY-2654A, and information on systems formed from these instruments are listed on page 192.

Boonton signal sources

Signal generators, available from the Boonton Division, include general-purpose oscillators and amplifiers, FM signal generators, sweep signal generators,

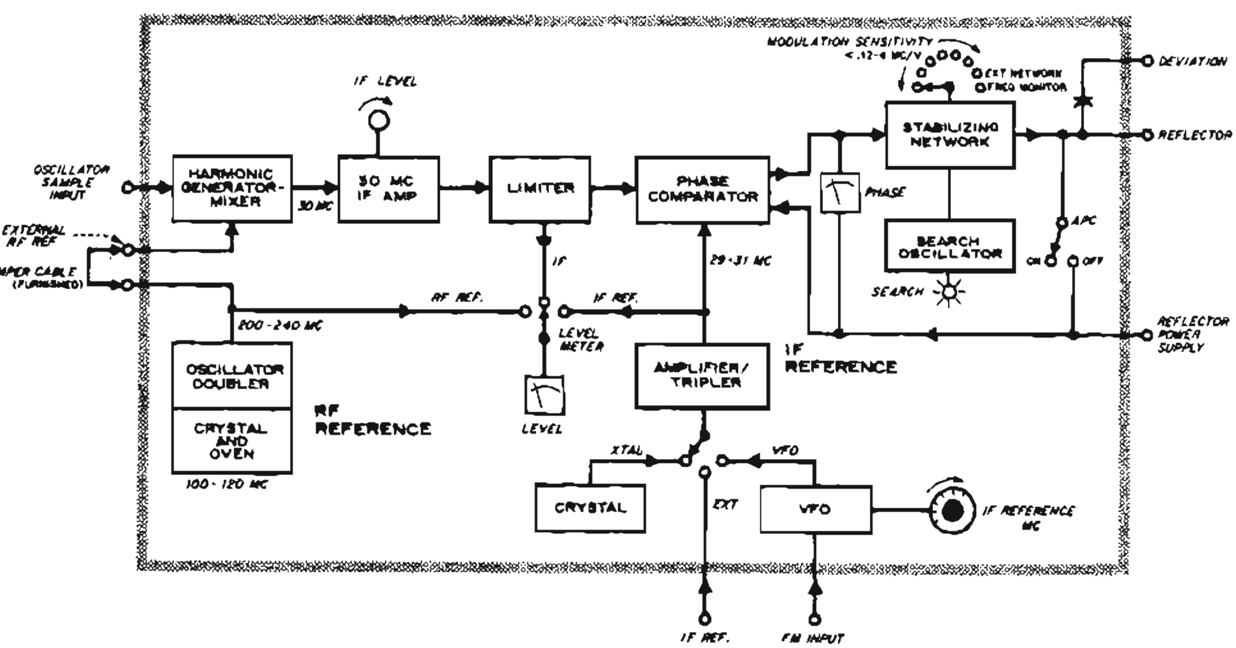


Figure 1. DY-2650A Oscillator Synchronizer.

FM stereo modulators and specialized signal generators for aircraft navigation systems.

The 3200A VHF Oscillator is a compact, versatile source in the 10 to 500 mc range suitable for driving bridges, slotted lines and general-purpose laboratory work. The 230A Signal Generator Power Amplifier provides a convenient means of obtaining power levels up to 5 watts in the 10 to 500 mc range when operated in conjunction with a signal generator.

FM signal generators were pioneered by Boonton in 1941 and represent the latest state of the art, offering excellent modulation linearity and stability. The 202H FM-AM Signal Generator operates in the 54 to 216 mc range and is designed to serve the broadcast FM, vhf-tv, and mobile communications markets. The 202J FM-AM Signal Generator is specifically designed for vhf telemetry and covers from 195 to 270 mc. The accessory 207H Univerter provides additional rf and IF frequency coverage when used with either the 202H or 202J Signal Generators.

The 240A Sweep Signal Generator provides continuous coverage from 4.5 to 120 mc and includes complete facilities for precision sweep measurements including both crystal birdie and pip markers; an internal mixer system is provided, so that the markers do not pass through the circuit under test. The 203B Univerter, as an accessory for the 240A, provides additional frequency coverage in the range from 100 kc to 25 mc.

The 219A FM Stereo Modulator is designed to reproduce flexibly the FM stereo broadcast signal as outlined in FCC Docket 13506. The output may be used directly with baseband circuits or may, in turn, be used to modulate the 202H Signal Generator.

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.

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 gc 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.

Modulators

Sinusoidal and complex modulation of microwave signals is possible with the hp 8730 Series PIN Modulators. The series covers the coaxial range from 0.8 to 12.4 gc in four overlapping bands, in addition to X-band in waveguide. Utilizing PIN diodes, the modulators present a good match and virtually eliminate frequency pulling.

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 mc. 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.

New modulation techniques are possible with the hp modulators, since they may be connected in series for compound modulation, such as amplitude modulation of rf pulses.

Two models of PIN modulators are available within each band: one which provides at least 35 db of attenuation range, and one which provides at least 80 db.

The 35 db version is especially useful as the control element in a closed-loop system for microwave power leveling. Conventional amplitude modulation also can be accomplished. The 80 db modulators provide high on/off ratios for critical pulse-modulation applications. The modulators are capable of achieving pulse rise and fall times of typically 30 nanoseconds. The hp Model 8403A Modulator provides complete control of

Group	Model	Frequency range	Output range	Modulation FM	Modulation AM	Application	Page
general-purpose	3200A	10-500 mc	up to 200 mw		0-30%	oscillator	186
	230A	10-500 mc	0 to 15 volts	reproduces driving signal		amplifier	184
FM	202H	54-216 mc	0.1 μv-0.2 v	0-250 kc	0-100%	FM, tv, mobile	208
	202J	195-270 mc	0.1 μv-0.2 v	0-300 kc	0-100%	telemetering	209
	207H	100 kc-55 mc	1 μv-0.1 v	reproduces 202H/J		202H/J accessory	211
stereo	219A	50 cps-75 kc	0-7.5 v	per FCC Docket 13506		FM stereo	210
sweep	240A	4.5-120 mc	1 μv-0.3 v	±30%	30%	sweep display	185
	203B	100 kc-25 mc	1 μv-0.1 v	reproduces 240A		240A accessory	185
aircraft navigation	211A	88-140 mc	0.1 μv-0.2 v		0-100%	VOR and localizer	204
	232A	329.3-335 mc	1 μv-0.2 v		0-100%	glide slope	205
	8925A	950-1250 mc	—10 to —120 dbm	special pulse		DME and ATC	206

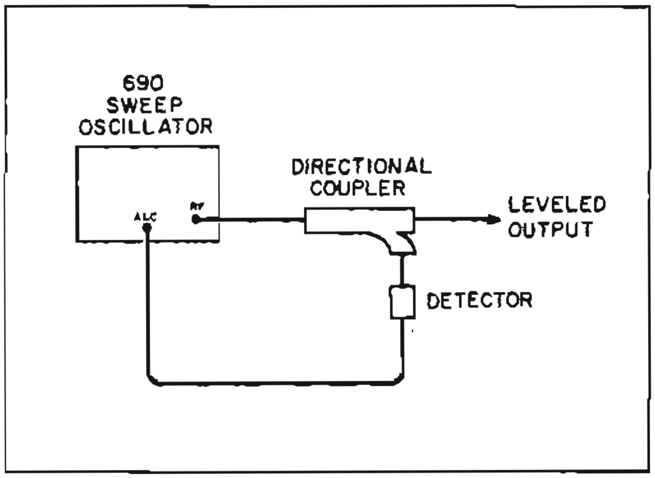


Figure 2. Basic closed-loop leveling system.

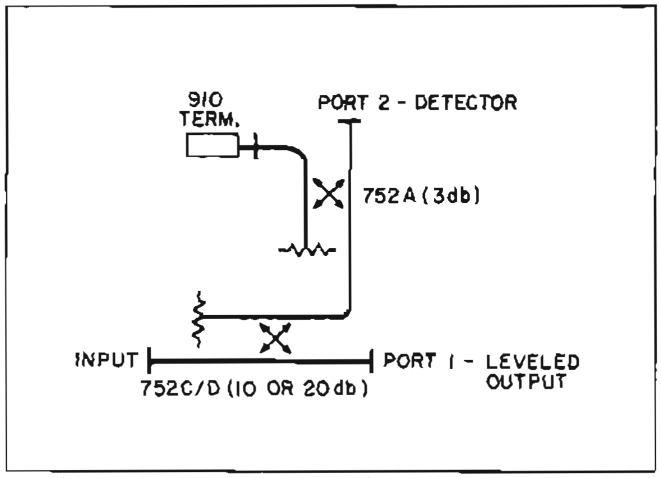


Figure 3. "Back-to-back" waveguide coupler arrangement for extremely flat output.

the PIN modulators, supplying the appropriate modulation wave shapes and bias levels for fast rise times, rated on/off ratios and amplitude modulation.

Sweep oscillators

Swept-frequency measurement techniques first became feasible when dependable means of sweeping the rf source were developed. The original mechanically swept sources (usually klystrons) later gave way to electronically-tuned backward-wave oscillators which brought added sophistication to swept measurements. Hewlett-Packard's extensive use of swept-frequency testing has not only resulted in major improvements in measurement techniques, but also has provided the experience that has led to development of the hp 690 Series Sweep Oscillators.

These instruments—covering 1 to 40 gc—combine unique features to make them the most flexible and most accurate sweepers available. 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 broad 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. These oscillators have voltage-tuned backward-wave tubes which generate cw and swept frequencies with a wide variety of modulation capabilities. Included is internal, square-wave modulation, with a range of 950 to 1050 cps, plus external AM and FM. External FM permits frequency programming including externally controlled sweeps over the whole range or any part of it.

Models in the 1 to 12.4 gc range can be provided with PIN diode attenuators which permit all of the amplitude-modulation functions, including leveling, to be performed independent of the BWO tube. The result is the virtual elimination of frequency pulling, which, in turn, results in extremely high frequency accuracy and linearity and very low incidental FM.

Leveled output from sweep oscillators

The development of closed-loop feedback systems for leveling sweep oscillator

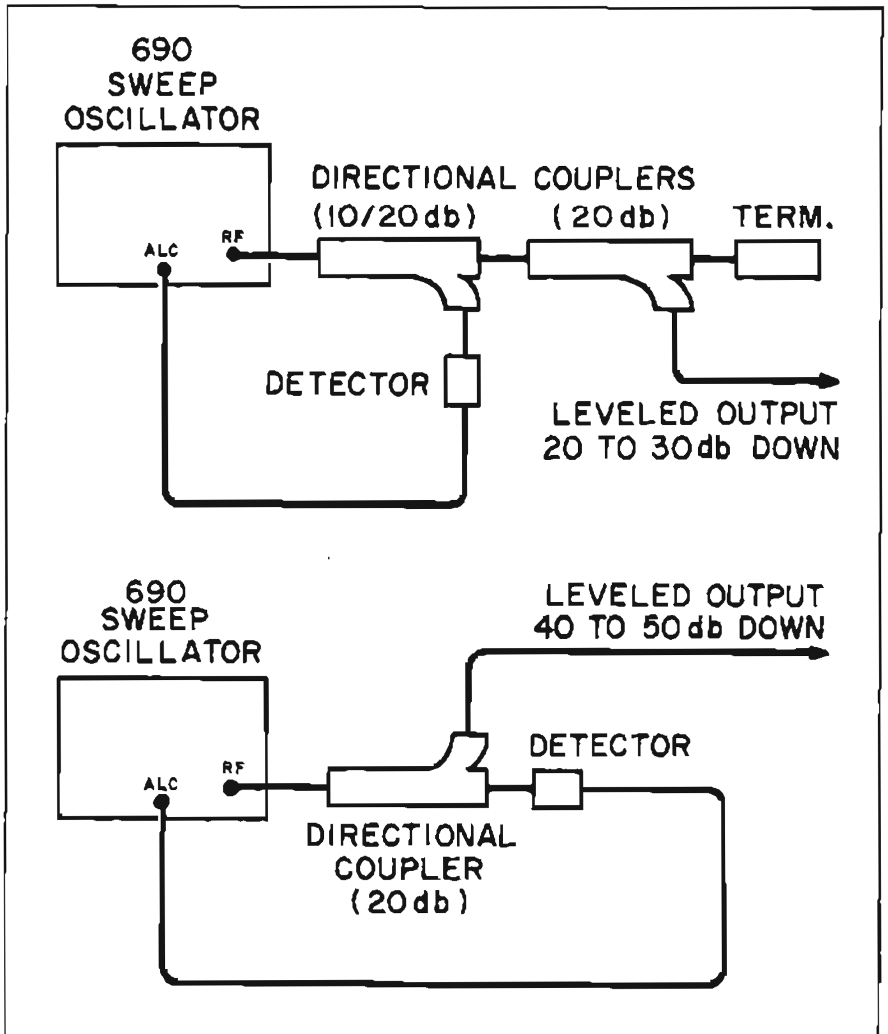


Figure 4. Two possible set-ups for generating leveled signals at reduced output power.

output power has greatly expanded the practical scope of swept-frequency measurements. The basic closed-loop system is shown in Figure 2.

The hp 690 Series Sweep Oscillators contain a high-performance leveling amplifier for automatic level control (ALC); the power variation that occurs at the system output is primarily determined by coupler and detector variation. Leveling can be accomplished with either a crystal detector or thermistor mount/power meter serving as the detector. For coaxial systems, hp has developed the 780 Series Directional Detectors (page 238) 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 hp directional detectors. For power meter leveling in coax, hp 790 Series Flat Directional Couplers (page 238) can be used in conjunction with the hp 478A Coax Thermistor Mount and 431B Power Meter (page 220). Power meter leveling allows establishment of known absolute power levels, and the 431B's range switch can serve as a very accurate attenuation control.

To level output power in waveguide systems, hp 752 Series Waveguide Directional Couplers (page 236) and 424A Series Waveguide Crystal Detectors (page 235) are used. With better than 40 db directivity, 752 Series Couplers in leveled systems provide an extremely 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 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 3. 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.

Typical leveled systems

The system block diagrams on these pages show typical equipment configurations for establishing various levels of flat power output. Each system can be constructed in either waveguide or coax, and either crystal detectors or thermistor mount/power meter detection can be employed.

Reflectometers

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.

Especially useful is the new hp 1416A plug-in for the 140A Oscilloscope (page 277). Designed expressly for use in leveled reflectometer systems employing square-law detectors, the 1416A provides a highly accurate 30 db of dynamic range when used with hp 423A and 424A Series Crystal Detectors. It also provides high resolution; sensitivity of 1 db/cm permits close examination of results.

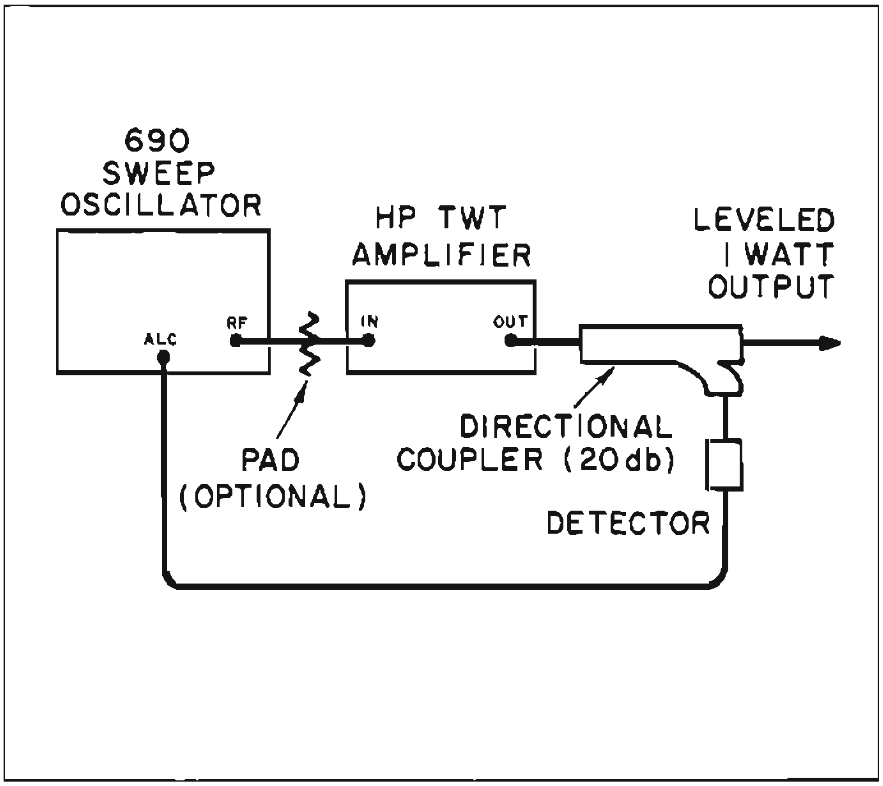


Figure 5. System for generating high level, flat output. The "pad" between the sweep oscillator and the TWT amplifier is used to keep the signal level into the amplifier below that which would saturate the TWT.

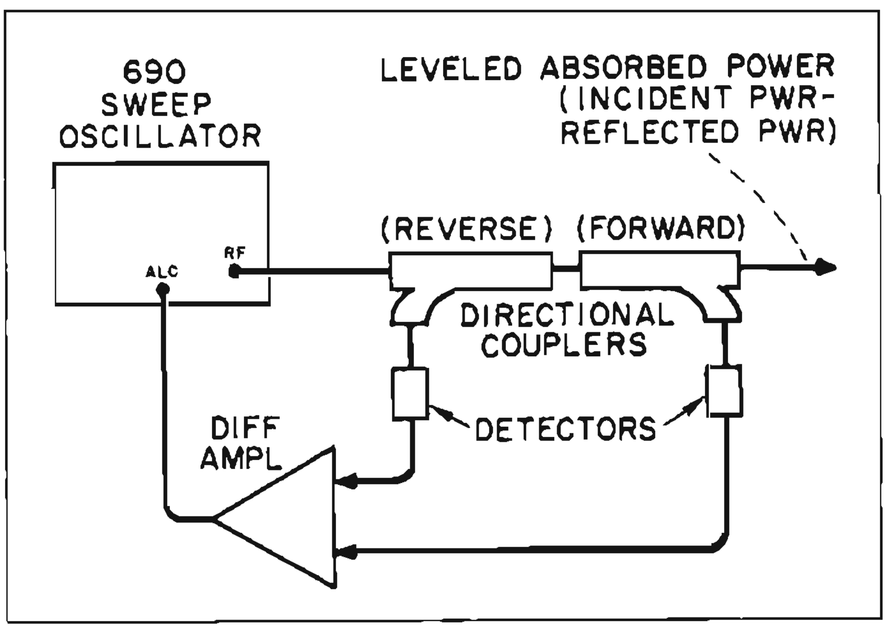


Figure 6. This system levels on the net forward (i.e., absorbed) power, making it useful for applications such as bolometer mount efficiency measurements, driving antennas, etc.

606A HF SIGNAL GENERATOR

Convenience and utility in a 50 kc to 65 mc signal generator

Advantages:

- Wide range; includes 30 and 60 mc IF bands
- Constant output level
- Constant modulation level
- Wide modulation capabilities
- 3 volt output into 50 ohms
- Crystal calibrator insures exact frequencies
- Low envelope distortion

Uses:

- Measuring receiver and IF circuit gain, selectivity and image rejection
- Driving bridges, antennas, filters

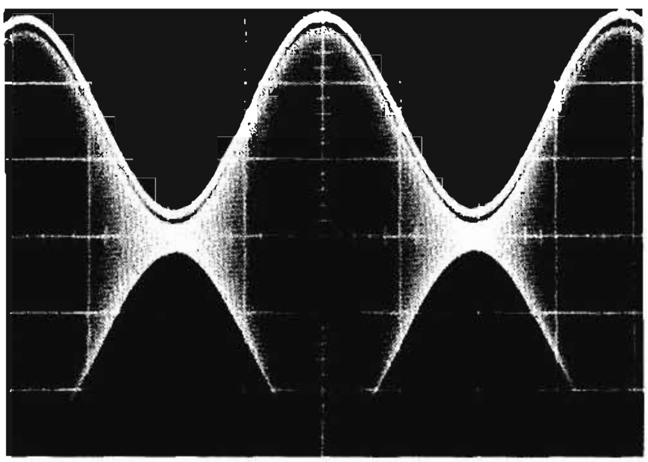


Figure 1. Dual-trace presentation comparing modulated output from hp 606A with internal 1 kc modulating waveform (positioned closely above rf envelope).

The hp 606A Signal Generator is an extremely versatile, easy-to-use signal source. Its wide frequency and output range, accurate calibration and excellent modulation characteristics fit it for many measurement applications.

A feedback circuit maintains both output level and per cent modulation essentially constant over the entire frequency range. Thus, it is usually unnecessary to readjust either the output level or modulation controls when varying frequency. Even the output level can be varied without seriously affecting per cent modulation. Another advantage provided by the feedback circuit is the reduction of envelope distortion during modulation.

Low distortion, broad modulation bandwidth

Because envelope distortion is low, overall distortion measurements may be made on high-fidelity AM receivers by applying the hp 606A output to the receiver's antenna terminals (see Figure 1).

The 606A may be modulated with signals from dc to 20 kc, by square waves and other complex signals (see Figure 2). Square-wave and pulse modulation of the carrier permit examination of the overall transient and pulse response of receivers. Such modulation characteristics permit tone-burst modulation and remote programming, as well as the more conventional applications.

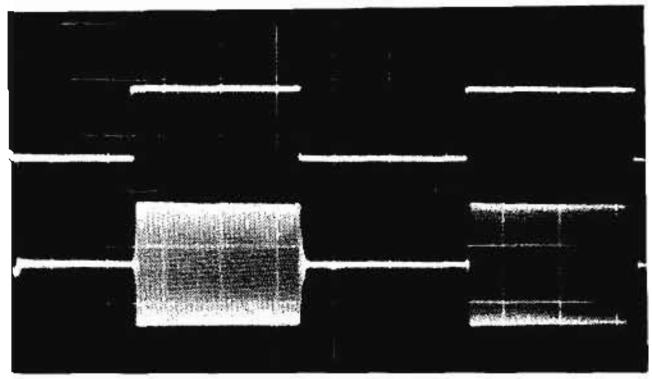


Figure 2. Dual-trace presentation showing carrier in the broadcast band modulated by a 1 kc square wave.

Accessory

The hp 11507A Output Termination (10:1) and IEEE dummy antenna (see "Accessories Available" under Specifications) is a multi-purpose termination which enhances the usefulness of the hp 606A by:

a. providing a matched 50-ohm termination and reducing the source impedance to 25 ohms.
b. providing a 20 db (10:1) divider which also reduces source impedance to 5 ohms.
c. providing a dummy antenna having the IEEE standard characteristics for receiver measurements.

Specifications

Frequency range: 50 kc to 65 mc in six bands: 50 to 170 kc; 165 to 560 kc; 530 to 1800 kc; 1.76 to 6 mc; 5.8 to 19.2 mc; 19 to 65 mc.

Frequency accuracy: within ±1%.

Frequency calibrator: crystal oscillator provides check points at 100 kc (useful to 6 mc), and 1 mc intervals (useful to 65 mc), accurate within 0.01% from 0° to 50°C.

RF output level: continuously adjustable 0.1 μv to 3 v into a 50-ohm resistive load; calibration in volts and dbm (0 dbm is 1 mw or 0.223 v rms into 50 ohms).

Output accuracy: within ±1 db into 50-ohm resistive load.

Frequency response: within ±1 db into 50-ohm resistive load over entire frequency range, any output level setting.

Output impedance: 50 ohms; swr less than 1.1 on 0.3 volt and lower ranges, less than 1.2 on 1 volt and 3 volt ranges; BNC output connector (female).

Spurious harmonic output: less than 3%.

Leakage: negligible; permits receiver sensitivity measurements down to at least 0.1 microvolt.

Amplitude modulation: continuously adjustable from 0 to 100%, indicated by a panel meter; modulation level is constant within ±0.5 db regardless of carrier frequency and output level changes.

Internal modulation: 0 to 100% sinusoidal modulation at 400 cps ±5% or 1000 cps ±5%; internal modulation voltage appears at modulation jack.

Modulation bandwidth: dc to 20 kc maximum, depends on carrier frequency, f_c, and per cent modulation as shown in the following table:

11507A

606A

Max. mod.	30% mod.	70% mod.	Square-wave mod.
Frequency	0.06 f_c	0.02 f_c	0.003 f_c (3 kc max)

Spurious AM: hum and noise sidebands are 70 db below carrier down to thermal level of 50-ohm output system.

Frequency drift (on 1 v and lower ranges): less than 0.005% or 5 cps, whichever is greater, for a 10-minute period after warm-up or restabilization at frequency of use.

Power: 115 or 230 v ±10%, 50 to 1000 cps, 135 w.

Dimensions: cabinet: 20¾" wide, 12½" high, 14¾" deep (527 x 318 x 370 mm); rack mount: 19" wide, 10½" high, 13-3/8" deep behind panel (483 x 266 x 340 mm).

Weight: net 54 lbs (24,3 kg), shipping 65 lbs (29,3 kg) (cabinet); net 51 lbs (23 kg), shipping 66 lbs (29,7 kg) (rack mount).

Accessories available: 11507A Output Termination with 50 ohms termination, 5 ohms termination (10:1 voltage division), and IEEE standard dummy antenna (10:1 voltage division), $70.

Price: hp 606A, $1350 (cabinet); hp 606AR, $1335 (rack mount).

608C,D VHF SIGNAL GENERATORS

Finest tools available for measurements 10 to 480 mc

Advantages:

- Wide range, direct calibration
- Convenient operation
- Incidental FM less than 1 kc
- Drift less than 0.005%
- High power output
- Microsecond pulsing
- Broad modulation capabilities

Uses:

- Testing and aligning vhf communications receivers
- Measuring gain, sensitivity, selectivity, image rejection of receivers, IF amplifiers, broadband amplifiers and other vhf equipment
- Driving bridges, slotted lines, antennas, filter networks, etc.

Hewlett-Packard 608C,D are designed as broadly applicable vhf signal generators. They offer the highest stability attained in production equipment of their type. There is almost a complete absence of incidental FM (less than 1 kc for the 608D), and frequency drift is held low despite line voltage variations. This performance is possible because of the master oscillator-output amplifier construction and close filament regulation of the tubes.

Premium quality 608D

Output of the 608D is calibrated from 0.1 μvolt to 0.5 volt throughout the frequency range of 10 to 420 mc. A built-in crystal calibrator provides accurate frequency check points in 1 and 5 mc steps throughout the range. Modulation capabilities are extremely broad, allowing pulse and transient testing of vhf receivers. At the same time, envelope distortion, incidental FM and drift are kept low, so that measurements of high-slope, narrow-band circuits are accurate and reliable. Low incidental FM is the result of using a buffer amplifier between the master oscillator and power amplifier. Pulses as short as 1 μsec are available at rf output frequencies above 100 mc. Percentage modulation is read directly on a front-panel meter.

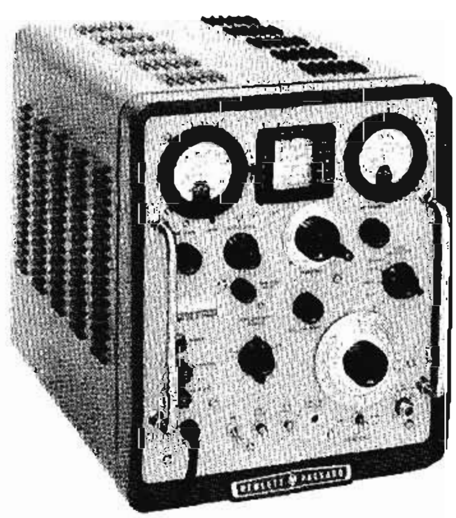
Finest construction

An important feature of the hp 608D is the mechanical design and construction employed throughout. Aluminum castings and cabinets reduce weight at no sacrifice in strength or ruggedness. Circuitry is clean and accessible. Dial, capacitor and turret drives are all precision-built and ball-bearing equipped. Variable capacitors are specially manufactured by Hewlett-Packard and feature electrically welded Invar low temperature steel plates to minimize drift. Sealed transformers are used throughout, and construction is militarized.

608C VHF Signal Generator

The 608C is a high-power, stable and highly accurate vhf signal generator for general laboratory and field use. Utilizing a master oscillator-power amplifier circuit, Model 608C provides 1 volt maximum output and a broad frequency coverage of 10 to 480 mc. It can be amplitude modulated to 95% and provides high-quality pulses as short as 1 μsec at rf output frequencies above 100 mc. As in the 608D, rf leakage is negligible, and the rf attenuator is calibrated to 0.1 μvolt.

The 608C is especially suited for measurements of gain, selectivity, sensitivity or image rejection of receivers, IF amplifiers, broadband amplifiers and other vhf equipment. It also provides ample output for driving bridges, slotted lines, transmission lines, antennas, filter networks and other circuits operating in the vhf band.



608D

Accessories

Terminated output cable 11508A is designed for use with hp 608C and 608D VHF Signal Generators. It provides an accurate termination which may be directly connected to the point of a circuit at which the signal is to be injected.

Another accessory, the 11509A Fuseholder, is particularly useful for these signal generators when tests on transceivers are being made. The fuseholder protects the output attenuator of the signal generator should the transmitter be keyed while the 608 is connected to the antenna.

Specifications

Frequency range: 608C, 10 to 480 mc in 5 bands; 608D, 10 to 420 mc in 5 bands.

Tuning control: main dial calibrated in mc, 45" (1143 mm) scale length; calibration every other mc, 130 to 270 mc, every 5 mc above 270 mc; vernier interpolation dial.

Frequency calibration accuracy: 608C, ±1% full range; 608D, ±0.5% full range.

Resettability: better than ±0.1% after warm-up.

Crystal calibrator (608D only): provides frequency check points every 1 mc (useful to 270 mc) or 5 mc 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 ambient temperatures; cursor on frequency dial adjustable over small range to aid in interpolation adjustment; calibrator may be turned off when not in use.

Frequency drift: less than 0.005% over a 10-minute interval after initial instrument warm-up (15 to 35°C ambient); when frequency is changed by dial, instrument must restabilize one minute for each 10% frequency change; when frequency is changed by band-switching, 10 minutes maximum are required to restabilize.

Output level: 608C, 0.1 μv to 1 v into 50-ohm resistive load, attenuator dial calibrated in volts and dbm; 608D, 0.1 μv to 0.5 v into 50-ohm resistive load, attenuator dial calibrated in volts and dbm; (0 dbm equals 1 mw).

Output voltage accuracy: ±1 db over entire frequency and attenuation range into 50-ohm load.

Generator impedance: 50 ohms; maximum swr 1.2.

Internal amplitude modulation: 400 cps ±10% and 1000 cps ±10%.

External amplitude modulation: 0 to 95% at output levels of 0 dbm and below at modulation frequencies 20 cps to 20 kc; input requirements, 0.5 v rms across 15 K.

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 mc to 220 mc, combined rise and decay time of rf pulse less than 4 μsec; above 220 mc, combined rise and decay time of rf pulse less than 1 μsec; pulse on-off ratio at least 20 db.

Incidental FM: 608C, less than 0.0025% at 30% amplitude modulation for rf output frequencies 21 to 480 mc; 608D, less than 1000 cps peak at 50% amplitude modulation for rf frequencies above 100 mc, less than 0.001% at 30% amplitude modulation below 100 mc.

Leakage: negligible; permits sensitivity measurements to at least 0.1 μv.

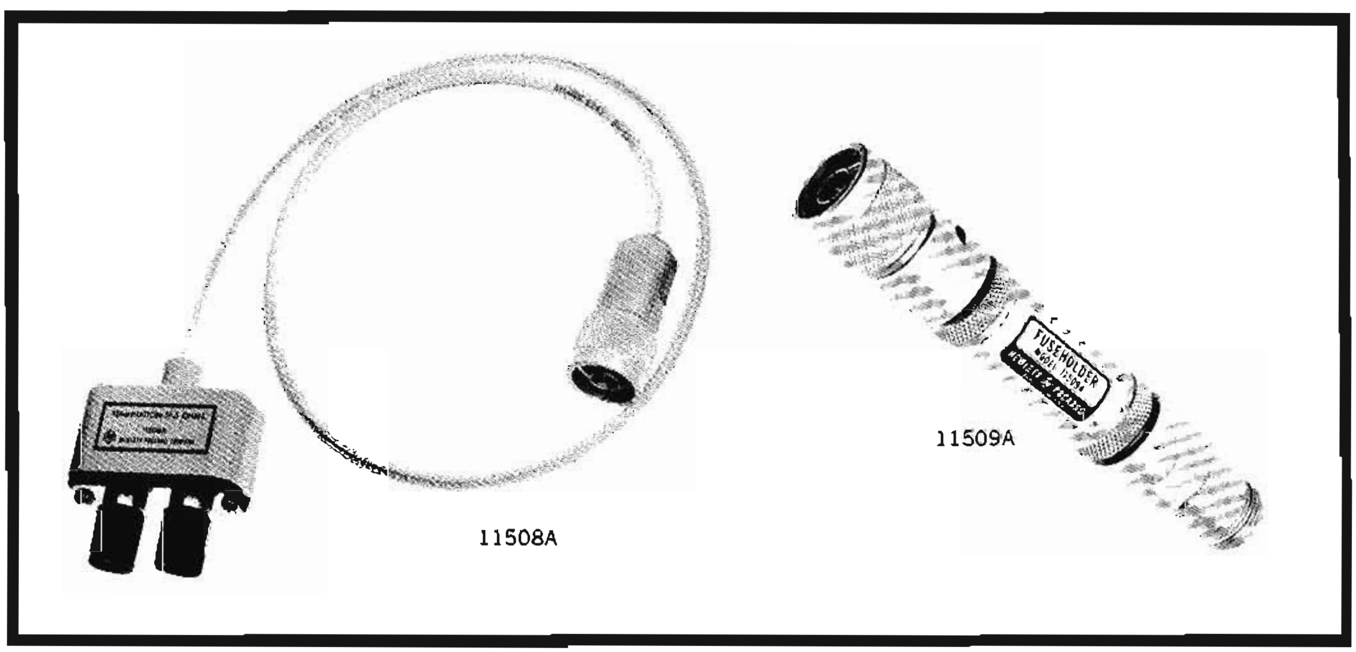
Power: 115 or 230 v ±10%, 50 to 1000 cps, 220 w.

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 355 x 467 mm).

Weight: net 62 lbs (27,9 kg), shipping 74 lbs (33,3 kg) (cabinet); net 62 lbs (27,9 kg), shipping 87 lbs (39,2 kg) (rack mount).

Accessories available: 11508A Output Cable, $18; 10503A Video Cable Assembly, $6.50; 11500A RF Cable Assembly, $15; 360A Low-Pass Filter, $70; 11509A Fuseholder, $25.

Price: hp 608C, $1200 (cabinet); hp 608CR, $1220 (rack mount); hp 608D, $1300 (cabinet); hp 608DR, $1320 (rack mount).



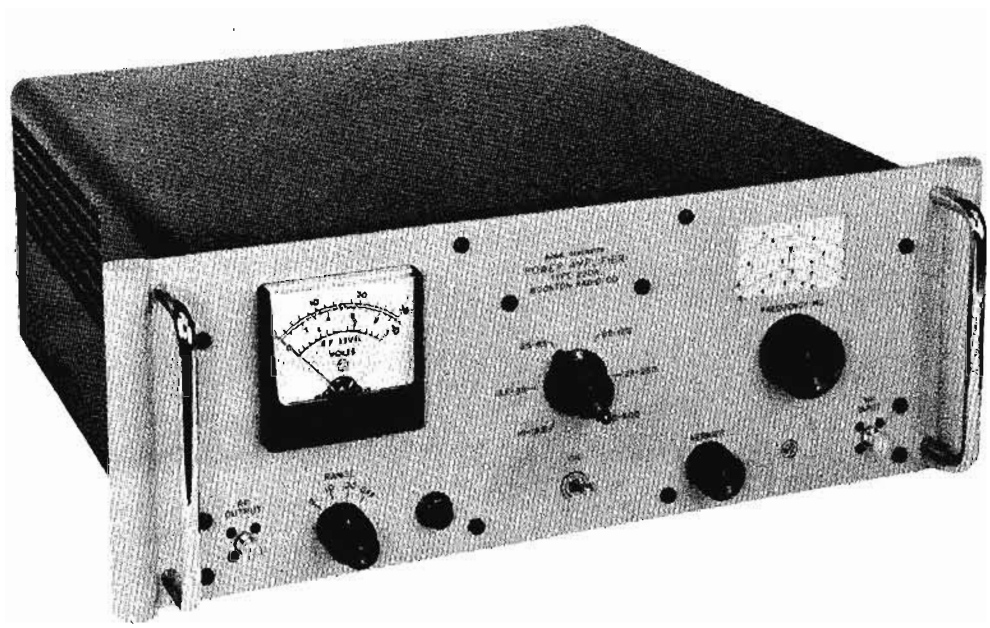
230A SIGNAL GENERATOR POWER AMPLIFIER

Provides more than 4.5 watts, 10 to 500 mc

The Boonton 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.



Specifications

Radio frequency characteristics

RF range: total range: 10 to 500 mc; number bands: 6; band ranges: 10 to 18.5 mc, 18.5 to 35 mc, 35 to 65 mc, 65 to 125 mc, 125 to 250 mc, 250 to 500 mc.

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 mc), ±1.5 db of f.s. (250 to 500 mc); impedance: 50 ohms; leakage: effective shielding is greater than 40 db.

RF bandwidth:* >700 kc (10 to 150 mc); >1.4 mc (150 to 500 mc).

RF input: level**: ≤0.316 volts, 30 db gain, (10 to 125 mc); ≤0.446 volts, 27 db gain, (125 to 250 mc); ≤0.63 volts, 24 db gain, (250 to 500 mc).

* 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 generators†.

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 kc deviation).

FM distortion: negligible distortion added to distortion of driving signal generator for deviations and modulation frequencies <150 kc.

Physical characteristics

Dimensions: 19½″ wide, 7-3/16″ high, 17-11/16″ deep (495 x 183 x 449 mm).

Weight: net 37 lbs (16,7 kg); shipping 45 lbs (20,3 kg).

Power: 105 to 125 or 210 to 250 v, 50 to 60 cps, 150 w.

Price: Boonton 230A, $1200.

† up to 5 volt max. carrier output for up to 100% AM

240A SWEEP SIGNAL GENERATOR

Continuous coverage 4.5 to 120 mc; includes crystal birdie and variable pip markers

The Boonton 240A Sweep Signal Generator has been designed for use in the development and testing of radio frequency passband amplifiers over the frequency range of 4.5 to 120 mc. It consists of a precision cw signal generator which may be amplitude modulated, and a sweep frequency generator providing linear frequency deviation over the range from ±1% of center frequency to ±30% of center frequency or ±15 mc, whichever is smaller.

Features of the 240A include a marker system which produces (a) crystal-referenced birdie-type markers, (b) adjustable pip interpolation markers, and (c) a composite signal containing the markers added to the response of the system under test. A precision output attenuator system operates on both cw and swept outputs. Provisions are included for sweeping from an external source of sweeping voltages and for providing to an oscilloscope the synchronized sweep voltage.

The 240A is useful in the determination of selectivity and sensitivity of test circuits, the study of bandpass characteristics, the adjustment of stagger tuned circuits, the study of cable characteristics, determination of linearity of FM discriminators and the study of crystal modes.

Specifications

Radio frequency characteristics

RF range: total range: 4.5 to 120 mc; number bands: 5; band ranges: 4.5 to 9 mc, 9 to 18 mc, 18 to 35 mc, 35 to 75 mc, 75 to 120 mc.

RF accuracy: ±1% (after four-hour warm-up) may be standardized against internal crystal to ±0.005%.

RF output: range: 1 μv to 0.3 v* (sweep), 1 μv to 0.1 v* (cw and AM); accuracy: ±20% of full scale RF level meter reading; impedance: 50 ohms (25 ohms at terminals of 501B Output Cable).

* across external 50-ohm load.

† decreases to ±0.75 mc or ±1.5% at 1000 cps repetition rate.

Swept-frequency characteristics

Sweep range: internal: ±1% to ±15 mc or ±30% of center frequency, whichever is smaller; external: ±1% to ±12 mc or ±24%† of center frequency, whichever is smaller (20 to 200 cps repetition rate).

Sweep linearity: ±10% over central ±80% of sweep excursion; ±20% over outer 20% of sweep excursion.

Output flatness: flat within <7%.

Repetition rate: internal: 20 to 70 cps (provision for synchronization with line frequency); external: 20 to 1000 cps.

Blanking: internal blanking of rf output provides zero base line display during return cycle of internal sweep.

Sweeping voltage output: 20 volts p-p (triangular waveform) available at front-panel posts.

Marker characteristics

Crystal birdie markers: frequency: 0.1, 0.5, and 2.5 mc; accuracy: ±0.005%.

Pip markers: number of markers: 2; position: continuously adjustable to any position on sweep excursion.

Internal mixer: function: adds markers to output of circuit under test; markers do not pass through circuit under test; gain: approx. 10 (for input level range 0.1 to 5 v p-p).

Amplitude modulation characteristics

AM level: approx. 30% from internal 1000 cps oscillator.

Physical characteristics

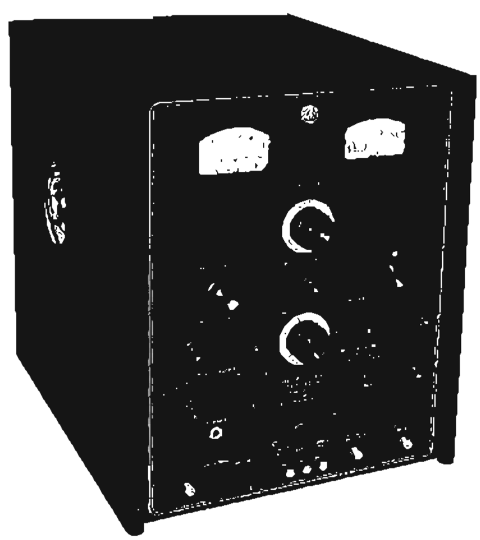
Dimensions: 14½" wide, 18" high, 19¼" deep (368 x 457 x 489 mm).

Weight: net 76 lbs (34,2 kg); shipping 100 lbs (45 kg).

Power: 240A, 105 to 125 volts, 60 cps, 280 watts; 240AP, 105 to 125 volts, 50 cps, 280 watts.

Accessory furnished: 501B Output Cable.

Price: Boonton 240A, $1995, Boonton 240AP, $1995; for rack mount models, add $25.



3200A VHF OSCILLATOR

Continuous coverage 10 to 500 mc; up to 200 mw output

The Boonton 3200A VHF Oscillator is designed for general-purpose laboratory use, including receiver and amplifier testing, driving bridges, slotted lines, antenna and filter networks and as a local oscillator for heterodyne detector systems in the frequency range from 10 to 500 mc.

The push-pull oscillator is housed in a rugged aluminum casting for maximum stability and extremely low leakage; six frequency ranges are provided for adequate bandspread on the slide-rule dial. Internal cw operation is provided; AM and pulse modulation may be obtained through the use of a suitable external source. The rf output is coupled through a waveguide-below-cutoff variable attenuator; in addition, an electrical rf level vernier is included as a front-panel control.

A solid-state power supply furnishes all necessary operating voltages, including regulated dc to the oscillator heaters for minimum hum modulation and maximum tube life. The cabinet is designed for bench use and can be readily adapted for standard 19-inch rack mounting.

NEW

Specifications

Radio frequency characteristics

RF range: total range: 10 to 500 mc; number bands: 6; band ranges: 10 to 18.8 mc, 18.5 to 35 mc, 35 to 68 mc, 68 to 130 mc, 130 to 260 mc, 260 to 500 mc.

RF accuracy: ±2% (after ½ hour warm-up).

RF calibration: increments of less than 4%.

RF stability*: short term: ±0.002% (5 minutes); long term: ±0.02% (1 hour); line voltage: ±0.001% (5 volts).

RF output: maximum power**: >200 mw (10 to 130 mc); >150 mw (130 to 260 mc); >25 mw (260 to 500 mc); range: 0 to >120 db attenuation from maximum output; load impedance: 50 ohms nominal.

RF leakage: sufficiently low to permit measurements at 1 μv.

*after 4-hour warm-up, under 0.2 mw load.
** across external 50-ohm load.

Amplitude modulation characteristics

AM range: external: 0 to 30%.

AM distortion: <1% at 30% AM.

External AM requirements: approximately 30 volts rms into 600 ohms for 30% AM.

Pulse modulation characteristics

External PM source requirements: 140 volts peak pulse into 2000 ohms for maximum power output; typically 10 volts peak (except 50 volts on 260 to 500 mc range) for 1 mw peak power output.

Physical characteristics

Dimensions: 7-25/32" wide, 6½" high, 12-17/32" deep (198 x 165 x 318 mm).

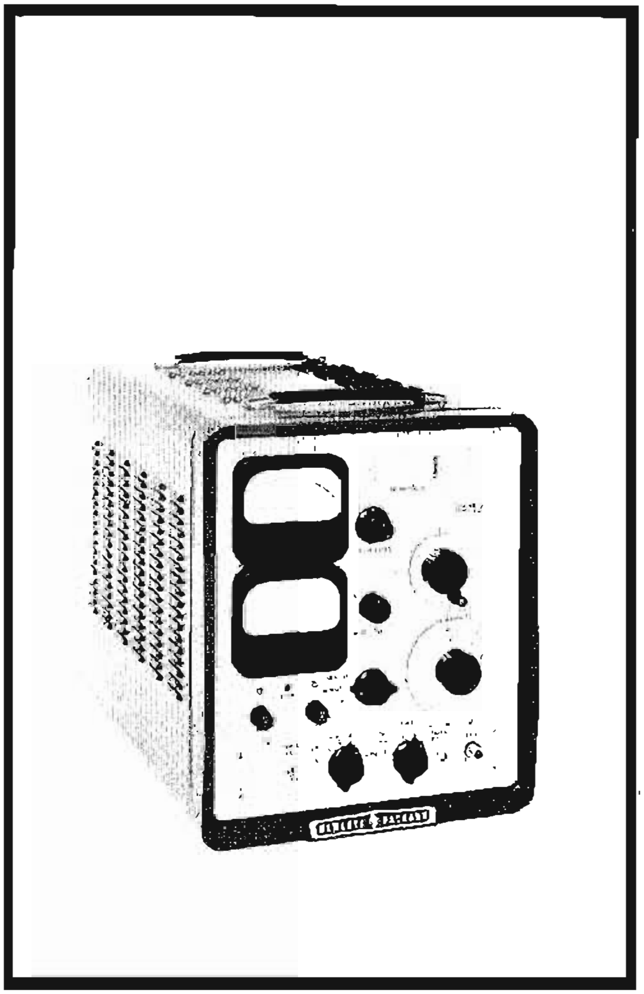
Weight: net 15 lbs (6,8 kg); shipping 19 lbs (8,6 kg).

Power: 105 to 125 or 210 to 250 volts, 50 to 60 cps, 30 watts.

Price: Boonton 3200A, $475.

612A UHF SIGNAL GENERATOR

All-purpose uhf signal generator, 450 to 1230 mc



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 (pages 190, 191) can be used with the 612A to obtain rf pulses with 30 nsec rise time and 0.1 μsec minimum duration — with on-off ratios approaching 80 db.

MO-PA circuit

The master oscillator-power amplifier circuit in hp 612A provides 0.5 volt into 50 ohms over the full frequency range of 450 to 1230 mc. There is very low incidental FM (less than 0.002% at 30% AM) and excellent modulation capabilities by all frequencies from 20 cps to 5 mc. 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 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. Non-contacting 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 insure accurate, reliable output down to 0.1 μvolt. 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 mc in one band; scale length approximately 15" (381 mm).

Calibration accuracy: within ±1%; resettability better than 5 mc 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 swr 1.2.

Leakage: negligible; permits receiver sensitivity measurements down to 1 μv.

Amplitude modulation: 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 cps ±10%; envelope distortion less than 2% at 30% modulation.

External modulation: 20 cps to 5 mc; above 470 mc, 2 v rms produces 85% AM at modulating frequencies up to 1 mc, at least 40% AM at 5 mc; 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 μsec.

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 μsec.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 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 57 lbs (25,5 kg), shipping 68 lbs (30,5 kg) (cabinet); net 57 lbs (25,5 kg), shipping 83 lbs (37,5 kg) (rack mount).

Accessories available: 11500A RF Cable Assembly, $15; 10503A Video Cable Assembly, $6.50; 360B Low-Pass Filter (may be used where harmonic output must be reduced to a minimum, as in slotted line measurements), $60.

Price: hp 612A, $1400 (cabinet); hp 612AR, $1420 (rack mount).

8614A, 8616A SIGNAL GENERATORS; 8614B, 8616B SIGNAL SOURCES

Stable, easy to use, cover 800 to 4500 mc

Advantages:

- High frequency accuracy, digital dial
- Precision attenuator, digital dial
- Amplitude modulation capability and automatic power leveling in the signal generators
- Compact, only 5¼" (133 mm) high

Use to measure:

- Receiver sensitivity
- Standing wave ratios
- Transmission line characteristics
- Conversion gain

The hp 8614A and 8616A Signal Generators are easy-to-use instruments which provide stable, accurate signals from 800 to 2400 mc (8614A) and from 1800 to 4500 mc (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

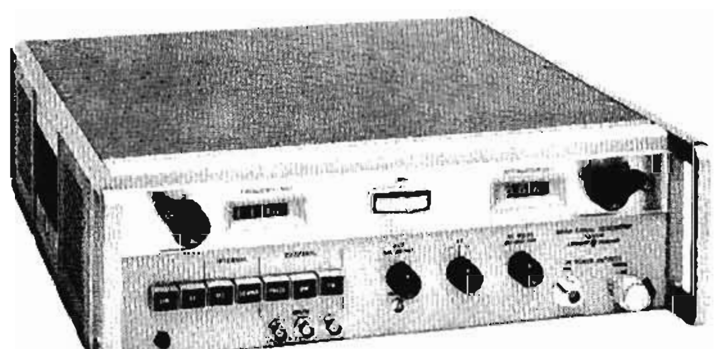
Two rf power outputs are simultaneously available from separate front-panel connectors. One provides at least 10 mw (2 mw above 3000 mc) or a leveled output from 0 to −127 dbm. The leveled output is flat within ±0.5 db (8614A) or ±0.8 db (8616A) across the respective bands with no resetting of the attenuator 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.

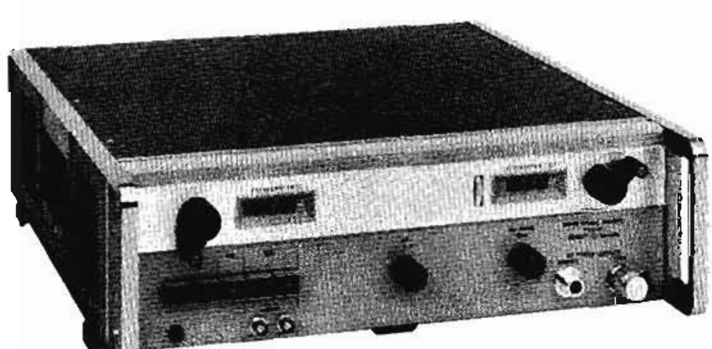
Modulation capabilities

A unique PIN diode modulator permits amplitude modulation from dc to 1 mc or furnishes rf pulses with a 2 μsec 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 gc, the hp 489A (1 to 2 gc) or hp 491C (2 to 4 gc) Microwave Amplifiers (see page 202) serve as ideal power boosters. The hp 8731 and 8732 Series PIN Modulators, driven by the hp 8403A Modulator (see pages 190 and 191), also are available for use with the signal generators when a sophisticated high-speed, low-jitter modulation system is required.



8614A

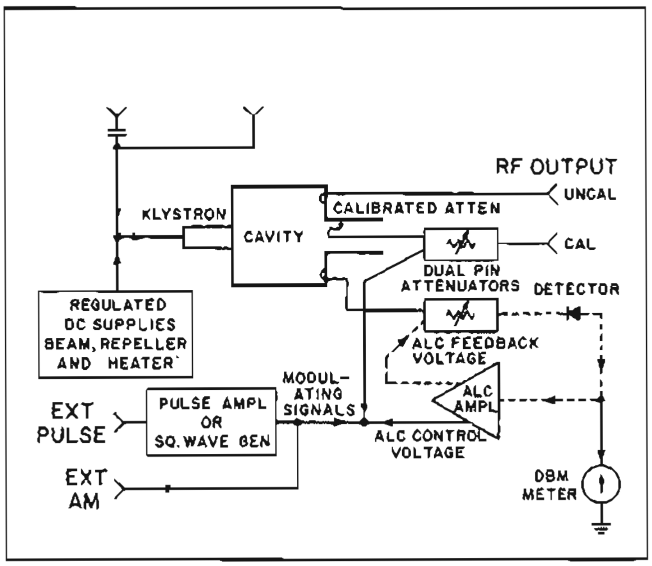


8614B

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 mc; 8616A and 8616B, 1800 to 4500 mc.

Leveled output: constant within ±0.5 db (8614A) and ±0.8 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 mc; 8614B, ±5 mc or ±0.5%, whichever is greater; 8616A, ±10 mc; 8616B, ±10 mc.

Vernier: △F control has a minimum range of 1.5 mc for fine tuning.

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 cps peak; 8614B, less than 0.0003% peak; 8616B, less than 6 kc 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 mc; +3 dbm (2 mw) to −127 dbm (0.1 μv) into a 50-ohm load, 3000 to 4500 mc; output attenuator directly calibrated in dbm from 0 to −127 dbm.

8616B; at least 15 mw maximum, 1800 to 3000 mc; at least 3 mw maximum, 3000 to 4500 mc; 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 −10 dbm.

8616A: +0, −1 db from 0 to −10 dbm.

All models: ±0.2 db ±0.06 db/10 db from −10 dbm to −127 dbm; direct-reading linear dial, 0.2 db increments.

Internal impedance: 50 ohms nominal.

SWR: 8614A, less than 2; 8614B, less than 1.5; 8616A, less than 2; 8616B, less than 1.7.

Modulation

Internal square wave: 950 to 1050 cps.

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 mc.

Incidental FM (8614A and 8616A only): negligible for power levels below −10 dbm.

External pulse:

8614A and 8616A: 50 cps to 50 kc, 2 μsec rise time, +20 to +100 volts input.

8614B and 8616B (below 4000 mc): 50 cps to 500 kc; +25 to +50 volts peak input; minimum rf pulse width, 300 nsec; rf rise time, typically 200 nsec.

External FM: (a) front-panel connector capacitively coupled to klystron repeller; input impedance, 220 K 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 cps, 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 and 8616A: net 48 lbs (21,6 kg), shipping 53 lbs (23,9 kg); 8614B and 8616B: net 37 lbs (16,7 kg), shipping 42 lbs (18,9 kg).

Price: hp 8614A, $2100; hp 8614B, $1450; hp 8616A, $2100; hp 8616B, $1450.

Option 01.: External modulation input connectors on rear panel in parallel with front-panel connectors; rf connectors on rear panel only; add $25.

8730 PIN MODULATORS, 8403A MODULATORS

Versatile modulation

8730 PIN Modulators

The Hewlett-Packard 8730 Series PIN Modulators increase the flexibility and performance of signal generators and 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 nsec, 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 gc 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 mc. 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 cps to 50 kc. In the pulse-modulation mode both pulse width and pulse delay are adjustable from 0.1 to 100 μsec, and jitter with respect to the sync pulse and pulse width is less than 1 nsec. An external AM input permits remote control of attenuation or sinusoidal modulation from dc to 10 mc.

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 cps to 50 kc, 3 decade ranges.

Symmetry: better than 45/55%.

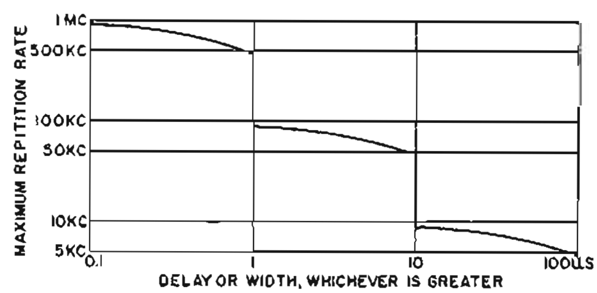
Pulse

Repetition rate: continuously variable from 50 cps to 50 kc, 3 decade ranges.

Delay: continuously variable from 0.1 μsec to 100 μsec, in 3 decade ranges, between sync out pulse and rf output pulse.

Width: continuously variable from 0.1 μsec to 100 μsec in 3 decade ranges.

Maximum duty cycle: see graph.



External sync

Amplitude: 5 volts to 15 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 μsec in advance of output pulse, as set by "Delay" control.

Delayed sync out: simultaneous with output pulse.

Amplitude: approximately −2 volts.

Source impedance: approximately 330 ohms.

External modulation

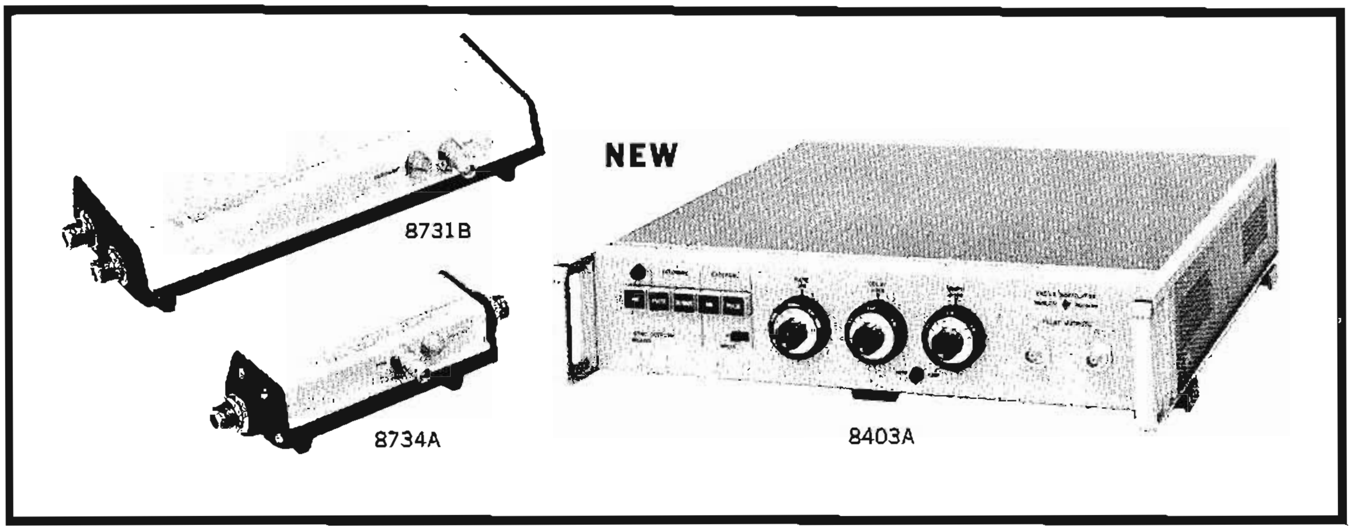
Pulse input

Amplitude and polarity: 5 volts to 15 volts peak, either positive or negative.

Repetition rate: maximum average prf, 1 mc/sec; maximum peak prf, 2 mc/sec.

Input impedance: approx. 2000 ohms, dc-coupled.

Minimum width: 0.1 μsec.



Maximum width: $\frac{1}{\text{prf}} - 0.4\ \mu\text{sec}$.

Continuous amplitude modulation

Maximum frequency: 10 mc, sinusoidal.

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 1000 cps, 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 14½ lbs (6,5 kg); shipping 20 lbs (9 kg).

Price: hp 8403A, $700.

Options

01. hp 8731A PIN Modulator installed, add $350.
02. hp 8731B PIN Modulator installed, add $550.
03. hp 8732A PIN Modulator installed, add $350.
04. hp 8732B PIN Modulator installed, add $550.
05. hp 8733A PIN Modulator installed, add $350.
06. hp 8733B PIN Modulator installed, add $550.
07. hp 8734A PIN Modulator installed, add $350.
08. hp 8734B PIN Modulator installed, add $550.

Specifications, 8730 Series

hp Model	8731A	8731B	8732A	8732B	8733A	8733B	8734A	8734B	8735A	8735B
Frequency range (gc)	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
Dynamic range (db)	35	80	35	80	35	80	35	80	35	80
Min. insertion loss (db)[1]	<1.5	<2.0	<2.0	<3.5[2]	<2.0	<3.0	<4.0	<5.0	<4.0	<5.0
Typical rise time (nsec)[3]	40	30	40	30	30	30	30	30	30	30
Typical decay time (nsec)[3]	30	20	30	20	20	20	20	20	20	20
SWR, min. attenuation	1.5	1.6	1.5	1.6[4]	1.8	2.0	1.8	2.0	1.7	1.9
SWR, max. attenuation	1.8	2.0	1.8	2.0	2.0	2.2	2.0	2.2	2.0	2.2
Maximum input power, peak or cw (watts)	1	1	1	1	1	1	1	1	1	1
Bias limits (volts)[5]	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10
Typical forward bias input resistance (ohms)[6]	300	100	300	100	300	100	300	100	300	100
RF connector type	N	N	N	N	N	N	N	N	W/G[7]	W/G[7]
Weight, net (lbs)	2¾	5½	2¾	5½	2	3	2	3	2	3
(kg)	1,2	2,5	1,2	2,5	0,9	1,4	0,9	1,4	0,9	1,4
shipping (lbs)	4	7	4	7	3	4	3	4	3	4
(kg)	1,8	3,2	1,8	3,2	1,4	1,8	1,4	1,8	1,4	1,8
Dimensions Length (in)	11⅛	11⅜	11⅛	11⅜	8⅜	12¼	8⅜	12¼	6¾	10½
(mm)	283	289	283	289	213	311	213	311	171	267
Width (in)	3¼	4⅞	3¼	4⅞	3¼	3¼	3¼	3¼	3¼	3¼
(mm)	83	124	83	124	83	83	83	83	83	83
Height (in)	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼	2¼
(mm)	57	57	57	57	57	57	57	57	57	57
Price	$300	$500	$300	$500	$300	$500	$300	$500	$300	$500

[1] +5 v bias
[2] 4.0, 4.0 to 4.5 gc
[3] Driven by hp 8403A Modulator
[4] 2.0, 4.0 to 4.5 gc
[5] Negative voltage applies forward bias to diodes (increases attenuation)
[6] At attenuation levels of 10 db or more
[7] Fits 1 x ½ in. (WR 90) waveguide

DY-2650A OSCILLATOR SYNCHRONIZER
DY-2654A FREQUENCY STANDARD SYNCHRONIZER

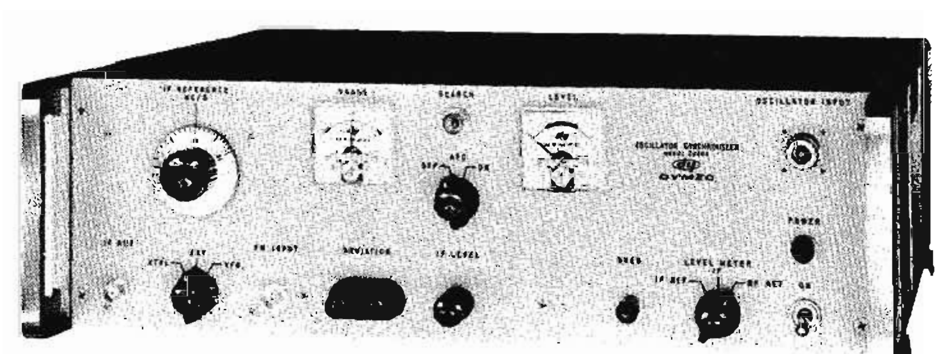
Generate highly stabilized microwave signals

Dymec synchronizers permit absolute control of frequency by phase locking a klystron oscillator to a crystal reference, achieving essentially the stability of the references. The synchronizer introduces no frequency error. Instruments will stabilize most reflex klystrons, 1 to 12.4 gc, with complete elimination of klystron long-term drift and minimization of all incidental FM caused by klystron noise, power supply ripple and mechanical shock. Sideband noise is typically 70 db down measured in any 1 kc band from 3 kc to beyond 100 kc from the desired output frequency. Theory of operation of the DY-2650A is detailed on page 160; the DY-2654A operation involves similar principles.

The DY-2650A incorporates an internal crystal reference to achieve stability of 1 part in 10^8 per second, 1 part in 10^8 per week. Temperature stability is 1 part in 10^6 from 0 to 50°C. The standard instrument stabilizes frequencies from 1 to 12.4 gc. Standard modifications are available to extend frequency coverage from 0.1 to 15 gc and to cover specified frequency ranges to 40 gc. The synchronizer samples less than 0 dbm of the klystron power. Additional capabilities of the DY-2650A permit FM to be applied to a klystron oscillator with deviations up to 500 kc at rates to 50 kc. A front-panel control permits manual tuning of the klystron frequency over a 2 mc range. The instrument may also be used to monitor a microwave signal frequency and provide an output for measurement by an electronic counter or frequency meter. The synchronizer samples less than 0 dbm of the klystron power.

The DY-2654A is similar to the DY-2650A, but phase-locks to an external 5 mc frequency standard such as hp 104AR and hp 107AR,BR Quartz Oscillators (pages 100, 101). Stability is essentially equal to that of the standard. In the case of the 107AR,BR, short-term (1 second) stability is better than 2 parts in 10^{11}; 24-hour stability is 5 parts in 10^{10}. Frequency lock points are available at 60 mc intervals through the 1 to 12.4 gc range.

Both the DY-2650A and DY-2654A are available as individual instruments to be coupled by the user with a klystron, power supply and, if applicable, 5 mc quartz oscillator. They are also available as complete, fully specified frequency generation systems. A choice of klystrons is available for these systems, covering all or part of the 8.2 to 12.4 gc range, at output powers from 30 to 500 mw. Data sheets are available on the DY-2041A System (incorporating the DY-2650A, hp 716B Klystron Power Supply and DY-2655A Klystron Signal Source) and DY-2042A (incorporating DY-2654A, hp 716B, DY-2655A and hp 107BR).



DY-2650A

Specifications, DY-2650A

Input frequency: 1 to 12.4 gc.

Stability (using internal crystal): $1/10^8$ per second, $1/10^8$ per week (over ±5°C), $1/10^6$ over range 0 to 50°C.

Output circuitry: suitable for connection to klystron reflector; floating and insulated up to 2000 v dc; a phase lag network provides optimum characteristics for matching klystron sensitivities to 4 mc/v.

Input power: 0 dbm at 12.4 gc; less at lower frequencies; maximum power input, +20 dbm.

RF reference: internal: provided by internal quartz crystal, 100 mc standard, others on special order; external: 100 to 400 mc, 2 volts into 50 ohms.

IF reference: internal: quartz crystal 10 mc ±0.001% of VFO tunable 29 to 31 mc by front-panel control; external: 29 mc to 31 mc, 0.5 v into 56 K, also 10 mc or 15 mc at higher levels.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 85 watts.

Dimensions: 16¾" wide, 5¼" high, 16⅜" deep behind panel (425 x 133 x 416 mm); hardware furnished converts unit to 19" wide rack mount.

Weight: net 21 lbs (9,5 kg); shipping 35 lbs (15,9 kg).

Price: DY-2650A, $1450 (supplied with 100 mc rf reference crystal; with special order crystal, $1480).

Specifications, DY-2654A

(Same as DY-2650A except)

Stability: equal to external oscillator (with hp 107AR,BR, $2/10^{11}$ rms averaged over 1 sec, $5/10^{10}$ per 24 hours).

RF reference, IF reference: taken from quartz oscillator.

Price: DY-2654A, $1750.

614A, 616B UHF SIGNAL GENERATORS

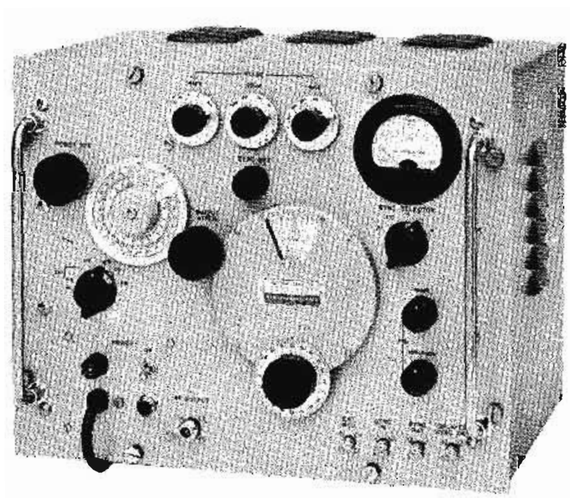
Direct reading, direct control, 800 to 4200 mc

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 mc, has constant internal impedance with less than 1.6 swr, and output 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 gc, 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 mc; 616B, 1800 to 4200 mc.

Frequency accuracy: ±1%.

Frequency stability: 0.005%/°C change in ambient temperature; line voltage changes of ±10% cause less than 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 mc, 1 mw or 0.224 volt to 0.1 μv (0 to −127 dbm) from 900 to 2100 mc; 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, swr less than 1.6; 616B, 50 ohms, swr less than 1.8.

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 μsec; delay variable from 3 to 300 μsec between synchronizing signal and rf pulse.

External pulse modulation: by external pulses, ±40 to ±70 v, 1 to 2500 μsec wide; may be square-wave modulated, 40 to 4000 cps.

Trigger pulses out: (1) simultaneous with rf pulse; (2) in advance of rf pulse, variable from 3 to 300 μsec (both approximately 1 μsec rise time, amplitude +10 to +50 volts).

External synchronization: pulses, ±10 to ±50 volts, 1 to 20 μsec wide; may also be synchronized with sine waves.

Frequency modulation: oscillator sweeps at power line frequency; deviation and phase adjustable; maximum deviation approx. 3 mc.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 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 lbs (26,5 kg); shipping 72 lbs (32,4 kg).

Accessory furnished: 11500A RF Cable Assembly.

Accessories available: 614A: 360C Low-Pass Filter, f_c = 2200 mc, $50; 10503A Video Cable Assembly, $6.50; 616B: S281A Waveguide-to-Coax Adapter, 2.6 to 3.95 gc, $50; G281A Waveguide-to-Coax Adapter, 3.95 to 5.85 gc, $40; 360D Low-Pass Filter, f_c = 4.1 gc, $50; 10503A Video Cable Assembly, $6.50.

Price: hp 614A or hp 616B, $1950 (cabinet); hp 614AR or hp 616BR, $1970 (rack mount).

618B, 620A SHF SIGNAL GENERATORS

Multiple-purpose signal generators for measurements 3.8 to 11 gc

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

Hewlett-Packard 618B and 620A SHF Signal Generators bring the simple yet versatile operation and the varied pulsing capabilities of hp uhf signal generators to the 3.8 to 11 gc frequency range.

These generators offer internal or external pulse modulation, internal square-wave modulation and FM. The pulse repetition rate is continuously variable from 40 to 4000 pps, and pulse width is variable from 0.5 to 10 microseconds. Sync out signals are simultaneous with the rf pulse, or in advance of the rf pulse by any time span from 3 to 300 microseconds. The instruments may be synchronized with an external sine wave or with positive or negative pulse signals.

Sawtooth sweep

For internal frequency modulation, both the 618B and 620A have a sawtooth voltage variable from 40 to 4000 cps, providing a variable frequency deviation. For external FM, the instruments provide capacitive coupling to the repeller of the klystron oscillator. Deviation is approximately 2.5 mc.

Both generators maintain the same high standards of accuracy found in hp vhf and uhf signal generators. Both also feature the same simple operation. Carrier frequency is set and read directly on the large central tuning dial. (Calibration of this dial is linear.) No voltage adjustments are necessary during operation because of an hp-developed coupling device which causes oscillator repeller voltage to track frequency changes automatically. RF output also is set and read directly; no calibration charts are needed for either voltage or frequency control or determination. A logging scale on the frequency dial permits you to reset frequencies within 0.1%.

Reflex klystron oscillator

The 618B and 620A 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 thermistor bridge 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.

Models 618B and 620A are designed to be the most broadly useful, accurate and dependable signal generators available in their frequency ranges. Their high stability, broad frequency coverage, precision accuracy and varied pulsing capabilities make them ideal for virtually all measurements requiring precisely known and controllable shf signals. They are sturdily built of the best components, many parts being specially manufactured for or by Hewlett-Packard. Circuitry is clean and accessible. The generators are designed for years of dependable service with little or no maintenance.

Specifications

hp 618B

Frequency range: 3.8 to 7.6 gc covered in a single band; repeller voltage automatically tracked and proper mode automatically selected.

Calibration: direct reading; frequency calibration accuracy better than 1%.

Frequency stability: frequency variation less than 0.006% per degree centigrade change in ambient temperature; line voltage change of ±10% causes less than 0.02% frequency change.

Output range: 1 milliwatt or 0.223 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 −7 dbm to −127 dbm, within ±3 db 0 to −7 dbm at the end of 6-foot output cable, terminated in 50-ohm load.

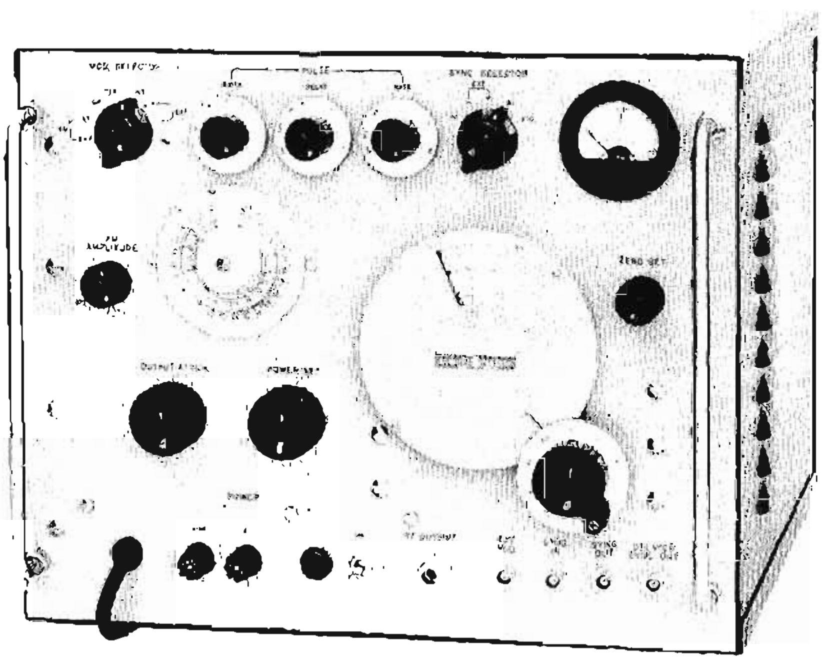
Internal impedance: 50 ohms nominal, swr less than 2.

Modulation: internal or external pulse, FM, square wave.

Internal pulse modulation: repetition rate variable from 40 to 4000 pps, pulse width variable 0.5 to 10 μsec.

Sync out signals: (1) simultaneous with rf pulse—positive; (2) in advance of rf pulse—positive, variable 3 to 300 μsec; (better than 1 μsec rise time and 25 to 100 volts amplitude into 1000-ohm load).

External synchronization: (1) sine wave: 40 to 4000 cps, amplitude 5 to 50 volts rms; (2) pulse signals: 0 to 4000 pps and 5 to 50 volts amplitude, both positive and negative, pulse width 0.5 to 5 μsec, rise time 0.1 to 1 μsec.



618B

Internal square-wave modulation: variable 40 to 4000 cps, controlled by "pulse rate" control.

Internal frequency modulation: sawtooth sweep rate adjustable between 40 and 4000 cps; maximum frequency deviation approximately 2.5 mc over most of the band.

External pulse modulation: pulse requirements: amplitude from 20 to 70 volts positive or negative, width 0.5 to 2500 μsec.

External frequency modulation: provides capacitive coupling to repeller of klystron; maximum deviation approximately 2.5 mc over most of the band.

Power: 115 or 230 v $\pm 10\%$, 50 to 60 cps, 250 watts.

Dimensions: cabinet: 17½" wide, 14" high, 19½" deep (445 x 353 x 496 mm); rack mount: 19" wide, 14" high, 17⅜" deep behind panel (483 x 356 x 441 mm).

Weight: net 94 lbs (42,5 kg); shipping 120 lbs (54 kg).

Accessories furnished: 11500A Cable Assembly.

Accessories available: 10503A Video Cable Assembly, $6.50; 11001A Cable Assembly, $5.50.

Price: hp 618B, $2250 (cabinet); hp 618BR, $2270 (rack mount).

Specifications

hp 620A

(Same as hp 618B except as follows)

Frequency range: 7 to 11 gc covered in a single band; repeller voltage automatically tracked and proper mode automatically selected.

Output accuracy: within ± 2 db from -7 dbm to -127 dbm; within ± 3 db from 0 to -7 dbm, at panel connector, terminated in 50-ohm load.

Price: hp 620A, $2250 (cabinet); hp 620AR, $2270 (rack mount).

626A, 628A SHF SIGNAL GENERATORS

Direct reading, high power, 10 to 15.5 gc, 15 to 21 gc

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 gc 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 gc. The 626A covers frequencies 10 to 15.5 gc, and the 628A covers frequencies 15 to 21 gc. 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 gc and 26.5 to 40 gc respectively). These doubler sets (see page 198) 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 μsec. Sync out signals are simultaneous with the rf pulse, or in advance of the rf pulse by any time span from 3 to 300 μsec. 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 ± 5 mc. For external FM, the generators have capacitive coupling 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

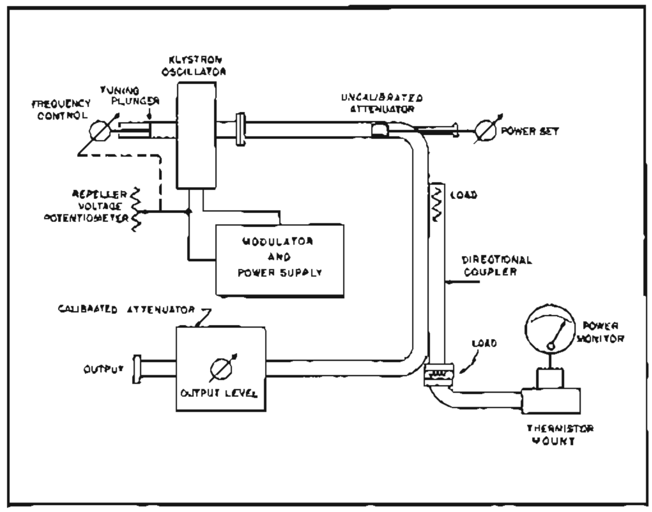


Figure 1. Basic circuit, hp 626A, 628A.

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 gc range.

Specifications

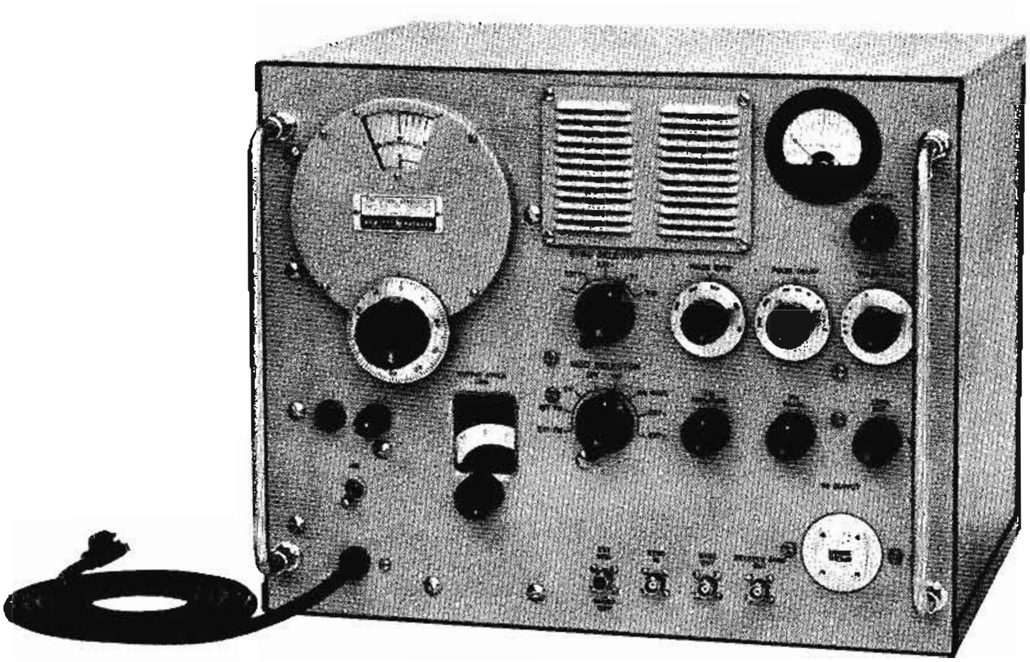
Frequency range: 626A, 10 to 15.5 gc; 628A, 15 to 21 gc.

Frequency calibration: dial direct reading in gigacycles; accuracy better than $\pm 1\%$.

Output range: 10 mw to 1 pw (+10 dbm to −90 dbm, 0 dbm = 1 mw); attenuator dial directly calibrated in output dbm; swr less than 2.5 at +10 dbm, 1.2 at 0 dbm and lower.

Output monitor accuracy: better than ± 1 db.

Output attenuator accuracy: better than $\pm 2\%$ of attenuation in db introduced by output attenuator.



628A

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 μsec.

Internal square-wave modulation: variable 40 to 4000 cps controlled by "pulse rate" control.

Internal frequency modulation: power line frequency, deviation up to ±5 mc.

External pulse modulation: pulse requirements: amplitude 15 to 70 volts peak positive or negative; width 1 to 2500 μsec.

External frequency modulation: provided by capacitive coupling to repeller of klystron; maximum deviation approximately ±5 mc.

Sync out signals: positive 20 to 50 volts peak into 1000-ohm load; better than 1 μsec rise time; (1) simultaneous with rf pulse; (2) in advance of rf pulse, variable 3 to 300 μsec.

External synchronization: (1) sine wave, 40 to 4000 cps, 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 μsec; rise time 1 μsec or less.

Power: 115 or 230 volts ±10%, 50 to 60 cps, 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 65 lbs (29,3 kg), shipping 74 lbs (33,3 kg); 628A,AR: net 63 lbs (28,4 kg), shipping 71 lbs (32 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, $6.50; for 626A: M362A Low-Pass Filter, $350; for 628A: N362A Low-Pass Filter, $350.

Price: hp 626A or 628A, $3400 (cabinet); hp 626AR or 628AR, $3420 (rack mount).

938A, 940A FREQUENCY DOUBLER SETS

Generate stable signals to 40 gc with these precision instruments

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 gc). Model 938A supplies power from 18 to 26.5 gc when it is driven by a 9 to 13.25 gc source; Model 940A supplies power from 26.5 to 40 gc when it is driven by a 13.25 to 20 gc 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 (pages 196, 197) or by sweep oscillators such as hp Models 694A, 694B and 695A (pages 199-201).

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.

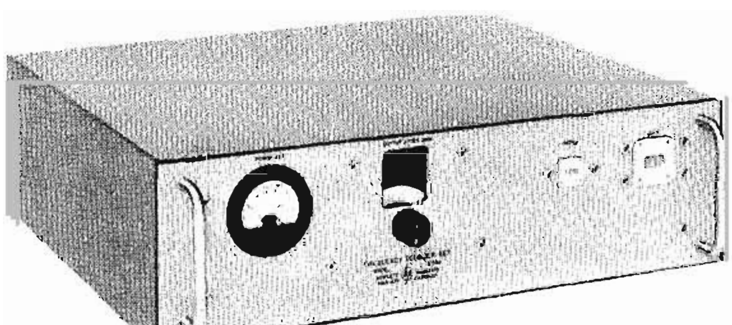
Output monitor

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, 694A,B or 695A 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 cps, or 60 cps (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 694A, 694B or 695A.



938A

Specifications

Frequency range: 938A, 18 to 26.5 gc; 940A, 26.5 to 40 gc.

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.

Input power required: 10 mw design center.

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 swr: approximately 2 at full output; less than 1.5 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); rack mount: 19" wide, 5-7/32" high, 16½" deep behind panel (483 x 133 x 419 mm).

Weight: net 20 lbs (9 kg); shipping 35 lbs (15,8 kg).

Accessories available: 938A, X281A Waveguide-to-Coax Adapter, 8.2 to 12.4 gc, $25; MX292B and MP292B Waveguide-to-Waveguide Adapters, $40 each (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; 694A,B and 695A Sweep Oscillators. 940A, 626A and 628A Signal Generators; 695A Sweep Oscillator.

Price: hp 938A or hp 940A, $1700 (cabinet); hp 938AR or hp 940AR, $1720 (rack mount).

690 SWEEP OSCILLATORS

Today's most convenient, versatile sweep oscillators

Advantages:

High flexibility with three automatic sweeps, two broadband, one narrow-band

PIN diode attenuator for AM and leveling in "B" models

Reduced oscilloscope and x-y recorder set- up time

Uses:

Combined broad, narrow range testing

Source of leveled microwave power

The Hewlett-Packard 690 Sweep Oscillators are today's most advanced sweepers. Incorporating performance and operating characteristics proved to be desirable in literally thousands of swept-frequency measurements, they combine many unique features which make them the most flexible and most accurate sweep oscillators available. Inexperienced personnel can operate the instruments with ease; the front panel is straightforward, and no combination of front-panel controls can cause damage.

Model designations

Two model designations are used in the 690 Series. The "A" models, covering 1 to 40 gc, use conventional BWO grid modulation and meet the requirements of most types of measurements. The "B" models cover the 1 to 12.4 gc range and include PIN diode attenuators which permit all of the amplitude-modulation functions, including leveling, to be performed independent of the BWO tube. The result is the virtual elimination of frequency pulling, which, in turn, results in extremely high frequency accuracy and linearity and very low incidental FM. Thus the 690B units meet the demands of the most exacting applications.

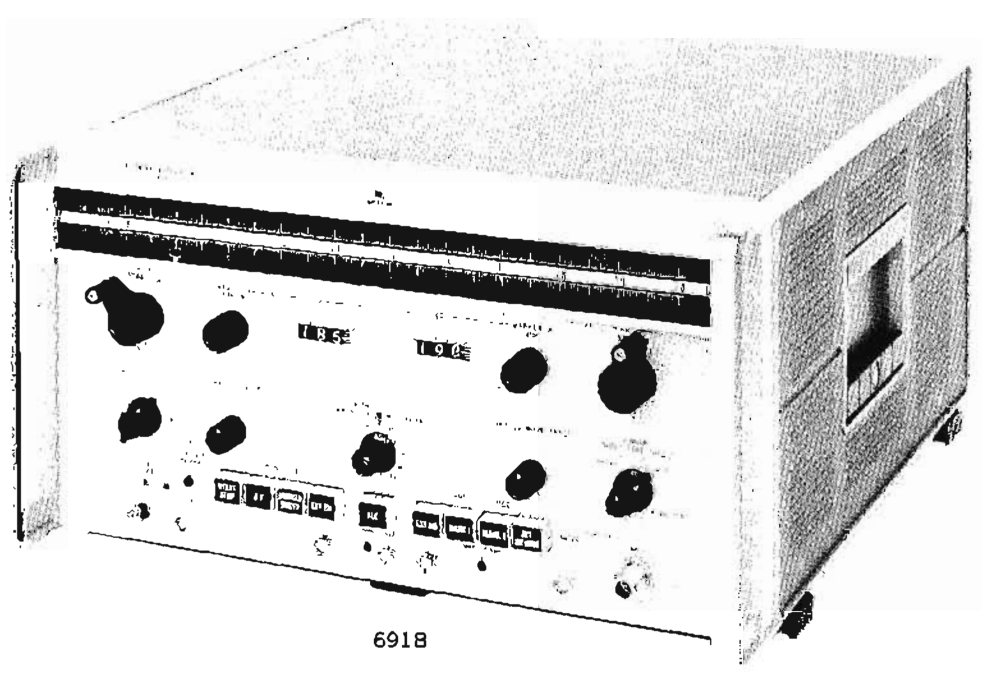
Sweep functions and markers

All 690 Sweep Oscillators provide a broadband "Start-Stop" sweep whose end points can be set anywhere in the band with independent controls. Thus, the units can sweep up or down, depending only on the setting of the start frequency with respect to the stop frequency.

Two independent frequency markers, set on separate digital dials and direct reading in gc, 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. This sweep starts at the Marker 1 frequency and ends at the Marker 2 frequency. Thus, the 690's have two independently adjustable broadband sweeps, providing a high degree of flexibility.

These sweep oscillators also provide a calibrated narrow-band sweep, the △F sweep, which is symmetrical about a center frequency. Calibrated directly in mc, △F sweep width is continuously adjustable from zero to 10% of the band. The frequency markers can be applied to the △F sweep, as well as the Start-Stop sweep.



6918

Sweep modes

Recurrent, triggered and manual sweeps are available. Recurrent and triggered sweep times are adjustable from 0.01 to 100 seconds, and the recurrent sweeps can be synchronized with the power line frequency, effectively eliminating residual FM. To enhance the clarity of oscilloscope presentations, rf power is blanked during retrace to produce a zero baseline; however, rf power is restored before the start of the sweep to eliminate transients. Blanking can be disabled with a rear-panel switch. For x-y recorder presentation, an automatic pen-lift circuit is provided.

On manual sweeps, a front-panel control varies rf frequency between the limits set on the selected sweep function. With the use of the manual sweep, x-y recorder set-up time is reduced to seconds.

Leveling

All 690 Sweep Oscillators can be leveled externally, and the lower frequency units can be leveled internally, as well. External closed-loop leveling is accomplished by driving the built-in leveling amplifier with a signal detected at the system point where constant power is desired. This technique has the advantage of eliminating transmission variations with frequency between the oscillator and the test point. Power variation using external leveling is primarily determined by coupler and detector variation. The detector can be either a power meter or crystal detector.

The internally leveled units (available under Option 01.) are useful in less critical applications where transmission variations between oscillator and test point are not significant or a package free from external elements is desired. The power level control, which has a 30 db range when the rf output is unleveled, becomes a level set control during leveled operation with a range of at least 10 db in "B" models and 6 db in "A" models.

Modulation

All modulation functions are selected by pushbutton. Included is internal square-wave modulation, with a range of 950 to 1050 cps, plus external AM and FM. External FM permits frequency programming, including externally controlled sweeps over all or any part of the band.

Specifications, all models

Sweep functions

Start-Stop sweep: sweeps from "Start" to "Stop" frequency setting; range: both settings continuously and independently adjustable over entire frequency range; can be set to sweep either up or down in frequency; end-point accuracy: same as frequency accuracy.

Marker sweep: sweeps from "Marker 1" to "Marker 2" frequency setting; range: both settings continuously and independently adjustable over entire frequency range, can be set to sweep either up or down in frequency; end-point accuracy: same as frequency accuracy.

ΔF sweep: sweeps upward in frequency, centered on cw setting; width: continuously adjustable from 0 to 10% of frequency band, calibrated directly in mc; width accuracy: $\pm 10\%$ of ΔF being swept $\pm 1\%$ of maximum ΔF ($\pm 20\%$ $\pm 2\%$ respectively for 691A and 691B); center-frequency accuracy: same as 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: same as frequency accuracy; resolution: better than 0.05% at any frequency; marker output: triangular pulse, typically -5 v peak into 1000-ohm load.

CW operation: single-frequency rf output selected by Start-Stop or Marker 1 control, depending upon sweep function selected; accuracy: same as frequency accuracy; preset frequencies: Start-Stop sweep end points and marker frequencies can be used as 4 preset cw frequencies.

Residual AM: at least 40 db below cw output.

Spurious signals: harmonics, at least 20 db below cw output; non-harmonics, at least 40 db below cw output.

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 μsec pulse width, and >0.1 v/μsec rise.

Sweep time: continuously adjustable in 4 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.

Sweep output: direct-coupled sawtooth, 0 to approximately +15 v, concurrent with swept rf output; 0 at start of the sweep, approximately +15 v at the end of the sweep regardless of sweep width or direction; source impedance, 10,000 ohms.

Reference output: direct-coupled voltage proportional to rf frequency, approximately +4 v at the low end of the band, approximately +70 v at the high end; output impedance, 2000 ohms.

Frequency linearity†: same as 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 automatically disabled for power meter leveling.

Pen lift: for use with x-y graphic recorders; pen lift terminals shorted during sweep, open during retrace.

Power variation, unleveled: <10 db over the entire band.

Power leveling amplifier: internal dc-coupled leveling amplifier provided.

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 (pages 238, 239), 423A and 424A Series Crystal Detectors (page 235).

Power meter input: 1000-ohm input resistance and amplifier characteristics matched to recorder output characteristics of 431 Power Meters (pages 220, 221).

† Correlation between frequency and either the sweep or reference output.

Leveling indicator: front-panel light flashes when power level set too high to permit leveling over entire selected sweep range.

Equivalent source match: externally leveled: depends upon coupler; unleveled: <2.5:1.

Modulation

Internal AM: square-wave modulation continuously adjustable from 950 to 1050 cps on all sweep times; on/off ratio greater than 20 db at rated output.

External AM

Frequency response: dc to 350 kc unleveled; dc to 50 kc leveled.

Sensitivity: −10 v reduces rf output level at least 30 db below rated cw output.

Input impedance: approximately 1000 ohms.

External FM

Frequency response: dc to 20 kc.

Sensitivity: deviation from cw setting approximately 3% of the frequency band per volt.

Maximum range: full band for modulation frequencies up to 150 cps (approx. 35 v p-p input), decreases to about 1% of the band for 20 kc modulation.

Input impedance: approximately 100,000 ohms.

General

Power: 115 or 230 volts ±10%, 50 to 60 cps, approx. 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: net 75 lbs (34 kg); shipping 97 lbs (43,5 kg).

External leveling accessories available

Directional detectors: 780 Series (pages 238, 239), 1 to 12.4 gc, $300 to $350.

Directional couplers: coaxial: 790 Series (pages 238, 239), 1 to 8 gc, $200 to $225; waveguide: 752 Series (pages 236, 237), 2.6 to 40 gc, $125 to $450.

Crystal detectors: coaxial: 423A (page 235), 10 mc to 12.4 gc, $125; waveguide: 424A Series (page 235), 2.6 to 18 gc, $135 to $250 and 422A (page 235), 18 to 40 gc, $250.

Power meter: 431B (pages 220, 221), $450.

Thermistor mounts: coaxial: 478A (page 221), 10 mc to 10 gc, $155; waveguide: 486A Series (page 221), 2.6 to 40 gc, $145 to $375.

Specifications, 690 Series

hp Model	Frequency range	Frequency accuracy	Maximum leveled power	Frequency stability: With temperature	With 10% change in line voltage	With 10 db power level change	Residual FM	Power variation, external leveling*	Output impedance	Output connector	Price	Option 01. Internal leveling: Power variation	Equivalent source match	Price	Option 02. RF output on rear panel: Price
691A	1 to 2 gc	±1%	≥100 mw	±0.01%/°C	±1 mc	±20 mc	<30 kc peak	±0.2 db	50 ohms	Type N	$3200	±0.4 db	1.13:1	$325	$15
691B	1 to 2 gc	±10 mc	≥60 mw	±0.01%/°C	±1 mc	±500 kc	<30 kc peak	±0.1 db	50 ohms	Type N	$3550	±0.3 db	1.13:1	$325	$15
692A	2 to 4 gc	±1%	≥70 mw	±0.01%/°C	±1 mc	±40 mc	<30 kc peak	±0.2 db	50 ohms	Type N	$3000	±0.4 db	1.16:1	$325	$15
H01-692A	1.7 to 4.2 gc	±1%	≥30 mw	±0.01%/°C	±1 mc	±40 mc	<30 kc peak	±0.2 db	50 ohms	Type N	$3300	±0.5 db	1.16:1	$375	$15
692B	2 to 4 gc	±10 mc	≥40 mw	±0.01%/°C	±1 mc	±500 kc	<30 kc peak	±0.1 db	50 ohms	Type N	$3350	±0.3 db	1.16:1	$325	$15
H01-692B	1.7 to 4.2 gc	±13 mc	≥15 mw	±0.01%/°C	±1 mc	±500 kc	<30 kc peak	±0.1 db	50 ohms	Type N	$3650	±0.4 db	1.16:1	$375	$15
693A	4 to 8 gc	±1%	≥20 mw	±0.01%/°C	±2 mc	±50 mc	<50 kc peak	±0.2 db	50 ohms	Type N	$3000	±0.5 db	1.25:1	$350	$15
H01-693A	3.7 to 8.3 gc	±1%	≥10 mw	±0.01%/°C	±2 mc	±50 mc	<50 kc peak	±0.2 db	50 ohms	Type N	$3300	±0.5 db	1.25:1	$350	$15
693B	4 to 8 gc	±20 mc	≥15 mw	±0.01%/°C	±2 mc	±1 mc	<50 kc peak	±0.1 db	50 ohms	Type N	$3350	±0.4 db	1.25:1	$350	$15
H01-693B	3.7 to 8.3 gc	±25 mc	≥5 mw	±0.01%/°C	±2 mc	±1 mc	<50 kc peak	±0.1 db	50 ohms	Type N	$3650	±0.4 db	1.25:1	$350	$15
694A	8 to 12.4 gc	±1%	≥20 mw	±0.01%/°C	±2 mc	±50 mc	<50 kc peak	±0.2 db	50 ohms	Type N	$3100	±0.7 db	1.25:1	$375	$15
H01-694A	7 to 12.4 gc	±1%	≥10 mw	±0.01%/°C	±2 mc	±50 mc	<50 kc peak	±0.2 db	50 ohms	Type N	$3400	±1 db	2:1	$400	$15
694B	8 to 12.4 gc	±30 mc	≥10 mw	±0.01%/°C	±2 mc	±1 mc	<50 kc peak	±0.1 db	50 ohms	Type N	$3450	±0.6 db	1.25:1	$375	$15
H01-694B	7 to 12.4 gc	±40 mc	≥5 mw	±0.01%/°C	±2 mc	±1 mc	<50 kc peak	±0.1 db	50 ohms	Type N	$3750	±1 db	2:1	$400	$15

hp Model	695A	696A	697A	
Frequency range	12.4 to 18 gc	18 to 26.5 gc	26.5 to 40 gc	
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 mc	±15 mc	±20 mc	
Residual FM	<150 kc	<200 kc	<350 kc	
Power variation, external leveling*	±0.2 db	±0.2 db	±0.2 db	
Output connector	UG-419/U	UG-595/U	UG-599/U	
Price	hp 695A, $3500	hp 696A, $4500	hp 697A, $6500	

*Excluding coupler and detector variation.

489A-495A TRAVELING-WAVE TUBE AMPLIFIERS

Broadband, high-gain, high-power amplification, 1 to 12.4 gc

Advantages:

DC-coupled modulation circuitry allows power leveling and remote programming

PPM focusing means fewer alignment problems

Uses:

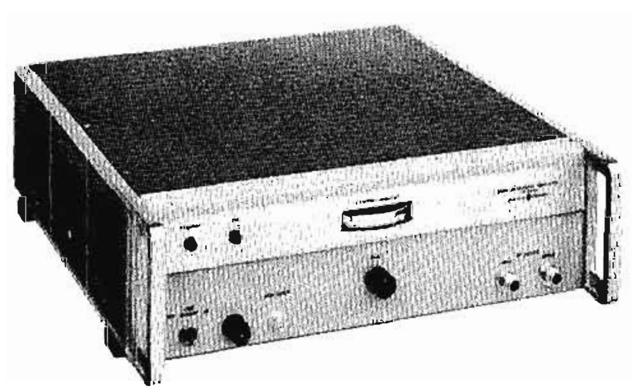
Antenna efficiency and pattern measurements

Extends attenuation measuring systems capability by at least 30 db

Amplification of frequencies from 1 to 12.4 gc 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.



Specifications

	489A	491C	493A	495A
Frequency range (gc)	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
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	$2250	$2250	$2600	$2600

For all models

Maximum rf input: 100 mw.

Input/output characteristics: impedance, 50 ohms; swr, 2.5 or less (cold); connectors, Type N female.

Amplitude modulation

Sensitivity: a signal −20 volts peak or less at the modulation input reduces rf output by more than 20 db.

Frequency response: dc to 100 kc (3 db).

Input impedance: 100 K shunted by approx. 50 pf.

Pulse response: 0.5 μsec 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 40 lbs (18 kg); shipping 46 lbs (20,7 kg).

Power: 115 or 230 volts ±10%, 50 to 60 cps, approx. 225 watts.

Accessories available: 11500A Cable Assembly, $15; 11501A Cable Assembly, $15.

623B, 624C, DY-5636 RF TEST SETS

For testing transmitters, receivers, communications systems

Advantages:

- Direct reading of power, frequency
- Stable, accurate input, output attenuators
- Compact package for easy portability in field

Uses:

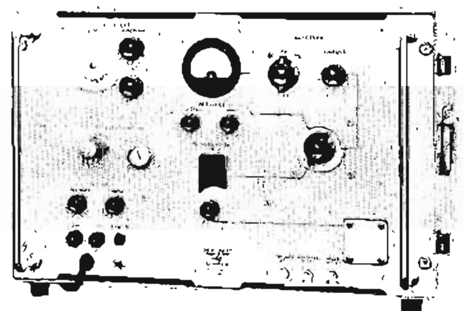
- Measure receiver sensitivity, selectivity
- Test transmitter timing, power level
- Test complete communications, control, video relay, radar, beacon systems

Each of these Dymec 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.

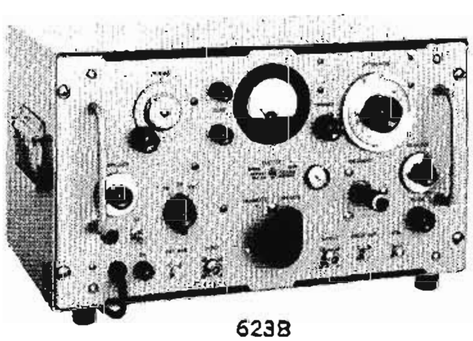
The 623B SHF Test Set is suitable for testing complete communications and video relay station equipment in the range 5925 to 7750 mc, using 3 klystrons. It can be frequency-modulated from an internal source or pulse-modulated from an external source, as can the DY-5636.

The DY-5636 H-Band Test Set more than covers the entire government communications band, 7125 to 8400 mc, and offers higher power than the 623B, permitting testing of receivers through directional couplers.

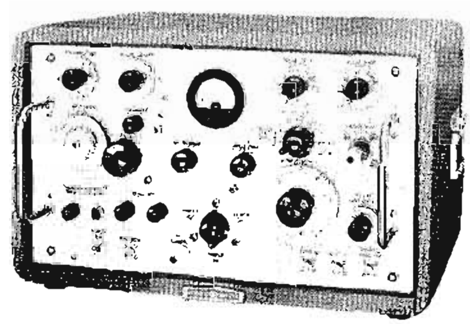
The 624C X-Band Test Set is designed for testing complete radar or fire control systems or radar beacon equipment. It covers the frequency range of 8500 to 10,000 mc. The 624C can be frequency- or pulse-modulated from an internal or external source.



DY-5636



623B



624C

Specifications

Model	Frequency range (mc)	Frequency meter range (mc)	Output power (dbm)	Output attenuator range (db)	Internal modulation	External modulation	Power measurement range (cw)	Panel height	Price
623B	5925-6575 or 6575-7175 or 7125-7750	5820-7780	0 (1 mw)	70	FM, 1 kc	FM, pulse, square-wave, 30 cps to 100 kc	−6 to +3 dbm	11½" (292 mm)	$2250 (transit case)
DY-5636	7100-8500	7100-8500	15 (30 mw)	100	FM, 1 kc	FM, pulse, square-wave, 30 cps to 100 kc	−6 to +40 dbm	14" (355 mm)	$3800 (transit case)
624C	8500-10,000	8500-10,000	0 (1 mw)	100	FM, power line frequency; pulse, 35 to 3500 pps	FM, pulse, square-wave, 35 to 3500 cps	−6 to +28 dbm	10½" (266 mm)	$2265 (cabinet) $2250 (rack mount)

211A CRYSTAL-MONITORED SIGNAL GENERATOR, 213A PHASE TEST SET

Tests and calibrates aircraft VOR and ILS localizer receivers

211A Signal Generator

The Boonton 211A 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 mc. It also may be used for laboratory and development work where a precision-type amplitude-modulated rf signal source is required.

A demodulator stage is included within the 211A Signal Generator which supplies to front-panel binding posts a portion of the demodulated rf carrier. This feature permits checking the actual modulation process within the instrument and enables the identification of beat points by the use of earphones in standardizing the master oscillator against harmonics of the crystal frequencies.

Specifications, 211A

Radio frequency characteristics

RF range: master oscillator: 88 to 140 mc in one range; crystal oscillator: 110.1 and 114.9 mc.

RF output: range: 0.1 μv to 0.2 volts (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 volts, 50 to 60 cps, 150 watts.

Price: Boonton 211A, 211AP1, $2190.

213A Phase Test Set

The Boonton 213A Test Set was developed to provide a simple and precise method of measuring and adjusting over-all phase shift in the 211A Crystal-Monitored Signal Generator. It is furnished complete with all interconnecting cables but requires the use of an auxiliary audio oscillator and oscilloscope.

Specifications, 213A

"30 Cycle Bridge" operation: sensitivity such that a phase shift of 1° can be made to produce at least 2" deflection on the oscilloscope screen for modulation percentages of the 211A of 30% or greater; self-calibrating for measurements of phase shift with a calibration error of less than 0.1° when the 1° "Bridge Calib" position is used.

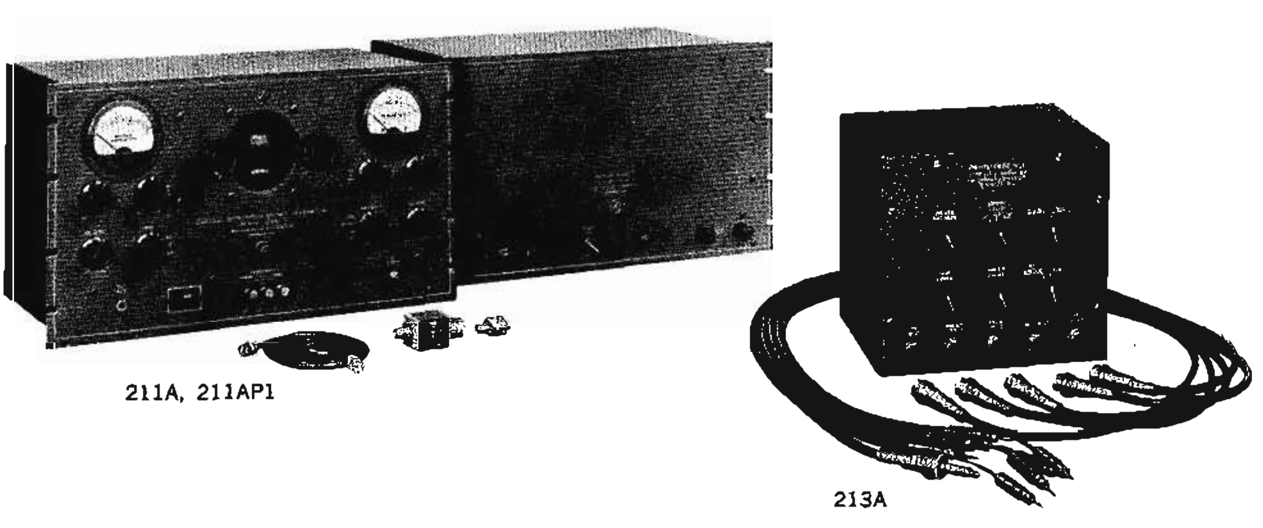
"Direct" measurements: useful at any modulation frequency between 20 and 11,000 cps (must be phased and have gain adjusted at each modulation frequency at which phase shift is checked).

Accessories furnished: 5 cables, 3 ft. long, mating with microphone jacks on test set at one end and terminating in clip leads for 4 cables and a phone plug for one cable.

Dimensions: 7¼" wide, 7¼" high, 5¼" deep (174 x 174 x 133 mm).

Weight: net 11 lbs (5 kg); shipping 15 lbs. (6,8 kg).

Price: Boonton 213A, $230.



211A, 211AP1

213A

232A GLIDE SLOPE SIGNAL GENERATOR

Tests and calibrates aircraft ILS glide slope receivers

Advantages:

- Provides 20 crystal-controlled rf output frequencies and one crystal-controlled IF output frequency
- Internal alternator driven by a synchronous motor modulates either the rf or IF generator simultaneously with 90 and 150 cps audio
- Modulation depth resulting from each tone can be independently adjusted to equality, and relative levels subsequently varied
- A 1000 cps audio oscillator included for general-purpose work
- Continuously variable attenuator calibrated in microvolts controls output of the rf or IF generator
- Demodulated output from the rf or IF generator available at front-panel terminals

Uses:

- Calibrating, testing glide slope receivers used in aircraft instrument landing systems
- Provides calibrated signals for measuring sensitivity, aligning rf and IF section of receiver
- Measuring, calibrating sensitivity and centering of receiver system for indicating vertical course position of airplane
- General study of receiver characteristics with 1000 cps modulated carriers

The FAA Instrument Landing System for aircraft includes a glide slope receiver for indicating the proper rate of descent. The glide slope signal generator 232A was designed for use in testing and calibrating these glide slope receivers.

The Boonton 232A includes two complete generators: an rf generator and an IF generator. Each is capable of being modulated to a depth of 100% by self-contained modulation sources or by an external modulation source.

Both generators use a common carrier monitor meter to indicate output level and a per cent modulation meter to indicate per cent modulation. The output of each generator is adjusted by a common knob and indicated in microvolts on a common attenuator dial. The rf generator supplies 20 crystal-controlled frequencies from 329.3 mc to 335 mc in 0.3 mc steps, and the IF generator supplies one crystal-controlled frequency. The IF frequency is 20.7 mc but can be changed to other frequencies from 15 to 30 mc by a change of crystals and internal adjustments. The power supply is internally regulated.

The glide slope receiver in an aircraft receives two carriers of the same frequency: one is modulated with 90 cps audio, and the other is modulated with 150 cps audio. The airplane's position is indicated at the output of the receiver by the relative levels of these two modulations. The rf carrier from the 232A can be internally modulated with 90 and 150 cps audio simultaneously, and the relative amounts of modulation can be varied by a front-panel switch. This provides a test of the sensitivity and course correctness of the receiver under test.

Specifications

Radio frequency characteristics

RF range: (A) 329.3 to 335 mc in increments of 0.3 mc; (B) 20.7 mc; other frequencies between 15 and 30 mc 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 cps; (B) 90 to 150 cps in the following tone ratios: 0 db, ±0.5 db, ±1 db, ±2 db, ±3.3 db, ± infinite db (calibrate).

Accessories furnished: 505B Attenuator; 506B Patching Cable; 507B Adapter; 514B Output Cable.

Accessories available: 502B Patching Cable, $6.50; 504A Adapter, $3.75; 509B Attenuator, $33; 510B Attenuator, $35.25.

Physical characteristics

Mounting: cabinet for bench use; when removed, suitable for 19" rack mounting.

Finish: gray wrinkle, engraved panel (other finishes available on special order).

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 volts, 60 ±1 cps, 150 watts.

Price: Boonton 232A, $2375.

8925A DME/ATC TEST SET

Specifically designed for testing, calibrating DME and ATC transponder aircraft equipment

The Boonton 8925A DME/ATC Test Set is specifically designed for the testing and calibration of DME (Distance Measuring Equipment) and ATC (Air Traffic Control) transponder aircraft equipment. The test set is completely self-contained (except for video modulators) and consists of a continuously tuneable signal generator, direct-reading frequency counter, solid-state modulator, frequency meter, peak power measuring system and all necessary circuitry for interconnection to the radio set under test.

The basic test signal is generated by a Hewlett-Packard H01-8614A Signal Generator, which covers the range 962 to 1213 mc. The test frequency is indicated approximately on the front-panel dial of the signal generator and is simultaneously monitored and indicated on a solid-state hp 5245L Electronic Counter, employing a 5254A Frequency Converter. Frequency may be set to within 50 kc with the Δf control on the H01-8614A. The rf output of the signal generator is automatically leveled, eliminating the need to adjust the output level as frequency is varied, and the output attenuator is calibrated to read out directly the applied signal level to the radio under test over the range from −10 to −100 dbm.

The cw output of the signal generator is modulated by a Hewlett-Packard H01-8403A Modulator employing PIN diodes as modulator elements. Pulsed video test signals simulating DME/ATC ground emission are fed to the modulator from either an external Collins Radio 578D-1 DME Bench Test Set modified for Gaussian pulse output or 578X-1 ATC Transponder Test Set. The modulator also incorporates complete provisions for side-lobe suppression measurements, in that the second pulse of a train of two or three pulses may be varied over the range +1 to −10 db from the first pulse with a calibrated front-panel control. TACAN bearing information also may be simulated, employing an external audio frequency source.

The modulated rf output is fed into a Boonton 13505A Isolator-Monitor, which performs three separate functions. Isolation is provided for the high-power transmitter output of the radio set under test by a microwave circulator, protecting the signal generator and modulator. Auxiliary calibrated rf outputs are provided for operation of the frequency meter and peak power measuring system. A diode and a linear heterodyne monitor are provided for viewing the pulsed rf test signals on an external oscilloscope such as the hp 175A (pages 283, 284). Switching from the normal operating mode to the monitoring mode is simply accomplished by operating a front-panel control which activates an internal electrically-operated coaxial switch. A transmitter interlock is provided via rear terminals for de-energizing the DME/ATC transmitter when the test set load is removed from the antenna of the radio set under test.

A Boonton 8905A Wavemeter provides direct measurement to ±0.5 mc of the ATC reply frequency over the range from 1070 to 1110 mc. Response of the self-powered transmission-type wavemeter is directly indicated on a front-panel meter.

A Boonton 8900B Peak Power Calibrator provides complete facilities for measuring the peak power output of DME and ATC transmitters over the range from 10 to 2000 watts. In operation, an external oscilloscope is connected to the video output, the front-panel controls are adjusted by observing the oscilloscope display, and the peak power is read directly on the panel meter. The calibrator also incorporates a wideband detector for viewing transmitter waveforms on an external oscilloscope. This output also provides a reply signal for DME distance measurements. The individual modules are mounted in an enclosed rack cabinet which includes a master power distribution system and forced air cooling. All necessary interconnecting cables are included.

Specifications

Radio frequency characteristics

RF range: 962 to 1213 mc.

RF accuracy: determined by ability to set to desired reading on counter.

RF settability: better than 100 kc.

RF stability: temperature, approx. 0.005% per degree C; line voltage, <0.003% (±10% line voltage change).

RF output

Range: −10 to −100 dbm across external 50-ohm load at output jack.

Accuracy:

Attenuator setting	ATC (1015 to 1045 mc)	DME (962 to 1213 mc)
−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

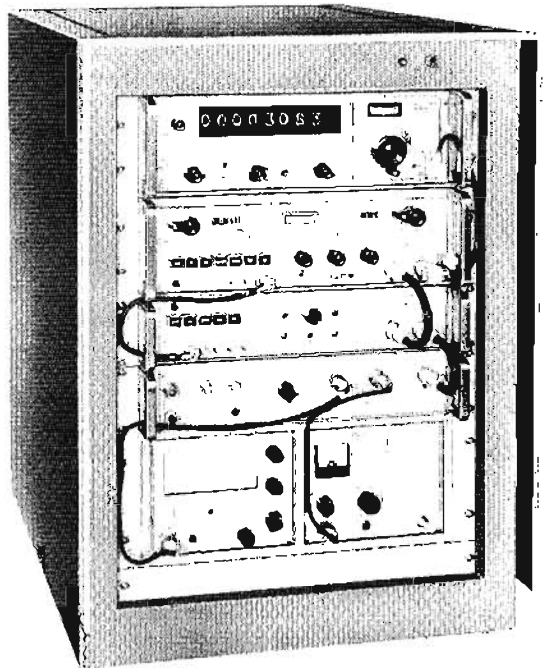
PM source: simulation of DME/ATC ground emission as provided by Collins 578X-1 and 578D-1 (modified for Gaussian pulse) Test Sets.

PM rise time: ATC, >50 nsec and <100 nsec; DME, controlled by pulse source to meet "Pulse Shape" Spec., Sect. G, Appendix A, RTCA 167-59/DO-99.

PM fall time: ATC, >50 nsec and <200 nsec; DME, controlled by pulse source to meet "Pulse Shape" Spec., Sect. G, Appendix A, RTCA 167-59/DO-99.

PM overshoot: ATC, <5%; DME, not meaningful.

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 μsec from the first pulse leading edge; (see RTCA 181-61/DO-112, Appendix A, T-6, Steps 1, 2, 3, 4, 9, 10); 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 mc.

RF power range: 100 to 2000 watts peak (ARINC units); 10 to 200/100 to 2000 watts peak* (Gen. Aviation & ARINC units) available as factory modification with accessory attenuator.

RF power accuracy: ±1.2 db (±0.6 db from calibration curve).

Frequency measurement characteristics

RF range: 1070 to 1110 mc.

RF accuracy: ±0.5 mc; direct meter indication for peak power 250 to 1000 watts; 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 mc (for beating oscillator 1025 ± 1 mc).

Output level: 0.5 volts peak minimum at —10 dbm rf level (at IF center frequency).

Load impedance: 150 ohms nominal.

Bandwidth: 9 mc nominal (equivalent low-pass bandwidth 4 mc).

Linearity: ±0.5 db (—10 to —20 dbm rf level).

Diode monitor (Diode Mon):

Frequency range: 962 to 1213 mc.

Output level: 0.1 v peak min. at —10 dbm rf level.

Low-pass bandwidth: 5 mc 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 mc 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.

Instrument complement: hp H01-8614A Signal Generator, hp H01-8403A Modulator, hp 5245L Electronic Counter, hp 5254B Frequency Converter, 13505A Isolator-Monitor, 8900B Peak Power Calibrator, 8905A Wavemeter.

Accessories available: hp 175A Oscilloscope, Collins 578D-1 DME Bench Test Set, Collins 578X-1 ATC Transponder Test Set.

Physical characteristics

Mounting: enclosed rack mounting complete with forced-air cooling.

Finish: gray (other finishes available on special order).

Dimensions: 23" wide, 32¼" high, 26" deep (584 x 819 x 660 mm).

Weight: net 285 lbs (129,3 kg); shipping 335 lbs (150,8 kg).

Power: 105 to 125 or 210 to 250 volts, 50 to 60 cps, 400 watts; a master circuit breaker/switch controls power to the complete rack.

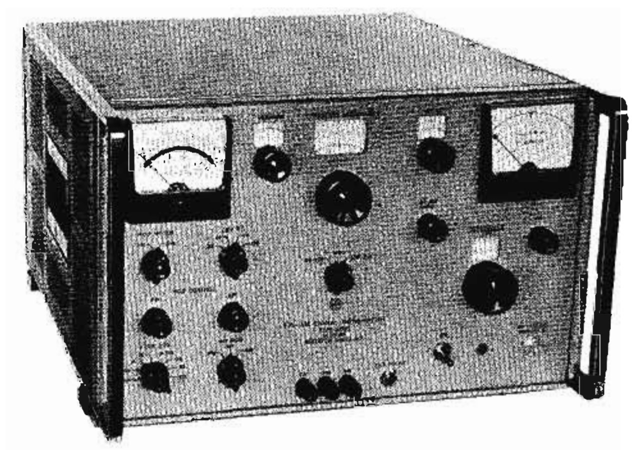
Price: Boonton 8925A, $12,090 complete; $8315 less hp 5245L/5254A Counter.

*Add $100 for 10 to 200/100 to 2000 watts dual range.

202H FM-AM SIGNAL GENERATOR

FM, AM, CW and pulse coverage 54 to 216 mc

The Boonton 202H FM-AM Signal Generator covers the frequency range from 54 to 216 mc 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.



Specifications

Radio frequency characteristics

- **RF range:** total range: 54 to 216 mc; number bands: 2; band ranges: 54 to 108 mc 108 to 216 mc.
- **RF accuracy (after 1 hour warm-up):** main dial: ±0.5%; electronic vernier: ± (10% +1 kc).
- **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 cps at 30% and 50% AM.
- **AM calibration:** 30, 50, 100%.
- **AM distortion:** <5% at 30%, <8% at 50%, <20% at 100%.
- **AM fidelity:** ±1 db, 30 cps to 200 kc.
- **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 kc in 4 ranges.
- **FM deviation accuracy:** ±5% of full-scale (for 400 cps sine wave).
- **FM calibration:** 0 to 7.5 kc in increments of 0.5 kc, 0 to 25 kc in increments of 1 kc, 0 to 75 kc in increments of 5 kc, 0 to 250 kc in increments of 10 kc.
- **FM distortion (at 400 cps mod. freq.):** <0.5% at 75 kc (100 mc), <1% at 75 kc (54 to 216 mc), <10% at 250 kc (54 to 216 mc).
- **FM fidelity:** ±1 db, 5 cps to 200 kc.
- **Signal-to-noise ratio:** >50 db below 10 kc.
- **Microphonism:** extremely low; shock-mounted rf unit.
- **External FM requirements:** <3 volts rms into 2 K ohms for 250 kc 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 μsec.
- **PM decay time:** <0.8 μsec.

Modulating oscillator characteristics

- **OSC frequency:** 50 cps, 400 cps, 1000 cps, 3000 cps, 7.5 kc, 10 kc, 15 kc, 67 kc.
- **OSC accuracy:** ±5%.
- **OSC distortion** (at FM terminals): <0.5%, 50 cps to 15 kc; <1.0%, 67 kc.

Physical characteristics

- **Dimensions:** 16¾" wide, 10⅜" high, 18⅜" deep (425 x 263 x 467 mm).
- **Weight:** net 45 lbs (20,3 kg), shipping 100 lbs (45 kg).

Power: 105 to 125 or 210 to 250 v, 50 to 60 cps, 100 w.

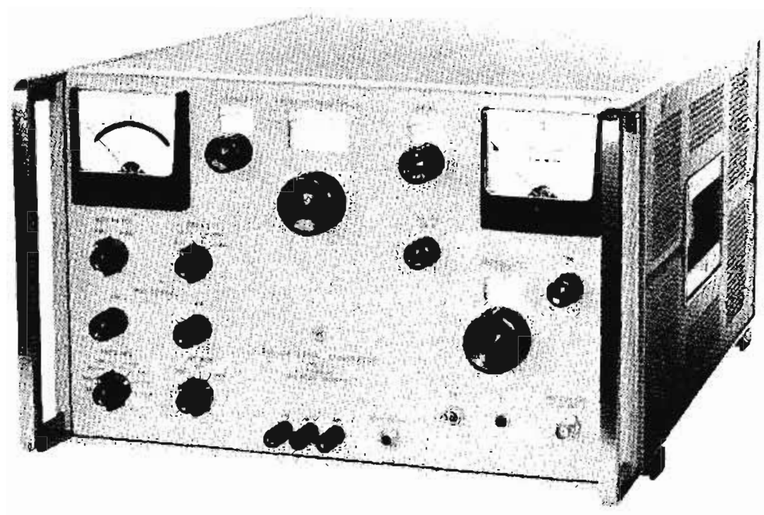
Accessories furnished: 502B Patching Cable.

Price: Boonton 202H, $1475.

202J TELEMETERING SIGNAL GENERATOR

FM, AM, cw and pulse coverage, 195 to 270 mc

The Boonton 202J Telemetering Signal Generator covers the frequency range from 195 to 270 mc and is designed for the testing and calibration of FM telemetering receiving systems in the 215 to 260 mc band. 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.



Specifications

Radio frequency characteristics

RF range: 195 to 270 mc.

RF accuracy: main dial: ±0.5%; electronic vernier: ±(10% + 1 kc) after one-hour warm-up.

RF stability: <0.2% 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.

Amplitude modulation characteristics

AM range: internal, 0 to 50%; external, 0 to 100%.

AM accuracy: ±10% of reading at 400 cps at 30% and 50% AM.

AM calibration: 30, 50, 100%.

AM distortion: <5% at 30%, <8% at 50%, <20% at 100%.

AM fidelity: ±1 db, 30 cps to 200 kc.

External AM requirements: approximately 50 volts rms into 7500 ohms for 100% AM.

Frequency modulation characteristics

FM deviation range: internal, 0 to 300 kc in 4 ranges; external, 0 to 300 kc in 4 ranges.

FM deviation accuracy: ±5% of full scale (indication proportional to p-p modulating waveform at 400 cps).

FM calibration: 0 to 15 kc in increments of 0.5 kc, 0 to 30 kc in increments of 1 kc, 0 to 150 kc in increments of 5 kc, 0 to 300 kc in increments of 10 kc.

FM non-linearity: <1.5% at 150 kc, <5% at 300 kc; ("least squares" departure from straight line passing through origin.)

FM fidelity: ±1 db, 5 cps to 500 kc; ±3 db, 3 cps to 1 mc.

Spurious FM: total rms spurious FM from 60 cps power source is at least 60 db below 150 kc (<150 cps).

Microphonism: extremely low; shock-mounted rf unit.

External FM requirements: <1 volt rms into 100 K ohms in parallel with less than 50 pf for 150 kc deviation.

Pulse modulation characteristics: PM source: external.

PM rise time: <0.25 μsec.

PM fall time: <0.8 μsec.

Modulation oscillator characteristics

OSC frequency: 50 cps, 400 cps, 1700 cps, 3900 cps, 10.5 kc, 30 kc, 70 kc, 100 kc.

OSC accuracy: ±5%.

OSC distortion: <0.5%.

Accessory furnished: 502B Patching Cable.

Physical characteristics

Dimensions: 16¾" wide, 10⅜" high, 18⅜" deep (425 x 263 x 467 mm).

Weight: net 45 lbs (20,3 kg); shipping 60 lbs (27 kg).

Power: 105 to 125 or 210 to 250 v, 50 to 400 cps, 100 w.

Price: Boonton 202J, $1595.

219A FM STEREO MODULATOR

Provides complete, versatile measurements on stereo broadcast receivers

The Boonton 219A FM Stereo Modulator is designed to provide a multiplex output signal in accordance with FCC Docket 13506 when fed with left (L) and right (R) audio stereo channel inputs and/or subsidiary communications FM subcarriers (SCA). The output of the modulator may be switched to provide either (L + R), (L − R), 19 kc pilot carrier, 38 kc residual carrier or the complete multiplex signal which can then be used to modulate a suitable FM signal generator. When used with the Boonton 202H, no external audio oscillator or other equipment is required, since the seven fixed 202H modulating oscillator test frequencies may be fed directly into either the left (L) or right (R) input of the 219A.

The Boonton 519A Output Cable (available as an optional accessory) provides a convenient means of interconnecting the FM stereo modulator with the 202H Signal Generator (page 208). Direct connection is provided between the output of the 219A and the external FM modulation input of the 202H.

A peak-reading metering system, calibrated in per cent of system deviation, is provided for setting and monitoring the levels of the individual sub-carriers. The internal matrix may be switched from the normal condition to provide either (L + R) or (L − R) null for checking the matrix in the receiver under test. The modulator is completely self-contained and housed in a single cabinet which may be adapted for standard rack mounting.

Specifications

Input characteristics: (Left (L) and right (R) inputs)
- **Frequency range:** 50 cps to 15 kc.
- **Level:** 1.7 ±0.3 volts rms (for 90% peak multiplex output with either an L or R input).
- **Impedance:** 10 K ohms shunted with 30 pf.
- **Pre-emphasis:** 75 μsec pre-emphasis switchable in or out of circuit.

Subsidiary Communications (SCA) Input
- **Frequency range:** 20 to 75 kc.
- **Level:** 1 v rms (for approx. 10% peak multiplex output).
- **Impedance:** 10 K ohms.

Modulating oscillator characteristics
- **OSC. frequency:** 1 kc.
- **OSC. accuracy:** ±10%.
- **OSC. output:** switchable into either L or R input.
- **OSC. distortion:** <1%.

Output characteristics
- **Level:** 0 to 7.5 volts peak (multiplex output).
- **Load impedance:** >1500 ohms shunted with <200 pf.
- **Residual hum and noise:** >60 db below 100% output.
- **Crosstalk (L − R) into (L + R):** >40 db below 100% output.

Metering
- **Range:** 0 to 10% (19 kc and 38 kc only); 0 to 100% (multiplex output; output adjustable 0 to 7.5 volts peak for 100% meter indication).
- **Calibration:** 0 to 10% in increments of 1%, 6 to 10%; 0 to 100% in increments of 5%.
- **Accuracy:** ±2% f.s. (±1% relative accuracy at 45% (L + R) and (L − R) and at ½ of 90% for multiplex signal).
- **Matrix:** normal, L + R null, L − R null.
- **Output modes:** switchable for L + R, L − R, 19 kc pilot carrier, 38 kc residual carrier or multiplex signal.
- **Pilot carrier:** frequency, 19 kc; accuracy, ±0.01%; level, 0 to 30% (multiplex output).
- **Monaural (L + R):** output level: 0 to 100% (multiplex output with either an L or R signal).
- **Fidelity:** 50 cps to 15 kc, ±1 db (±0.2 db and ±1.5° relative to (L − R)).
- **Distortion:** <1% (at 45% composite output).

Double sideband suppressed carrier (L − R)
- **Frequency:** 38 kc.
- **Frequency accuracy:** ±0.01%.
- **Carrier level:** <0.5% (composite output).
- **Output level:** 0 to 100% (composite output with either an L or R signal).
- **Fidelity:** 50 cps to 15 kc ±1 db (±0.2 db and ±1.5° relative to (L + R)).
- **Distortion:** <1% (at 45% composite output).

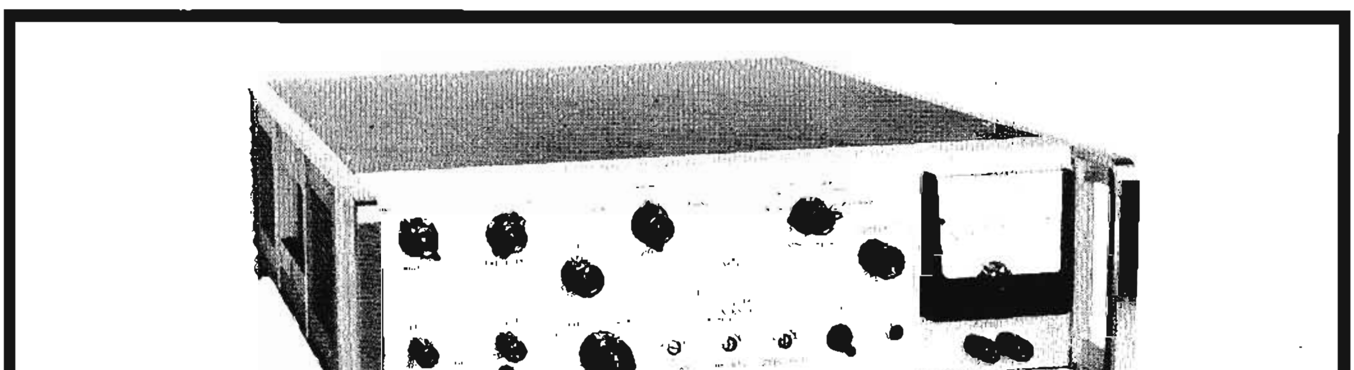
Subsidiary Communications (SCA)
- **Output level:** 0 to 20% (composite output).
- **Fidelity:** 20 to 75 kc ±0.5 db.
- **Distortion:** <1% (at 10% composite output).

Oscilloscope synchronizing signal
- **Frequency:** 19 kc.
- **Output level:** 0.5 volts rms nominal.
- **Impedance:** 25 ohms nominal.

Physical characteristics
- **Dimensions:** 16¾" wide, 5-7/32" high, 16⅜" deep (425 x 133 x 417 mm).
- **Weight:** net 35 lbs (15,8 kg); shipping 45 lbs (20,3 kg).

Power: 105 to 125 or 210 to 250 volts, 50 to 60 cps, 130 watts.

Price: Boonton 219A, $975.



207H UNIVERTER

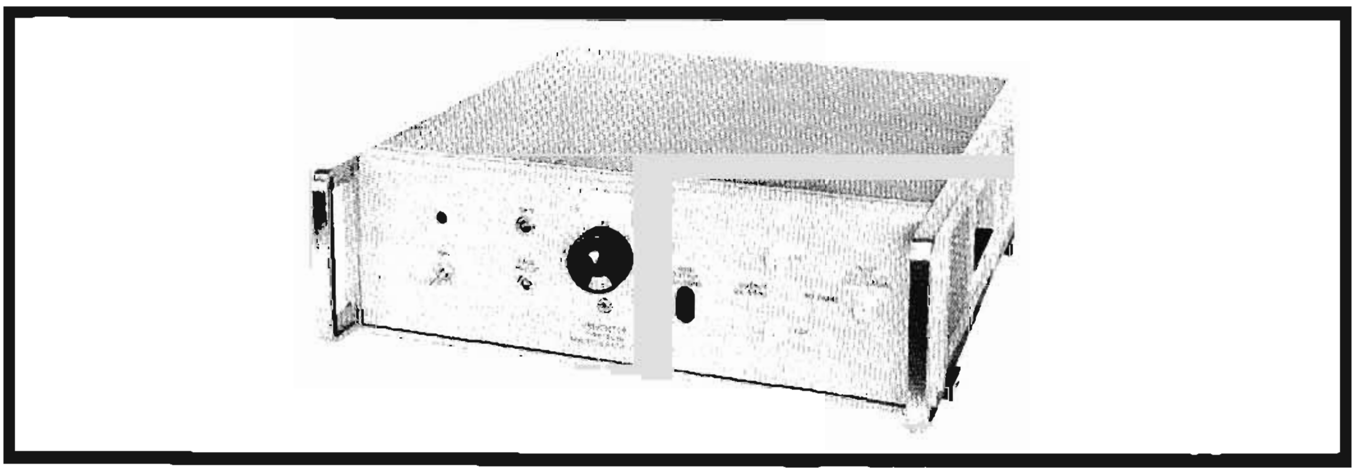
Provides extended frequency coverage 100 kc to 55 mc for 202H, J Signal Generators

The Boonton 207H Univerter, a frequency converter with unity gain, is designed for use with Boonton 202H FM-AM Signal Generator (page 208) and the 202J Telemetering Signal Generator (page 209) to provide additional frequency coverage from 100 kc to 55 mc, including commonly used intermediate frequencies.

The univerter consists essentially of a semi-fixed frequency, 200 mc heterodyne oscillator, a wideband amplifier and a self-contained regulated power supply. In operation, the internal heterodyne oscillator beats with the output signal of the 202H (199.9 to 145 mc) or 202J (200.1 to 255 mc), and the difference frequency is passed through the wideband amplifier to the output system.

The output frequency of the univerter is easily determined by subtracting 200 mc from the frequency dial reading of the 202J or subtracting the 202H frequency dial reading from 200 mc. In addition, a front-panel incremental frequency control, calibrated in 5 kc increments provides continuous control over a ±300 kc range. External adjustments are provided for setting the overall gain of the instrument to unity and for adjusting the center frequency of the local oscillator to zero beat with the 200 mc dial calibration of the 202H or 202J.

To use the univerter, it is only necessary to connect the rf output of the associated 202H or 202J Signal Generator to the input of the univerter; three separate outputs are provided. The X1 output provides unity gain, under the control of the signal generator attenuator, and is suited for most general-purpose applications. The X0.01 output attenuates the input signal level, as well as the random noise power output, 40 db, and is specifically provided for receiver measurements in the low microvolt region. An uncalibrated, high-level output provides a minimum of one volt into a 300-ohm load, with 0.1 volt input.



Specifications

(when used with 202H and 202J Signal Generators)

Radio frequency characteristics

RF range: 100 kc to 55 mc (with 199.9 to 145 mc input from 202H, with 200.1 to 255 mc input from 202J).

RF calibration: incremental range, ±300 kc; incremental calibration, increments of 5 kc; incremental accuracy, ±(3% + 1 kc).

RF stability: short-term, <0.001%† (5 minutes); long term, <0.005%† (1 hour); line voltage, <400 cps/v.

RF output

Range: (A) 1 μv to 0.1 v* (X1); (B) 0.01 μv to 1 mv* (X0.01); (C) >1 v**, high output.

Accuracy: (A) reproduces output of 202H or 202J ±1 db; (B) reproduces output of 202H or 202J ±2 db.

Impedance: (A) 50 ohms nominal; (B) 50 ohms nominal; (C) 300 ohms nominal.

Spurious output: all spurious output voltages are better than 25 db‡ below desired output; spurious output of 207H alone consists of random noise and 200 mc local oscillator; at X0.01 output, noise power essentially equivalent to 50-ohm resistor at room temperature.

Modulation characteristics

Range: duplicates FM and AM modulation of 202H or 202J.

Distortion: FM, no appreciable distortion; AM, no appreciable distortion for input levels <0.05 v.

Accessories furnished: 524A Patching Cable; high-output plug.

Accessories available: 501B Output Cable, \$15.50; 502B Patching Cable, \$6.50; 506B Patching Cable, \$6.50; 514B Output Cable, \$15.50.

Physical characteristics

Mounting: cabinet for bench use; readily adaptable for 19" rack mounting.

Finish: gray panel; blue cabinet (other finishes available on special order).

Dimensions: 16¾" wide, 5-33/64" high, 18⅜" deep (425 x 140 x 467 mm).

Weight: net 26 lbs (11,7 kg); shipping 38 lbs (17,1 kg).

Power: 207H: 95 to 130 volts, 60 cps, 50 watts; 207 HP: 95 to 130/190 to 260 volts, 50 cps, 50 watts.

Price: Boonton 207H, \$595; Boonton 207HP, \$595.

†after one-hour warm-up.
*across external 50-ohm load at panel jack.
**with 0.1 v input and 300-ohm output load.
‡for input levels <0.05 volts.

ACCESSORIES FOR BOONTON SIGNAL GENERATORS

Cables, adapters, attenuators

501B, 514B, 517B Output Cables

The 501B Output Cable consists of shielded coaxial cable with a characteristic impedance of 50 ohms terminated at one end with a plug-type BNC connector. The other end is terminated in a 50-ohm resistor mounted in a molded holder, connected across two binding post connectors. Open circuit impedance across the binding posts, with the BNC connector connected to a 50-ohm signal generator is 25 ohms. Overall length is 3 ft 3 in. (991 mm). Connects signal generators to receivers. Price: Boonton 501B, $15.50.

The 514B Output Cable consists of a shielded coaxial cable with a characteristic impedance of 50 ohms terminated at one end in a plug-type BNC connector. The other end is terminated in a 50-ohm resistor, mounted in a molded housing connected across two alligator clips. Overall length is 6 ft (1829 mm). This cable is used generally at IF frequencies to connect signal generators to terminals within a receiver. Price: Boonton 514B, $15.50.

The 517B Output Cable consists of a coaxial cable with a characteristic impedance of 50 ohms terminated at one end in a jack-type BNC connector. The other end is terminated in a coaxially mounted 50-ohm metalized disc resistor followed by a 25-ohm series coaxial center conductor resistor to a plug-type BNC connector. It produces a 6 db attenuation between a voltage, when connected by a 50-ohm source impedance to the cable input and the terminated output voltage. Under these conditions, the impedance looking into the open circuit output is 50 ohms. Price: Boonton 517B, $24.75.

502B, 506B Patching Cables

The 502B and 506B Patching Cables consist of shielded coaxial cable with a characteristic impedance of 50 ohms terminated at each end by a plug-type BNC connector. Overall length of 502B is 3 ft (914 mm), of 506B is 6 ft (1828 mm). These cables are intended for connecting signal generators to the attenuators and adapters listed on this page. Prices: Boonton 502B, $6.50; Boonton 506B, $6.50.

504A, 507B, 508B Adapters

The 504A Adapter consists of an interconnected jack-type BNC connector and plug-type N connector. The unit is intended for adapting plug-type BNC connectors on 502B and 506B Patching Cables to receivers with jack-type N input connectors. Price: Boonton 504A, $3.75.

The 507B Adapter is used for connecting a 95-ohm balanced load to a 50-ohm unbalanced source. It produces an attenuation of 6 db between the input voltage and the terminated output voltage when the input voltage is connected to the attenuator input through a 50-ohm source impedance. Under these conditions, the impedance looking into the output is 95 ohms. The input connector is a jack-type BNC and the output connector is a plug-type small twin connector. Price: Boonton 507B, $35.25.

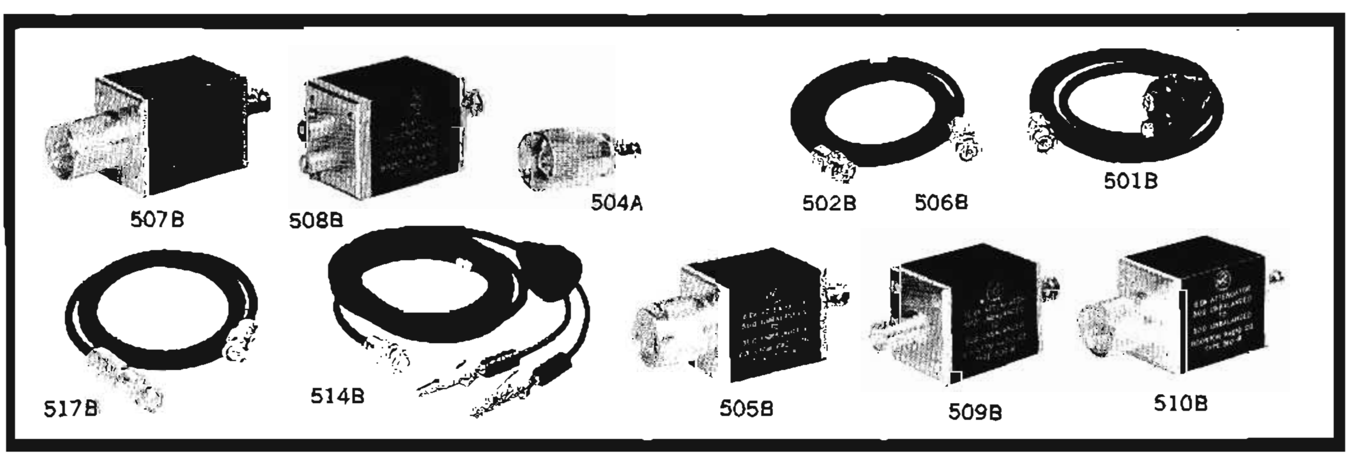
The 508B unit adapts 300-ohm balanced loads to 50-ohm unbalanced sources. It produces an attenuation of 6 db between the input voltage and the terminated output voltage when the input voltage is connected to the attenuator input through a 50-ohm source impedance. Under these conditions, the impedance looking into the output is 300 ohms. The input connector is a jack-type BNC connector and the output connection is to two binding posts. Price: Boonton 508B, $35.

505B, 509B, 510B Attenuators

The 505B unit includes an unbalanced "T" type resistive attenuator inserted between a jack-type BNC and plug-type N connector. It produces an attenuation of 6 db between the input voltage and the terminated output voltage when the input voltage is connected to the attenuator input through a 50-ohm source impedance. Under these conditions, the impedance looking back into the output is 50 ohms. This unit is used for isolating receiver and signal generator and as a dummy antenna. Price: Boonton 505B, $34.

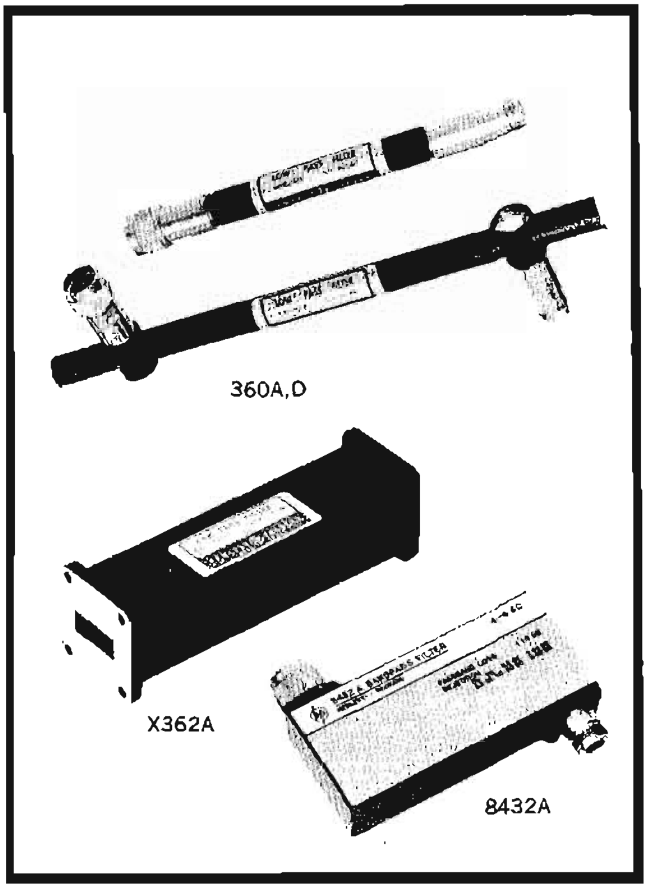
The 509B unit includes an unbalanced "T" type resistive attenuator inserted between two jack-type BNC connectors. It produces an attenuation of 20 db between the input voltage and the terminated output voltage when the input voltage is connected to the attenuator input through a 50-ohm source impedance. Under these conditions, the impedance looking into the output is 50 ohms. This attenuator is used for isolating the receiver from the signal generator and as a dummy antenna. Price: Boonton 509B, $33.

The 510B unit includes an unbalanced "T" type resistive attenuator inserted between a jack-type BNC and plug-type UHF connector. It produces an attenuation of 6 db between the input voltage and the terminated output voltage when the input voltage is connected to the attenuator input through a 50-ohm source impedance. Under these conditions, the impedance looking back into the output is 50 ohms. This unit is used for isolating receiver and signal generator and as a dummy antenna. Price: Boonton 510B, $35.25.



360A-D, 362A LOW-PASS FILTERS; 8430 BANDPASS FILTERS

Effective elimination of undesirable signals



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 851A/8551A Spectrum Analyzer (pages 216, 217). As such, they permit the maximum utilization of the analyzer's broad spectrum-width capability while assuring virtually spurious-free displays.

Specifications, 360 Series

hp Model	360A	360B	360C	360D
Cut-off frequency	700 mc	1200 mc	2200 mc	4100 mc
Insertion loss	$\le$1 db below 0.9 times cut-off frequency			
Rejection	*$\ge$50 db at 1.25 times cut-off frequency*			
Impedance	50 ohms through passband; should be matched for optimum performance			
SWR	$<$1.6 to within 100 mc of cut-off		$<$1.6 to within 200 mc of cut-off	$<$1.6 to within 300 mc of cut-off
Connectors	Type N, one male, one female			
Overall length (in) (mm)	10⅞ 276	7-7/32 183	10-25/32 274	7⅜ 187
Center line (in) to male end (mm)	2⅛ 54	2⅛ 54	— —	— —
Center line (in) to female end (mm)	2¼ 57	2¼ 57	— —	— —
Shipping (lbs) weight (kg)	2 0,9	2 0,9	2 0,9	2 0,9
Price	$70	$60	$50	$50

Specifications, 362A Series

hp Model	X362A	M362A	P362A	N362A	K362A*	R362A*
Passband (gc)	8.2–12.4	10.0–15.5	12.4–18.0	15.0–21.0	18.0–26.5	26.5–40.0
Stop band (gc)	16–37.5	19–47	23–54	29–63	31–80	47–120
Insertion loss	less than 1 db	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 40 db	at least 35 db
SWR	1.5	1.5	1.5	1.5	1.5	1.8
Waveguide size, in. (EIA)	1 x 0.5 (WR 90)	0.850 x 0.475 (WR 75)	0.702 x 0.391 (WR 62)	0.590 x 0.335 (WR 51)	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)	3-1/32(77)	2½(64)	1-21/32(42)
Shipping weight, lbs. (kg)	2(0.9)	2(0,9)	1(0,45)	1(0,45)	½(0,23)	½(0,23)
Price	$325	$350	$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 (gc)	Max. passband insertion loss	Rejection band attenuation: Below passband: Frequency (gc)	Below passband: Attenuation	Above passband: Frequency (gc)	Above passband: Attenuation	Dimensions (in)	Dimensions (mm)	Shipping weight (lb)	Shipping weight (kg)	Price
8430A	1 to 2	1.5 db	$\le$0.8	$\ge$50 db	2.2 to 20	$\ge$45 db	5½ x 4¾ x 1	140 x 121 x 25	3	1,4	$210
8431A	2 to 4	1.5 db	$\le$1.6	$\ge$50 db	4.4 to 20	$\ge$45 db	5½ x 3 x 1	140 x 76 x 25	2	0,9	$210
8432A	4 to 6	1.5 db	$\le$3.5	$\ge$50 db	6.5 to 20	$\ge$45 db	4½ x 2 x 1	114 x 51 x 25	2	0,9	$275
8433A	6 to 8	1.5 db	$\le$5.5	$\ge$50 db	8.5 to 20	$\ge$45 db	4 x 1½ x 1	102 x 38 x 25	2	0,9	$275
8434A	8 to 10	1.5 db	$\le$7.5	$\ge$50 db	10.5 to 17	$\ge$45 db	4⅝ x 1 x 1	118 x 25 x 25	2	0,9	$275
8435A	4 to 8	1.5 db	$\le$3.2	$\ge$50 db	8.8 to 20	$\ge$45 db	3⅝ x 1¾ x 1	92 x 45 x 25	2	0,9	$210
8436A	8 to 12.4	1.5 db	$\le$6.9	$\ge$50 db	13.5 to 17	$\ge$45 db	2⅞ x 1 x 1	73 x 25 x 25	1	0,45	$210

Connectors: Type *N*, one male, one female.

SPECTRUM ANALYSIS

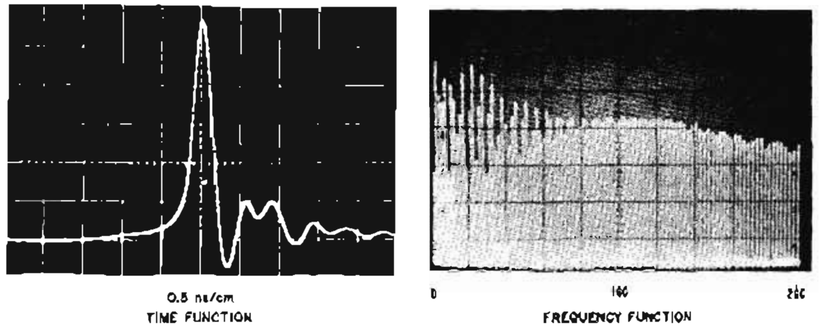


Figure 2. Nanosecond pulse and spectrum resulting.

Spectrum analysis is the study of energy distribution across the frequency spectrum for a given electrical signal. Evaluation of the relative amplitudes and frequencies of the discrete components of rf signals yields information on bandwidths, modulation characteristics, spurious signal generation and other valuable data impossible or impractical to obtain by any other means.

Microwave spectrum analysis has assumed added importance since the introduction of the Hewlett-Packard Model 851A/8551A Spectrum Analyzer. With its fully calibrated controls and displays, plus wide spectrum coverage, this analyzer brings welcome practicality to frequency-domain measurements and opens up new areas of application.

Broadband applications

Radio Frequency interference (RFI) testing, spectrum surveillance and gathering of spectrum signatures—these are important fields being revolutionized by the hp spectrum analyzer. 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 the analyzer. Wide dynamic range and broad spectrum coverage in the hp spectrum analyzer permit measurements of signals widely separated in frequency and amplitude. Transients and random interference can be recorded by a time-exposed photo of the analyzer's crt display taken with an oscilloscope camera. Displays of repetitive signals may be plotted on an x-y recorder, using the vertical and horizontal output signals from the analyzer. Figure 1 shows the radiation present throughout the entire vhf spectrum in a large metropolitan area as viewed on the hp spectrum analyzer. Note the cluster of FM broadcast stations on the left and the television aural and video carriers appearing at center-right of the display. This display represents only 15% of the analyzer's maximum spectrum width capability. Power density measurements are another important application of the spectrum analyzer, made possible by calibrated IF bandwidths. By knowing the effective noise bandwidth of the IF amplifier, a calibrated output in terms of noise power per megacycle is possible using an rf indicator such as the hp 411A RF Millivoltmeter (page 123) to measure the analyzer's 20 mc IF output. Calibration is achieved by feeding a known signal level into the analyzer rf input from a signal generator and noting the output level on the rf millivoltmeter. This level then becomes a reference to which all power density measurements may be referred.

Solid-state applications

Tuning varactor multiplier strings and parametric amplifier circuits can be tedious and time consuming by conventional techniques. There also is a good chance that spurious signals may be present in the output of such devices, even when everything seems "peaked up" correctly. The hp spectrum analyzer allows people working with microwave solid-state circuits to observe all output frequencies of such devices simultaneously and make adjustments for optimum output free of spurious signals.

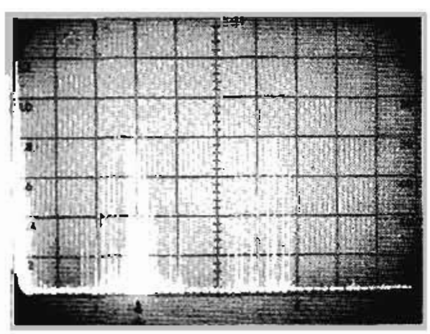


Figure 1. VHF spectrum as viewed on hp spectrum analyzer. Display shows frequencies from 10 mc to 300 mc at a spectrum width setting of 30 mc/cm.

Fast rising, short duration pulse waveforms in the nanosecond region can be generated by semiconductor diodes driving a shorted transmission line. Often, it is desirable to obtain a uniform output across large segments of the spectrum with such devices (Figure 2). With the broad frequency display and flat amplitude response of the 851A/8551A, it is a simple task to measure narrow, fast rising pulse spectra and make adjustments for discontinuities in the generating system.

Narrowband measurements

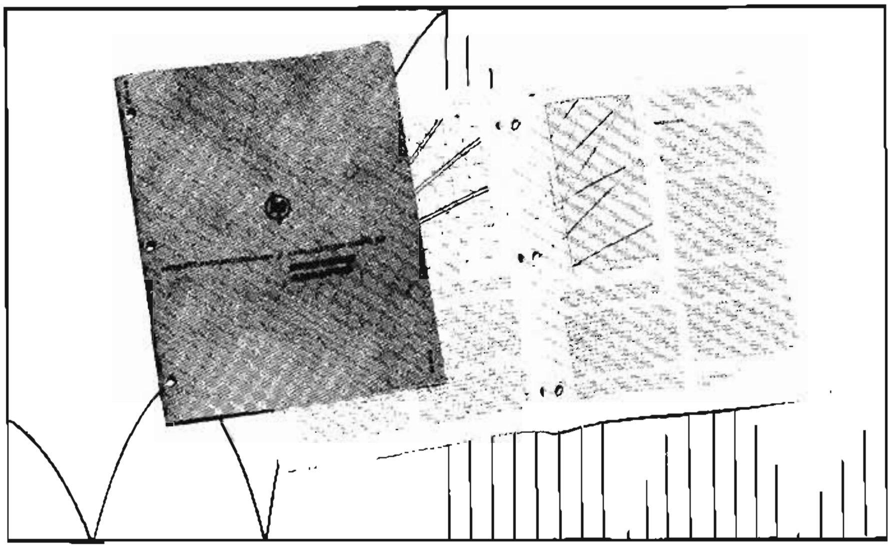
In addition to the broad spectrum capability of the analyzer, calibrated spectrum widths down to 10 kc/cm allow detailed analysis of very narrow segments of the band. A unique phase-lock stabilization system reduces local oscillator residual FM in the analyzer to less than 1 kc peak-to-peak deviation when viewing narrower spectrum widths. This system permits stable displays of narrow spectra, plus the convenience of remaining stabilized while tuning across the band. Narrow spectrum widths are useful for applications such as FM deviation measurements and residual FM checks on signal sources. The 60 db dynamic range and display makes FM measurements by the "carrier-zero" method extremely accurate since the modulation frequency may be adjusted to the precise point where all the signal energy is contained in the sidebands. The modulation frequency is measured on an electronic counter and noted. Then, using a table of Bessel functions, carrier deviation is a simple calculation:

$f_c = mf_a$,

where f_c = carrier deviation

m = modulation index (from Bessel table)

f_a = modulation frequency



Application Note 63

Well illustrated applications and specific information on spectrum analysis are yours for the asking in hp Application Note 63. An introduction to spectrum analysis and interpretation of spectral displays explain the basic principles of this important branch of microwave measurements. More rigorous treatment of the subject is included in an appendix showing the application of Fourier Analysis to spectrum analyzer displays.

One section of the note contains spectrum analyzer applications in detail, suggesting time-saving methods and solutions of difficult measurement problems. Your copy of Application Note 63 is available on request through hp Sales Offices in your area.

Spectrum 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 do an effective job, 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.

A simplified block diagram of the hp 851A/8551A Spectrum Analyzer is shown in Figure 3. The rf section contains the local oscillators, mixers and two of the three IF amplifiers, comprising a triple conversion superheterodyne receiver. The first local oscillator is a backward wave oscillator which is capable of being swept or tuned from 2 to 4 gc. Input signals of 10 mc to 10 gc pass through the 0-60 db rf attenuator to a crystal harmonic mixer and are converted to the 2 gc IF. After amplification, the 2 gc IF is converted to 200 mc, amplified, and converted again to 20 mc. The use of a 2 gc first IF keeps images *4 gc* apart, preventing a confusing double response for a single input frequency. The first mixer is carefully designed for minimum spurious generation and flat frequency response.

The display section contains the 20 mc IF attenuator, bandpass filters, amplifiers, and video detector, plus the crt, sweep generator and display shapers.

Except for the crt, this section is designed with solid-state components throughout. The input consists of an accurate 0-80 db attenuator calibrated in 1 db steps. Bandpass filters, controlling the analyzer's resolution, follow the attenuator. These have accurately controlled bandwidths of 1, 3, 10, 100 kc and 1 mc. The switching logic of the Sweep Time and Spectrum Width selectors automatically select the optimum filter for best resolution without sacrifice in gain. Manual selection of the filters also is provided. A current controlled attenuator and feedback network comprise a display shaper which allows calibrated readout on the crt in terms of input power (square law), db (logarithmic) or voltage (linear). A full discussion of spectrum analyzer design considerations is included in Application Note 63.

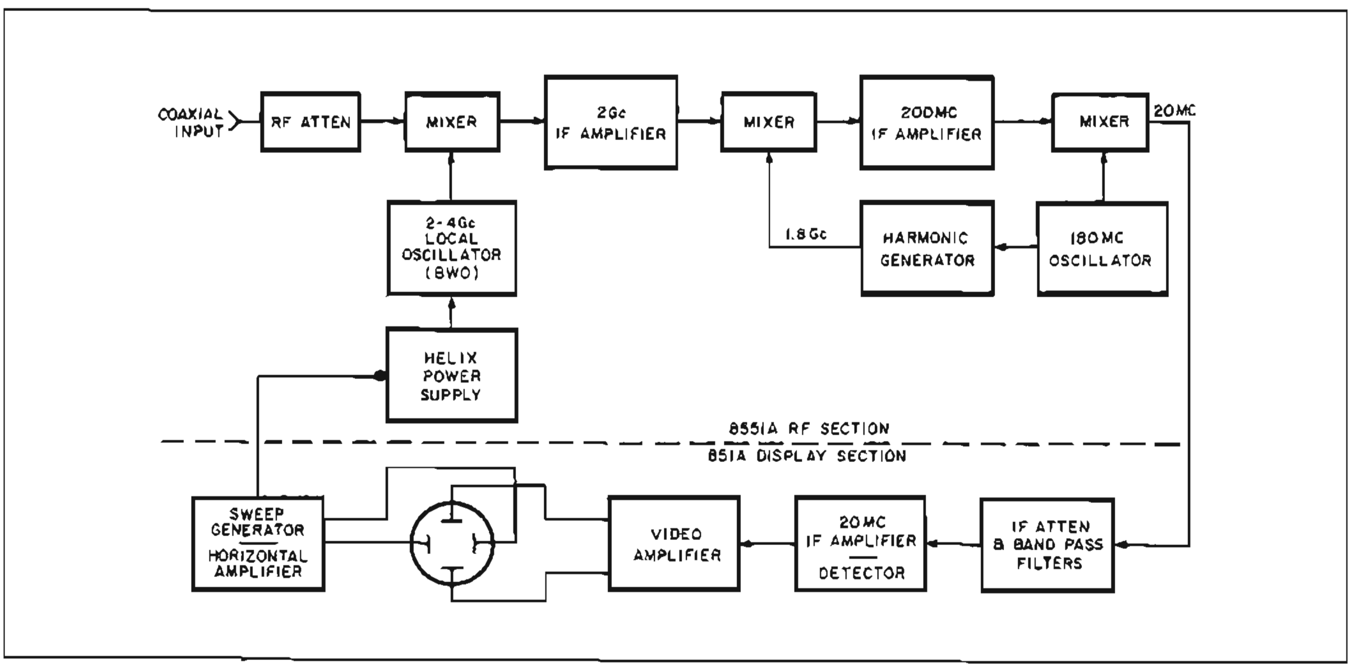


Figure 3. HP Model 851A/8551A Spectrum Analyzer simplified block diagram.

851A, 8551A SPECTRUM ANALYZER

Totally new concept in microwave spectrum analysis

The new Hewlett-Packard 851A/8551A Spectrum Analyzer is truly an advance in the state of the art. It provides a 60 db display dynamic range, flat response over spectrum widths from 100 kc to 2 gc and image separation of 4 gc; all controls are calibrated, including the logarithmic, linear and squared vertical displays. High sensitivity and broad frequency range, plus a unique signal identifier, are additional features which make this instrument the most versatile and useful spectrum analyzer available today.

Calibrated IF bandwidths, important in power density measurements, can be selected either manually or automatically. In the automatic mode, IF bandwidth is selected for best resolution of a cw signal with each combination of spectrum width and sweep time. In addition, sweep time is calibrated, and the crt has an internal graticule for parallax-free viewing. A base-line clipper is provided to dim the base line on the crt for clearer and more comfortable viewing and improved photography of low-repetition-rate signals.

RF characteristics

The 851A/8551A Spectrum Analyzer covers the frequency range from 10 mc to 40 gc, 10 mc to 10 gc in coax, 8.2 to 40 gc in waveguide with external mixers and adapters (Figure 1). The coaxial input is inherently broadband; however, the range can be limited with pre-selection filters such as the hp 360 and 8430 Series (page 213) to eliminate interference from signals outside the frequency range of interest.

Ten calibrated spectrum widths from 100 kc to 2 gc are available. This wide range of spectrum widths permits observation of widely separated signals and broad spectra, as well as detailed examination of individual signals, distortion products, etc. The 4 gc image separation (a 2 gc first IF) assures a display uncluttered by overlapping images. For investigation of signals close to 2 gc, a 200 mc first IF can be selected.

Amplitude control

Signal amplitude is controlled by a 0 to 60 db rf attenuator (10 db steps) in the coaxial input system, plus a 0 to 80 db IF attenuator (1 db steps plus vernier). When an external waveguide mixer is used, rf attenuation can be accomplished with the appropriate hp 382 Waveguide Attenuator (page 225).

Specifications, 8551A RF Section

Frequency range: coaxial input: 10 mc to 10 gc; waveguide input: 8.2 to 40 gc (accessory mixers and adapters required).

Spectrum width: 10 calibrated spectrum widths, 100 kc to 2 gc in a 1, 3, 10 sequence to 1 gc; vernier allows continuous adjustment between calibrated ranges and can reduce width to zero.

Swept-frequency linearity*: ±5% when local oscillator (LO) is stabilized and swept 10 mc or less; ±10% (typically 5%) when LO is swept more than 10 mc.

Image separation: 4 gc.

Phase-lock: internal phase-lock provided for stabilizing LO; LO sweep tracks sweep of voltage-tuned 10 mc reference oscillator.

Phase-lock range: unit can be phase locked for spectrum widths up to N x 10 mc, where N is the harmonic of the LO.

Phase lock tuning: reference oscillator automatically tracks with Tune control over 2 gc LO range.

Tuning: selectable continuous coarse, fine and stabilized (phase locked) tuning determines center frequency about which LO is swept; tuning is accomplished with a single front-panel Tune control.

*Correlation between LO frequency and sweep position on Model 851A crt as a percentage of the selected spectrum width.

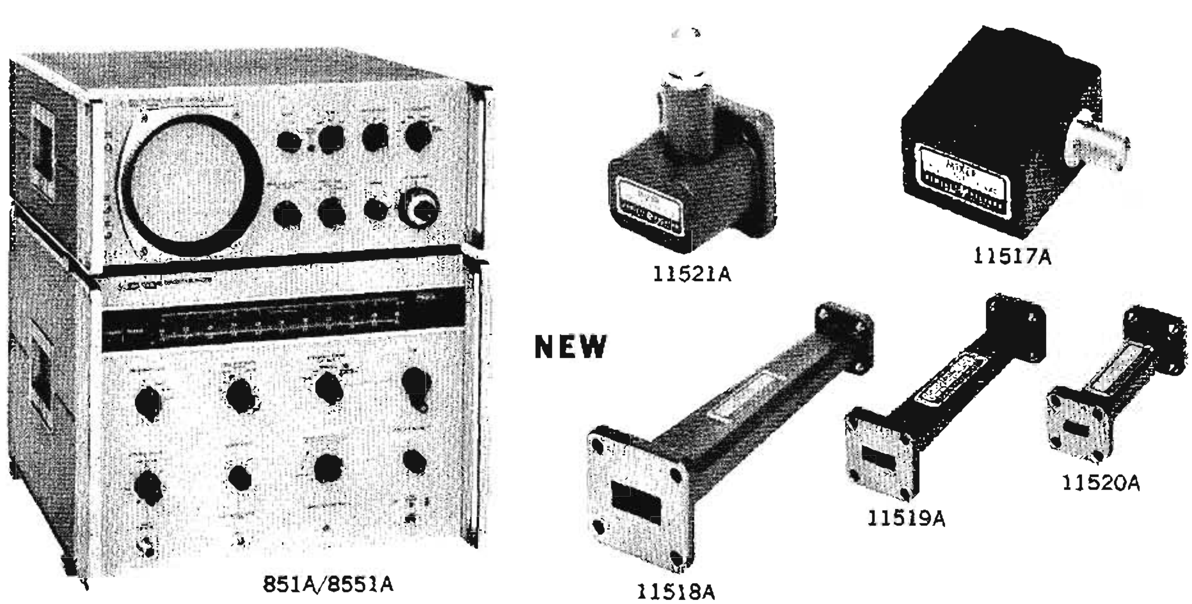


Figure 1. hp 11517A-11521A external mixers and adapters.

Fine tuning: frequency change of LO fundamental is 10 mc ±2 mc per revolution of the Tune control; maximum accumulative error across the band, ±20 mc; settability of a signal on the crt with the Tune control, ±50 kc (fundamental mixing).

Stabilized tuning: frequency change of LO fundamental is 10 mc ±1 mc per revolution of the Tune control; maximum accumulative error across the band, ±2 mc; settability of a signal on the crt with the Tune control, ±5 kc (fundamental mixing).

Tuning accuracy: ±1% of LO fundamental or harmonic.

Sensitivity (10 kc IF bandwidth): 10 mc to 2 gc, −95 dbm; 1.8 to 4.2 gc, −100 dbm (400 mc image separation); 2 to 4 gc, −80 dbm; 4 to 6 gc, −95 dbm; 6 to 10 gc, −80 dbm; 8.2 to 18 gc, −80 dbm; 18 to 26 gc, −75 dbm; 26 to 40 gc, −65 dbm; with a source stability better than 1 kc, greater sensitivity can be achieved by using a narrower IF bandwidth.

Coaxial input attenuator: range: 0 to 60 db in 10 db steps; insertion loss: 0 at 10 mc, less than 2 db at 10 gc.

Maximum input power (for 1 db compression)

Coaxial Input		
Input atten. setting	Max. input 2 gc IF	Typical max. input 200 mc IF
0 db	0 dbm	−5 dbm
10 db	+10 dbm	+5 dbm
20 db	+20 dbm	+15 dbm
30 db	+30 dbm	+25 dbm
40 thru 60 db	+30 dbm	+30 dbm
Waveguide Input		
11521A (8.2 to 12.4 gc)	typically −10 dbm	
11517A (12.4 to 40 gc)	typically −15 dbm	

Frequency response: coaxial input: ±1.5 db over any 200 mc range using fundamental mixing, ±3 db over any 200 mc range using 2nd harmonic mixing, ±5 db (typically ±3 db) over any 2 gc range except when signal or LO is within 60 mc of 2 gc, including mixer and rf attenuator response with attenuator setting ≥10 db.

Signal identifier: switch shifts display in inverse proportion to harmonic of LO used in mixing; direction of shift depends upon whether signal frequency is higher or lower than LO harmonic.

IF output frequency: 20 mc.

Residual LO fm: 1 kc peak to peak or less when phase locked; approximately 30 kc peak to peak when not phase locked.

Residual responses (no input signal): less than −90 dbm referred to Signal Input on fundamental mixing (−85 dbm when LO is within 60 mc of 2 or 4 gc).

LO noise sidebands: greater than 60 db below cw signal level 90 kc or more away from signal.

LO type: 2 to 4 gc backward wave oscillator.

LO output: approximately 1 mw available for use with wavemeters or frequency counters; output connector, female Type N on rear panel.

RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D and MIL-I-16910C.

Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 250 w.

Dimensions: 16¾" wide, 12½" high, 18⅜" deep (425 x 318 x 467 mm); hardware furnished for rack mount 19" wide, 12-7/32" high, 16⅜" deep behind panel (483 x 310 x 416 mm).

Weight: net 95 lbs (43 kg); shipping 136 lbs (61,2 kg).

Accessories supplied: 4 cable assemblies to interconnect RF and Display Sections; 908A Termination for LO output.

Accessories available: 11517A Mixer for P-, K- and R-bands (12.4 to 40 gc), $160; 11518A Adapter, adapts 11517A Mixer to P-band waveguide (12.4 to 18 gc), $65; 11519A Adapter, adapts 11517A Mixer to K-band waveguide (18 to 26 gc), $65; 11520A Adapter, adapts 11517A Mixer to R-band waveguide (26 to 40 kc), $65; 11521A Mixer for X-band waveguide, $75.

Price: hp 8551A, $7100.

Specifications, 851A Display Section

Vertical display: linear, square (power) or logarithmic.
Dynamic range: linear, 70:1; square, 70:1; log, 60 db. Accuracy: linear, ±3% of full scale; square, ±5% of full scale*; log, ±2 db*.

IF bandwidth:
- Manual: bandwidths of 1, 3, 10, 100 kc and 1 mc can be selected.
- Auto-Select: one of the above bandwidths automatically selected for best resolution of a cw signal with each combination of spectrum width and sweep rate.
- Bandwidth accuracy: individual bandwidths are calibrated within ±20%; bandwidth repeatability and stability typically better than ±3%.

IF input: 20 mc center frequency; 50 ohms input impedance.

Maximum cw input signal: −14 dbm.

IF gain set: two-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; 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 rate: six calibrated rates, 3 msec/cm to 1 sec/cm in a 1, 3, 10 sequence; vernier provides continuous adjustment between calibrated rates and extends slowest rate to at least 3 sec/cm.

Sweep rate accuracy: ±3%.

Sweep synchronization: internal: sweep free runs; line: sweep synchronized with power line frequency; external: sweep synchronized with externally applied signal +3 to +15 volts peak; single sweep: sweep actuated by panel pushbutton.

Output signals: vertical and horizontal signals applied to crt are available for external monitoring; vertical: 0 to −4 volts, output impedance, 4700 ohms; horizontal: 10 volts p-p ±0.3 volt, sweep approximately symmetrical about zero, output impedance 4700 ohms.

Cathode-ray tube: 7.5 kv post-accelerator tube with P2 medium-persistence phosphor (others optional) and internal graticule; light blue filter supplied.

Internal graticule: parallax-free 7 x 10 cm, marked in cm squares with 2 mm subdivisions on major vertical and horizontal axes.

RFI: conducted and radiated leakage limits are below those specified in MIL-I-6181D and MIL-I-16910C.

Power: 115 or 230 v ±10%, 50 to 1000 cps, approx. 25 w.

Dimensions: 16¾" wide, 7¼" high, 18⅜" deep (425 x 185 x 467 mm); hardware furnished for rack mount 19" wide, 6-31/32" high, 16⅜" deep behind panel (483 x 177 x 416 mm).

Weight: net 34 lbs (15 kg); shipping 45 lbs (20,3 kg).

Accessory supplied: joining bracket kit for semi-permanently mounting 851A on 8551A.

Price: hp 851A, $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.

*Except pulse spectrums on 1 mc bandwidth.

MICROWAVE POWER MEASUREMENT

At microwave frequencies, the current and voltage in a circuit are complex in nature and difficult to evaluate in terms of their ability to do work. Power, on the other hand, is a real quantity that can be measured and easily related to circuit performance. Unlike the voltage and current levels along a transmission line, microwave power remains constant with position of measurement (in a lossless line). For these reasons, power is one of the basic measurements made at microwave frequencies.

A great many microwave power measurements are well below 10 milliwatts where signal generators supply test signals for checking receiver, small-signal amplifier and detector performance. In some cases the power level may be on the order of only a few microwatts, requiring high sensitivity and stability in the measuring equipment.

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. The use of thermistors is more prevalent because they are more rugged, both physically and electrically, than barretters. These tiny bolometer elements are mounted in devices that ideally present a perfect 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 (or modification thereof) through the bias connection, and bridge excitation is applied. The dc or low-frequency ac bridge excitation serves as the bolometer element bias power which affects the bolometer's resistance, so that the bridge is essentially balanced. When the unknown microwave power is applied to the bolometer, the resulting temperature rise causes the element's resistance to change, tending to unbalance the bridge. By withdrawing a like amount of dc or ac bias power from the element, the bridge may be returned to balance, and the amount of bias power removed can be measured and displayed on an indicating meter.

Automatic bolometer bridges

There are a number of bolometer bridge designs which provide various degrees of accuracy, speed, and convenience.

The Hewlett-Packard Model 431B Power Meter is a temperature-compensated, automatically balanced thermistor bridge of versatile design. Operating with any of the hp temperature-compensated thermistor mounts, the 431B automatically maintains bridge balance and reads substituted bias power to a basic accuracy of ±3% of full scale. The 431B power ranges of 10 microwatts to 10 milliwatts (full scale) encompass virtually all levels involved in small signal microwave power testing.

Since all bolometer elements are temperature-sensing devices, they are, in themselves, unable to distinguish between applied power level changes and environmental temperature changes. As bolometer bridge sensitivity is increased, even minute temperature variations appear as though a varying power were being applied to the bolometer element. The result, if not compensated for, is "zero drift" of the power meter and erroneous power measurements.

A dual bridge arrangement, as shown in Figure 1, is used in the 431B to compensate for variations in temperature at the thermistor mount. The thermistor mounts used with the 431B have two thermistor elements, one for sensing applied power (R_d) and one for sensing ambient temperature (R_c). Each element is connected to its own bridge circuit in the meter, which automatically controls bias power. The elements are in close thermal proximity, but R_c is isolated from applied microwave power. This arrangement compensates for temperature changes, thus reducing zero drift in the 431B by a factor of 100 over older uncompensated meters. Another advantage of the 431B 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 0.5% on all ranges). The 431B also provides a dc output proportional to the microwave power measured, an output useful for recording purposes or control of external circuits. This feature is extremely valuable for power meter leveling of microwave sweep oscillators and signal generators.

Thermistor mounts designed specifically for operation with the 431B include the hp 478A Coaxial and 486A Waveguide Series. The 478A Coax Mount operates from 10 mc to 10 gc, while the 486A Series covers frequencies in waveguide bands from 2.6 to 40 gc. All mounts present low swr over full waveguide bands without tuning. Full particulars on the Hewlett-Packard 431B Power Meter and the temperature-compensated thermistor mounts will be found on pages 220 and 221.

Non-temperature-compensated bridges

Also available is the hp Model 430C Power Meter, which operates with a number of non-temperature-compensated barretter or thermistor mounts such as the hp 477B Coaxial and 487 Waveguide Series. Accuracy of the 430C in measuring substituted power is ±5% of full scale. (See page 222 for full specifications on 430C.)

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

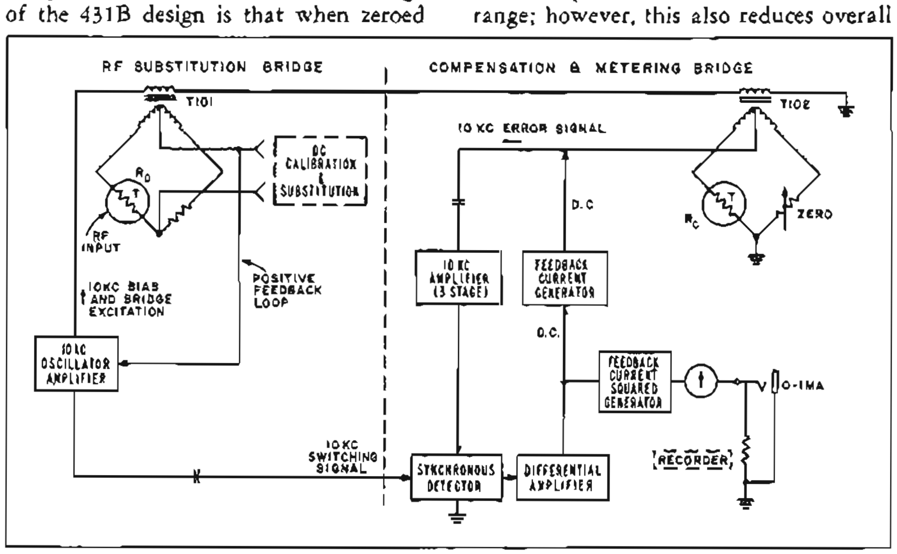


Figure 1. Block diagram of hp 431B Power Meter. Dual bridge provides proper bias to thermistor mount to correct for temperature variation and reduce zero drift.

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 which ideally 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.

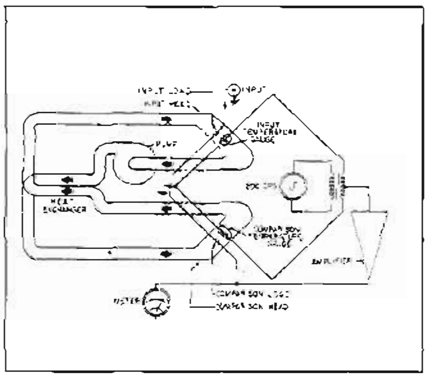


Figure 2. Simplified diagram of hp 434A Calorimetric Power Meter, showing oil flow path.

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 2, 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, where medium-power TWT's, klystrons, and low-power magnetrons produce power levels above the bolometer's range, and too low for large calorimetric systems. Further information on the 434A Calorimetric Power Meter is on page 224.

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. The Boonton Division of Hewlett-Packard produces a versatile instrument that conveniently measures peak power directly in the 50 mc to 2 gc region. This instrument (the Boonton 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. The optional custom calibration chart increases accuracy to 0.6 db for critical applications. (See page 223 for more information on the 8900B.)

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. Certain other applications, however, demand varying degrees of accuracy improvement. 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.

Efficiency: A bolometric power meter can only measure power that is absorbed by the bolometer *element*, not that which is dissipated elsewhere in the mount. 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 two sources of error are measured in certain frequency bands by NBS (National Bureau of Standards) and presented as the *effective efficiency* of the mount. Because of the importance of high efficiency to accurate power measurement, hp uses standards directly traceable to NBS, wherever possible, to test all bolometer mounts to assure consistently high efficiency throughout the operating range of the instrument. Broadband thermistor mounts are tested on a swept frequency basis, so the effects of even sharp resonances on efficiency are revealed and eliminated. Even though direct NBS traceability is not yet available in certain bands, the extensive tests and cross-checks conducted by hp on literally thousands of thermistor mounts assure a uniformly high level of efficiency in all mounts. Similar efforts are applied to the calorimetric power meter to verify its efficiency.

Instrumentation: hp 431B power meters provide a basic accuracy of ±3% in substituted power to the thermistor. A dc input on the rear panel allows external dc substitution for increased accuracy when required. The hp 8402A Power Meter Calibrator may be connected to the dc substitution jack on the 431B to reduce instrumentation error to ±0.5%. The recorder output current, also available from the Hewlett-Packard 431B, allows connection of a stable 1000 ohm resistor and digital voltmeter (such as the hp 3440A, pages 150-152) for high precision duplication of power meter readings.

The 434A Calorimetric Power Meter basic accuracy is ±5% of full scale, which includes both instrumentation error and efficiency. The built-in calibration source provides a 0.1 watt check point accurate to 1% for convenient verification of the 434A calibration. The 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, and is accurate to ±0.5% of output.

Step-by-step procedures with examples of error reduction and analysis are an important part of hp Application Note 64.

431B POWER METER; 478A, 486A THERMISTOR MOUNTS, 8402A CALIBRATOR

Power measurements 1 μw to 10 mw; meter calibration

Continual zero-setting is a thing of the past, even on the 10 μw range, with the hp 431B Power Meter. Extremely high stability means that in typical laboratory environments one zero setting will hold for hours. In addition, only one zero adjustment is needed to calibrate the 431B for all ranges. Even in less favorable environments only occasional adjustment is necessary.

The extreme temperature stability of this instrument makes possible (and usable) an additional 10 db of sensitivity compared to previously available equipment. Full-scale readings of 10 μw to 10 mw are covered in 7 ranges. The meter face also is calibrated in dbm with 5 db between ranges. Direct-reading accuracy is ±3% of full scale.

Temperature-compensated thermistor mounts are required for operation with the hp 431B. The hp 478A Coaxial Mount covers 10 mc to 10 gc, and the 486A Waveguide Mounts span 2.6 to 40 gc.

Microwave standards measurements can be made to high accuracy and resolution with the Model 431B by using the instrument as a transfer device. A dc calibration input jack permits precise dc substitution power measurements. The grounded output jack will then drive an appropriate digital voltmeter for increased resolution.

The 431B also has an optional rechargeable battery pack which will give up to 24 hours of completely portable operation. A front-panel control selects ac operation with trickle-charge, battery operation or battery charge alone.

Circuit description

Two balanced bridges are employed in the hp 431B. Each contains a temperature-sensitive element, a thermistor, which is housed in an external thermistor mount. In close thermal proximity, the thermistors are electrically isolated. One thermistor and bridge senses the rf power. The other thermistor and bridge senses only the ambient temperature conditions and corrects for zero drift. Both bridges are continuously maintained in a balanced condition so both thermistor elements have similar heat transfer characteristics at all times.

This unique circuit approach gives a self-balancing device for both rf power and temperature changes, with all critical components located within a feedback loop. If thermistors and mounts were available that tracked identically with temperature, no zero setting would ever be necessary. The hp 478A and 486A dual thermistor mounts use extremely high heat-conductivity metals and selected thermistors for exceedingly close tracking, even in the presence of thermal shocks.

Specifications, 431B

Instrument type: automatic, self-balancing power meter for use with temperature-compensated thermistor mounts.

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 −30 to +10.

External bolometer: temperature-compensated thermistor mounts required for operation (478A and 486A series).

Accuracy: ±3% of full scale from +20°C to +35°C; ±5% of full scale from 0°C to +55°C.

Meter movement: taut-band suspension; mirror-backed meter scale matched to pointer deflection within ±0.25% of full scale.

Zero carry-over: less than 0.5% of full scale when zeroed on most sensitive range.

Zero balance: continuous control about zero point; range below zero is equivalent to at least 3% of full scale.

Recorder/voltmeter output: phone jack on rear with 1 ma maximum into 1000 ohms ±10%; one side grounded.

Calibration input: binding posts on rear for calibration of bridge with 8402A or precise dc standards.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 2.5 watts.

Dimensions: 7-25/32" wide, 6-3/32" high, 11" deep from front panel (190 x 155 x 279 mm).

Weight: net 8 lbs (3,5 kg), shipping 11 lbs (5 kg); net with battery 11½ lbs (5,2 kg), shipping with battery 14 lbs (6,3 kg).

Accessory furnished: 5 ft (1520 mm) cable for hp temperature-compensated thermistor mounts.

Accessories available: 431B-95A Rechargeable Battery Pack for field installation, $100; 431B-95B Recorder Output Cable, $6.50.

Price: hp 431B, $450.

Options

01. Rechargeable battery installed, provides up to 24 hours' continuous operation, add $100.
02. Rear input connector wired in parallel with front-panel input connector, add $15.
10. With 20 ft (6100 mm) cable for 100- or 200-ohm mount, add $50.
11. With 50 ft (15240 mm) cable for 100-ohm mount, add $100.
12. With 100 ft (30480 mm) cable for 100-ohm mount, add $150.
13. With 200 ft (60960 mm) cable for 100-ohm mount, add $250.
21. With 50 ft (15240 mm) cable for 200-ohm mount, add $100.
22. With 100 ft (30480 mm) cable for 200-ohm mount, add $150.
23. With 200 ft (60960 mm) cable for 200-ohm mount, add $250.

478A and 486A Thermistor Mounts

These thermistor mounts are designed for use with the hp 431B Power Meter. Each mount contains a pair of negative-coefficient thermistor sets in similar thermal environments. One thermistor set responds to the rf input and ambient temperature; the other responds only to ambient temperature and compensates for temperature changes. Extremely close tracking is achieved, even with the application of thermal shocks. Hence, the instruments are remarkably free from drift and conveniently measure power as low as one microwatt. Furthermore, dc calibration power may be applied and a dc digital voltmeter used to read out from the 431B Power Meter. Such a precedure permits accurate, high-resolution, transfer-power measurements in standards systems.

Model 478A is designed for 50-ohm coaxial systems which operate from 10 mc to 10 gc. The rf thermistor pair presents a good match to 50-ohm systems over its full frequency range. No tuning is required.

Model 486A mounts are designed for waveguide systems operating from 2.6 to 40 gc. Each mount provides a good match over its waveguide range, and no tuning is required.

Specifications

hp Model	Frequency range, gc	Maximum swr	Operating resistance (ohms)	Price
478A	10 mc to 10 gc	1.6, 10 to 25 mc 1.3, 25 mc to 7 gc 1.5, 7 to 10 gc	200	$155
S486A	2.60 to 3.95	1.35	100	$195
G486A	3.95 to 5.85	1.5	100	$180
J486A	5.30 to 8.20	1.5	100	$170
H486A	7.05 to 10.0	1.5	100	$165
X486A	8.20 to 12.4	1.5	100	$145
M486A	10.0 to 15.0	1.5	100	$195
P486A	12.4 to 18.0	1.5	100	$195
K486A*	18.0 to 26.5	2.0	200	$300
R486A*	26.5 to 40.0	2.0	200	$375

* Circular flange adapters: K-band (UG-425/U) hp 11515A, $35 each; R-band (UG-381/U) hp 11516A, $40 each.

For all models

Power range with hp 431B: 1 μw to 10 mw.

Output connector: mates with 431B cable.

Shipping weight: 1 lb (0,5 kg) except S486A, 3 lbs (1,4 kg), and G486A, 2 lbs (0,9 kg).

8402A Power Meter Calibrator

Full-scale calibration and meter tracking of hp Models 431A and 431B can be verified with the 8402A Power Meter Calibrator, which also can be used with a precision voltmeter to measure operating resistance of a thermistor mount and thereby permit more accurate power measurements.

The 8402A is a constant current power supply which furnishes an accurately known dc current to the power-sensing thermistor. For full-scale calibration of the power meters, the dc current is within ±0.1% of the value calculated for the nominal operating resistance of the thermistor. Accuracy of the substituted dc power is typically ±0.5%. The 8402A, in conjunction with a precision dc voltmeter and a 431A or B, can measure rf power by the dc substitution method. Simple equations permit easy and accurate calculation of the dc substitution power, which is within 0.5% ±0.1 μw of the calculated value if the dc voltmeter is accurate within 0.1%.

Specifications, 8402A

Calibration function

Full-scale values: 0.01, 0.03, 0.1, 0.3, 1, 3 and 10 mw, corresponding to full-scale range of 431A,B Power Meters.

Meter tracking: 10, 8, 6, 4 and 2 mw.

Accuracy: ±0.1% of calculated current; ±0.5% dc substituted power ±0.3 μw.

DC substitution range: current variable over range compatible with measurements from 1 μw to 10 mw (precision dc voltmeter required).

Thermistor operating resistance

Range: 100 or 200 ohms, nominal.

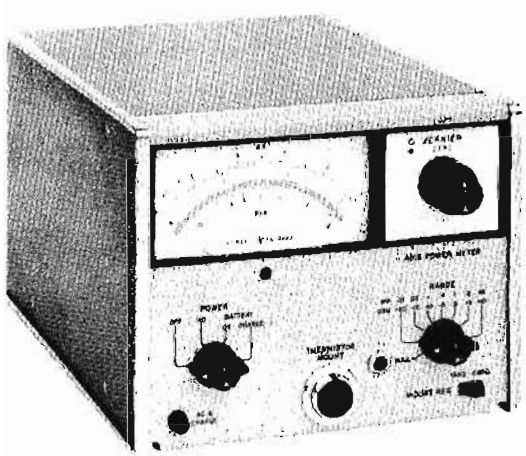
Accuracy: ±0.2% using a dc voltmeter with 1% accuracy.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 2.5 watts.

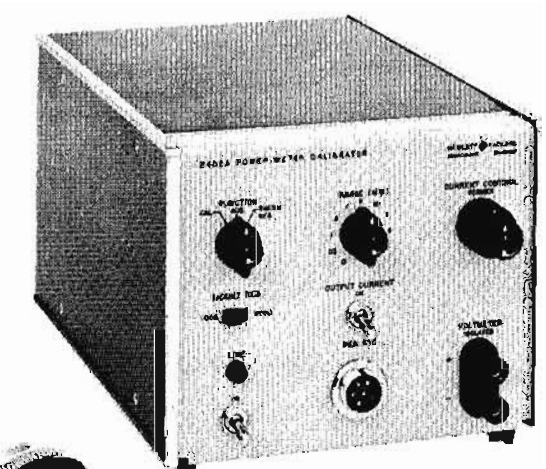
Dimensions: 7-25/32" wide, 6-3/32" high, 11" deep from front panel (190 x 155 x 279 mm).

Weight: net 8 lbs (3,6 kg); shipping 9 lbs (4,1 kg).

Price: hp 8402A, $475.



431B



8402A

487A

X486A

430C MICROWAVE POWER METER

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 gc. Barretters and thermistors can be used for measurements at much higher frequencies, up to 12.4 gc for barretters (in hp mounts) and up to 40 gc for certain thermistors.

Hewlett-Packard waveguide bolometer mounts for the 430C are available covering, collectively, the frequency spectrum from 2.6 to 40 gc. In addition, Model 477B Thermistor Mount covers the frequency spectrum from 10 mc to 10 gc.

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 1000 cps, 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 lbs (6,3 kg), shipping 16 lbs (7,2 kg) (cabinet); net 18 lbs (8,1 kg); shipping 27 lbs (12,2 kg) (rack mount).

Price: hp 430C, $275 (cabinet); hp 430CR, $280 (rack mount).

477B Thermistor Mount

This coaxial thermistor mount, designed for use in 50-ohm systems with the hp 430C, covers 10 mc to 10 gc with an swr of less than 1.5. It requires no tuning and employs long-time-constant elements that assure 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 mc to 10 gc.

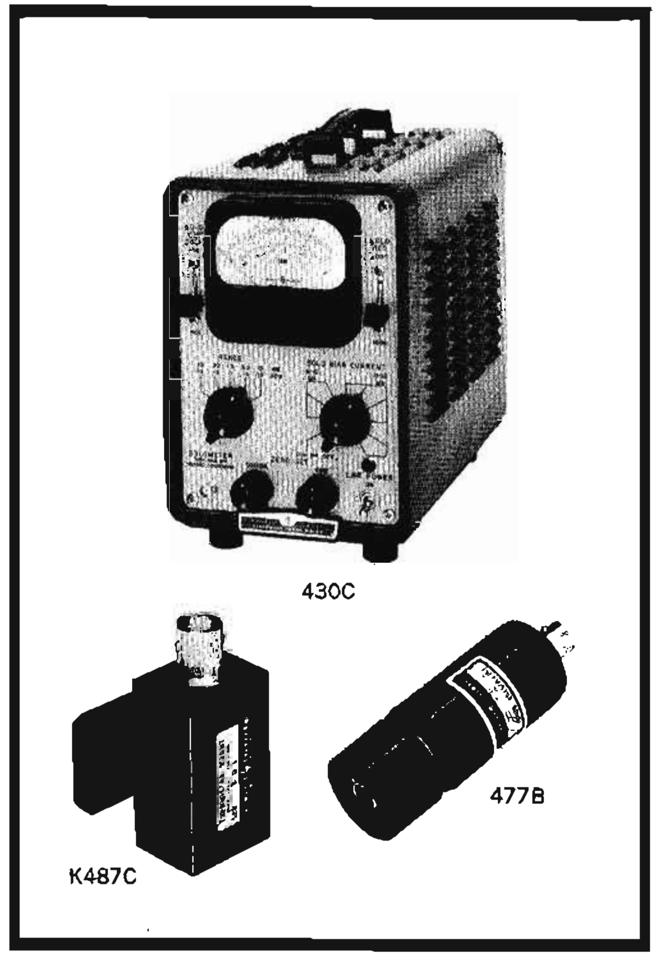
SWR: less than 1.5 (less than 1.3, 50 mc to 7 gc).

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, $75.



487 Waveguide Thermistor Mounts

Hewlett-Packard Series 487 instruments, for use with hp 430C Power Meters, collectively cover all frequencies from 2.6 to 40 gc. 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 gc	Price
S487B	1.35	2.60 - 3.95	$105
G487B	1.5	3.95 - 5.85	$ 95
J487B	1.5	5.3 - 8.2	$ 90
H487B	1.5	7.05 - 10.0	$ 80
X487B	1.5	8.2 - 12.4	$ 75
M487B	1.5	10.0 - 15.0	$110
P487B	1.5	12.4 - 18.0	$110
K487C*	2.0	18.0 - 26.5	$225
R487B*	2.0	26.5 - 40.0	$275

*Circular flange adapters: K-band (UG-425/U) 11515A, $35 each; R-band (UG-381/U) 11516A, $40 each.

8900B PEAK POWER CALIBRATOR

Peak power measurements, 50 to 2000 mc, to ±0.6 db

The Boonton 8900B Peak Power Calibrator provides a convenient means for measuring the peak rf power of pulses in the range from 50 to 2000 mc. 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 mc.

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).

RF power precision: 0.1 db.

RF pulse width: >0.25 μsec.

RF repetition rate: 1.5 mc 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 mc.

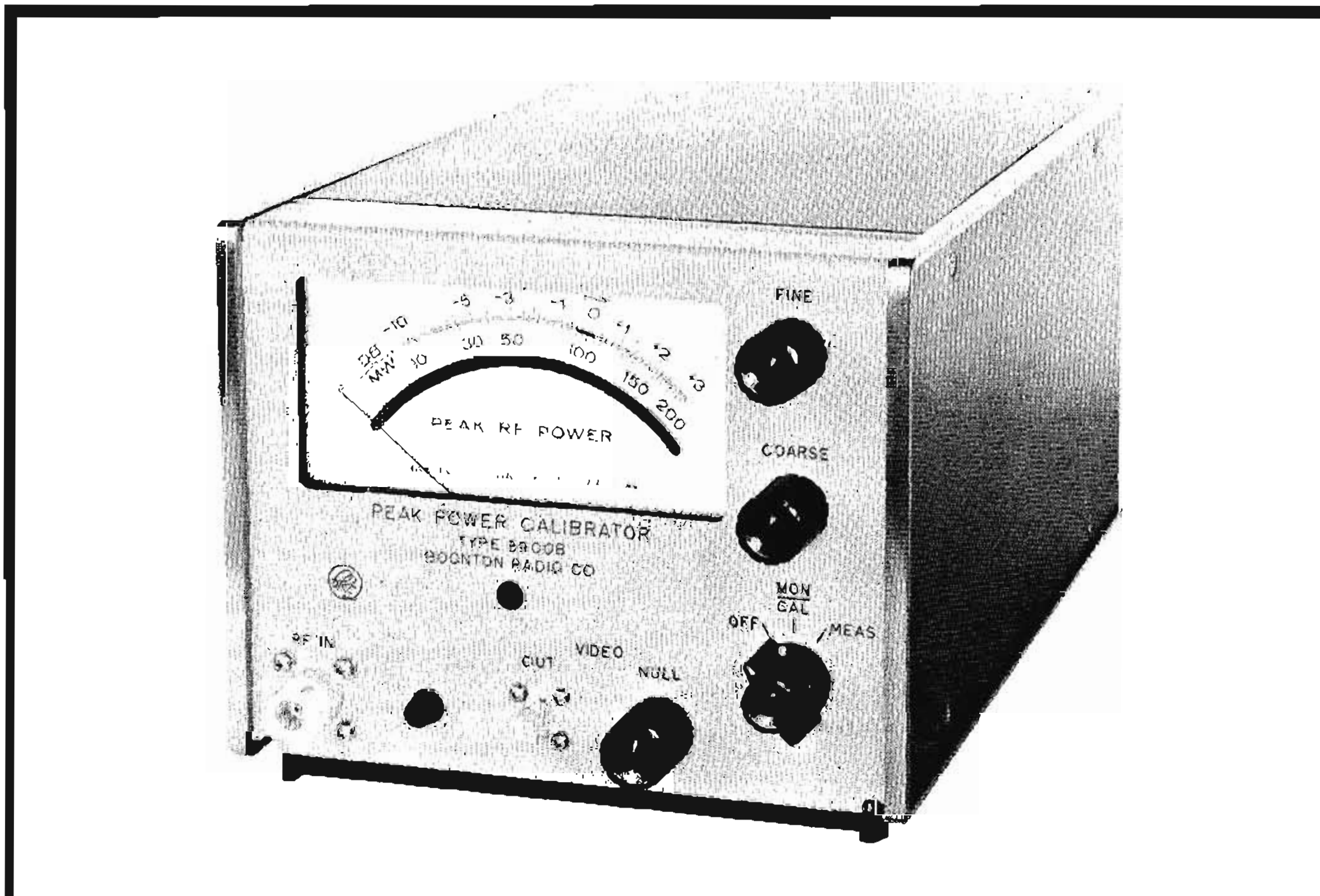
Physical characteristics

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 cps.

Price: Boonton 8900B, $485; custom calibration curve, $75.



434A CALORIMETRIC POWER METER

Just connect, read power 10 mw to 10 watts

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 non-technical personnel.

Model 434A fills the important range between bolometer-type microwave power meters such as hp 431B (pages 220, 221) and conventional calorimeters whose lower range is approximately 10 watts. But, unlike previous cumbersome and costly equipment suggested for its 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.

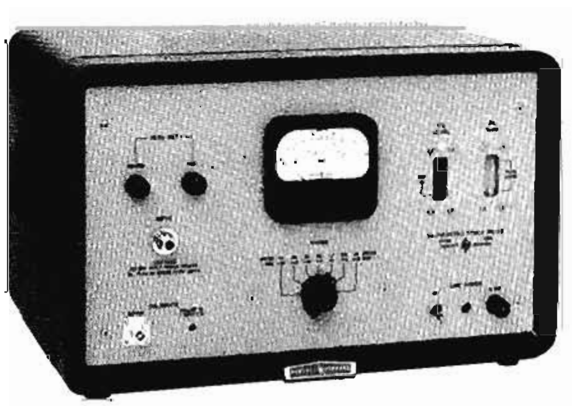
Rapid response time

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 insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger just prior to entering the heads. Identical flow rates are obtained by placing all elements of the oil system in series.



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 gc.

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 gc	1%	3%
1 to 4 gc	2%	4%
4 to 10 gc	3%	5%
10 to 12.4 gc	4%	5%

DC input resistance: 50 ohms ±5 ohms at Type N input jack.

Input swr: dc to 5 gc, <1.3; 5 to 11 gc, <1.5; 11 to 12.4 gc, <1.7.

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 ±10%, 50 to 60 cps, approximately 155 watts with no input, 175 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 lbs (22,1 kg), shipping 59 lbs (26,6 kg) (cabinet); net 44 lbs (19,8 kg), shipping 65 lbs (29,3 kg) (rack mount).

Accessories available: 281A Waveguide-to-Coax Adapters (see page 174); K02-434A DC Test Set (for more accurate power measurements), $1000.

Price: hp 434A, $1600 (cabinet); hp 434AR, $1585 (rack mount).

382A,B,C PRECISION VARIABLE ATTENUATORS

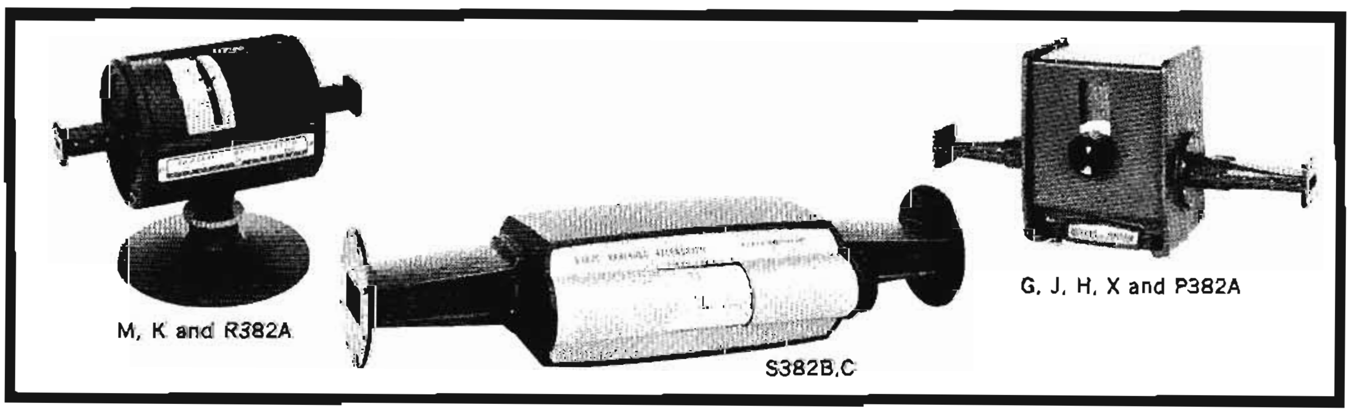
Frequency coverage to 40 gc

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 is assured regardless of temperature and humidity. The instruments can handle considerable power and feature large, easily read dials. Insertion loss at the zero setting is less than 1 db, and swr is less than 1.15. Accuracy is ±2% of reading or 0.1 db, whichever is greater.

hp Model		G382A	J382A	H382A	X382A	M382A	P382A	K382A*	R382A*
Frequency range	(gc):	3.95 - 5.85	5.3 - 8.2	7.05 - 10.0	8.2 - 12.4	10.0 - 15.0	12.4 - 18.0	18.0 - 26.5	26.5 - 40.0
Waveguide size	(in): (EIA):	2 x 1 WR187	1½ x ¾ WR137	1¼ x ⅝ WR112	1 x ½ WR90	.850 x .475 WR75	.702 x .391 WR62	½ x ¼ WR42	.360 x .220 WR28
Power handling capacity, watts, average continuous duty:		15	10	10	10	10	5	2	1
Size**	length: height: depth:	31⅛ (803) 9⅝ (245) 7¾ (197)	25⅛ (638) 7-15/16 (202) 6½ (165)	20 (508) 7-15/16 (202) 6½ (165)	15⅝ (397) 7⅝ (194) 4-11/16 (119)	13-7/32 (336) 5½ (140) 5½ (140)	12½ (318) 7¾ (197) 4¾ (121)	7⅝ (194) 5½ (140) 3⅝ (92)	6-7/16 (164) 5½ (140) 3⅝ (92)
Weight***	net: shipping:	25 (11,3) 32 (14,4)	12 (5,4) 24 (10,8)	10 (4,5) 22 (9,9)	5 (2,3) 8 (3,6)	4 (1,8) 12 (5,4)	5 (2,3) 9 (4,1)	4 (1,8) 9 (4,1)	4 (1,8) 9 (4,1)
Price:		$500	$375	$350	$275	$650	$300	$475	$500

* Circular flange adapters: K-band (UG-425/U) 11515A, $35 each; R-band (UG-381/U) 11516A, $40 each.
** In inches and (millimeters). *** In pounds and (kilograms).

For all models: Dial calibration range: 0 to 50 db (above insertion loss at zero setting).
Phase shift variation: less than 3° from 0 to 50 db.
Insertion loss at zero setting: less than 1 db.
SWR: less than 1.15 over entire range of attenuation and frequency.
Accuracy: ±2% of the reading in db, or 0.1 db, whichever is greater; includes calibration error and frequency error.



The hp S382B,C extend the inherent advantages of the rotary vane attenuation principle into the range from 2.6 to 3.95 gc. To realize the merits of this attenuation principle the center barrel of the attenuator must be several wavelengths long. This length, in addition to that necessary to make smooth transitions from rectangular to circular guide, would result in S-band units of considerable size. The hp S382B,C, nonetheless, achieve both long electrical length and short physical dimensions. Dielectric loading in the attenuator decreases the velocity of the wave, thereby shortening its wavelength. The result is an S-band attenuator that is only 25¼" long, yet has 1% accuracy and a standing wave ratio less than 1.2.

The S382 is calibrated in degrees of rotation, as well as in db (S382B in 0.1° increments, S382C in 0.01° increments). This provides high resolution, as is desired in a transfer standard. In addition, the instruments provide attenuation from 0 to 60 db and are capable of handling 10 watts average power.

Specifications, S382B,C

Frequency range: 2.6 to 3.95 gc.

Calibrated attenuation range: 0 to 60 db.

Accuracy: ±1% of reading or 0.1 db, whichever is greater, from 0 to 50 db; ±2% of reading above 50 db.

Insertion loss: less than 1 db.

SWR: less than 1.2, 2.6 to 3 gc; less than 1.15, 3 to 3.95 gc.

Phase shift variation: less than 3° from 0 to 60 db.

Power: 10 watts continuous duty.

Degree dial: 0 to 90°; S382B calibrated in 0.1° increments, S382C calibrated in 0.01° increments.

Fits waveguide size: 3" x 1½" (WR284).

Size: 25¼" long, 6" high, 8" deep (641 x 152 x 203 mm).

Weight: net 18 lbs (8,1 kg); shipping 28 lbs (12,6 kg).

Price: hp S382B, $650; hp S382C, $700.

370, 372, 375A WAVEGUIDE ATTENUATORS

Three series useful to 40 gc

370 Fixed Waveguide Attenuators

These attenuators are waveguide sections providing fixed amounts of attenuation. They are useful in reducing power flowing in a waveguide system, reducing reflection of loads or sources, or isolating parts of a waveguide system. They consist of rectangular waveguide sections containing a rigidly mounted resistive strip. The resistive strip has been carefully designed to keep swr less than 1.15 and attenuation constant over the full waveguide band. Accuracy over the band is within ±20% of the nominal attenuation. The 370 is available in attenuations of 3, 6, 10 and 20 db. Either end may be used as the input.

Specifications, 370

hp Model*	Frequency (gc)	Power dissipation (watts)	Length (in.)	(mm)	Fits waveguide size (in.)	Price
S370	2.6 - 3.95	1.0	12	305	3 x 1½	$100
G370	3.95 - 5.85	1.0	10⅛	257	2 x 1	$ 95
J370	5.3 - 8.2	1.0	8⅛	206	1½ x ¾	$ 85
H370	7.05 - 10.0	1.0	6⅜	162	1¼ x ⅝	$ 75
X370	8.2 - 12.4	1.0	5¼	133	1 x ½	$ 65
P370	12.4 - 18.0	1.0	4⅛	105	.702 x .391	$ 80
K370**	18.0 - 26.5	0.5	3¼	83	½ x ¼	$115
R370**	26.5 - 40.0	0.5	3	76	.360 x .220	$125

*For 3 db attenuation, add suffix "A" to model number; for 6 db, add "B"; for 10 db, add "C"; for 20 db, add "D"

372 Precision Attenuators

Model 372 Precision Attenuators are rugged, dependable, broadband instruments, remaining precisely calibrated regardless of humidity, temperature or age. Models with either 10 or 20 db of attenuation are offered. SWR is 1.05; mean attenuation is within ±0.4 db (±0.7 db for K- and R-bands) of nominal; variation across band is less than ±0.5 db (±0.6 db for R372D) from mean. Calibration within ±0.1 db may be obtained at 10 points across the band as an extra-cost option (calibration is normally furnished at 5 points).

Specifications, 372

hp Model*	Frequency (gc)	Power dissipation (watts)	Length (in.)	(mm)	Fits waveguide size (in.)	Price
S372	2.6 - 3.95	2.0	46	1168	3 x 1½	$425
G372	3.95 - 5.85	2.0	30	762	2 x 1	$300
J372	5.85 - 8.2	1.0	21¾	552	1½ x ¾	$190
H372	7.05 - 10.0	1.0	20⅞	530	1¼ x ⅝	$135
X372	8.2 - 12.4	1.0	19⅛	486	1 x ½	$110
P372	12.4 - 18.0	1.0	15½	394	.702 x .391	$125
K372**	18.0 - 26.5	0.5	11½	292	½ x ¼	$240
R372**	26.5 - 40.0	0.5	10	254	.360 x .220	$275

*For 10 db attenuation, add suffix "C" to model number; for 20 db, add "D"

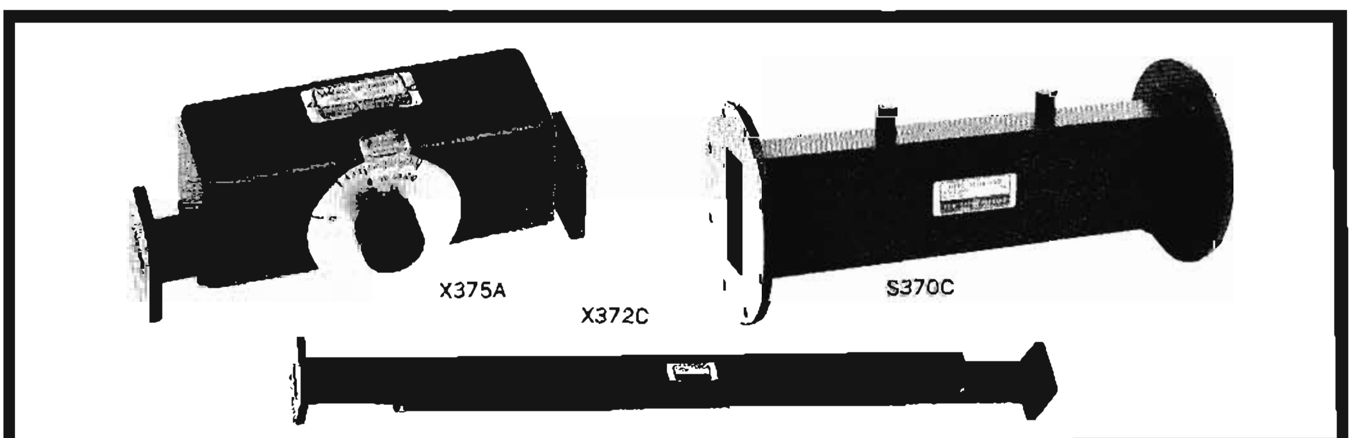
375A Variable Attenuators

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 0 to 20 db. Dial calibration is accurate within ±1 db from 0 to 10 db, ±2 db from 10 to 20 db. Maximum swr is 1.15.

Specifications, 375A

hp Model	Frequency (gc)	Power dissipation (watts)	Length (in.)	(mm)	Fits waveguide size (in.)	Price
S375A	2.6 - 3.95	2.0	14⅛	359	3 x 1½	$165
G375A	3.95 - 5.85	2.0	13	330	2 x 1	$145
J375A	5.3 - 8.2	2.0	13	330	1½ x ¾	$135
H375A	7.05 - 10.0	2.0	8¼	210	1¼ x ⅝	$125
X375A	8.2 - 12.4	2.0	7-3/16	183	1 x ½	$100
M375A	10.0 - 15.0	1.0	6¼	159	.850 x .475	$190
P375A	12.4 - 18.0	1.0	7¼	184	.702 x .391	$135
K375A**	18.0 - 26.5	0.5	4½	114	½ x ¼	$185
R375A**	26.5 - 40.0	0.5	4⅜	111	.360 x .220	$200

**Circular flange adapters: K-band (UG-425/U) 11515A, $35 each; R-band (UG-381/U) 11516A, $40 each.



355C,D, 393A, 394A VARIABLE COAXIAL ATTENUATORS

Versatile application, dc to 2 gc

355C,D VHF Attenuators

Unique design provides accurate attenuation from dc to 1 gc 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 assure 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 mc; hp 394A covers 6 to 120 db from 1 to 2 gc. 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.

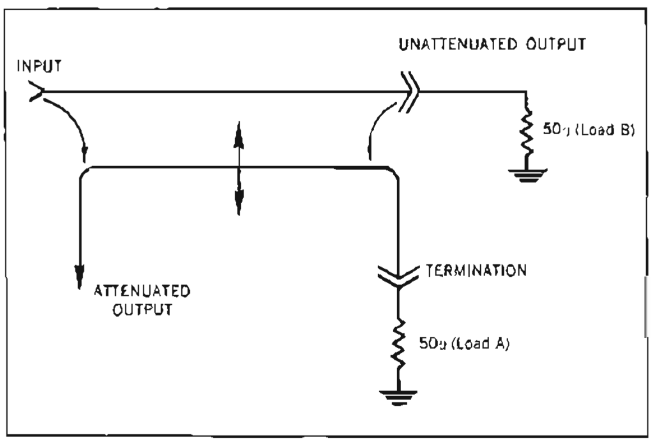
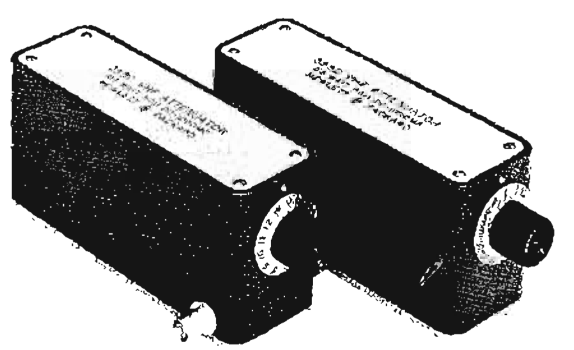


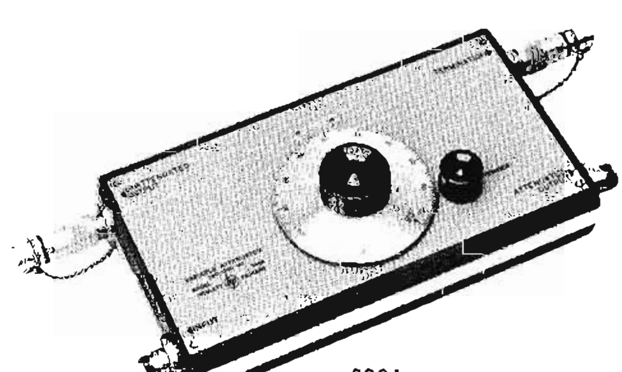
Figure 1. With loads A and B in place the instrument is an attenuator. With load A only, the instrument is a variable directional coupler.

Specifications	355C	355D
Attenuation:	12 db in 1 db steps	120 db in 10 db steps
Frequency range:	dc to 1 gc	
Overall accuracy:	±0.1 db at 1000 cps; ±0.25 db dc to 500 mc; ±0.35 db dc to 1 gc	±0.3 db to 120 db at 1000 cps, ±1.5 db to 90 db below 1 gc; ±3 db to 120 db below 1 gc
Impedance:	50 ohms nominal	
Power dissipation:	0.5 watt average, 350 volts peak	
Maximum swr (input and output):	1.2 below 250 mc; 1.3 below 500 mc; 1.5 below 1 gc	
Maximum insertion loss:	0.2 db at 100 mc; 0.75 db to 500 mc; 1.5 db to 1 gc	
Dimensions:	6" long, 2¾" wide, 2⅝" high (152 x 70 x 67 mm)	
Weight:	net 1½ lbs (0.7 kg); shipping 3 lbs (1,4 kg)	
Price:	hp 355C, $140	hp 355D, $140

Specifications	393A	394A
Frequency range:	500 mc to 1 gc	1 to 2 gc
Attenuation or coupling:	5 to 120 db, variable	6 to 120 db, variable
Directivity (with loads less than 1.05 swr):	at least 10 db, 10 to 40 db attenuation	
Absolute accuracy (between matched generator and load):	±1 db or ±1% 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:	5½" wide, 12" long, 2¾" deep (140 x 305 x 70 mm)	
Weight:	net 6 lbs (2,7 kg); shipping 13 lbs (5,8 kg)	
Price:	hp 393A, $525	hp 394A, $550
Option 01.	supplied without 908A coaxial terminations, less $70	



355C,D



393A

NOISE FIGURE MEASUREMENTS

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.

Noise figure is discussed in detail in Hewlett-Packard Application Notes 43 and 57, both of which are 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. Application Note 43, "Continuous Monitoring of Radar Noise Figures," reviews automatic noise measuring theory, examines radar system requirements for integral noise figure meters and describes the hp 344A Noise Figure Meter. This noise figure meter has been designed specifically for radar system applications in which time-shared noise figure measurements play an important role in maintaining radar sets at the peak of their performance.

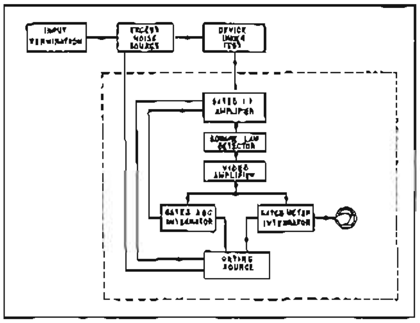


Figure 1. Automatic noise figure measurement system.

340B, 342A Noise Figure Meters; 343A, 345B, 347A, 349A Noise Sources

Advantages:

- Reads noise figure directly in db
- Completely automatic measurement
- Easily used by non-technical personnel
- No periodic recalibration needed
- Fast response; ideal for recorder operation

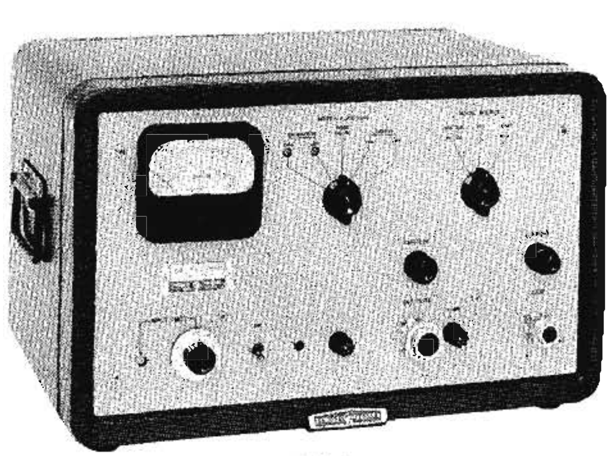
Uses:

- 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

Receiver and component alignment jobs which once took skilled engineers a full hour are now done in 5 minutes by a semi-skilled worker. Receiver noise figure often can be improved over the best adjustment previously possible. For instance, a 3 db improvement in receiver noise figure is equivalent to doubling transmitter output. Since accurate alignment is easy, equipment is better maintained and peak performance enjoyed regularly.

These are some of the time-saving, cost-cutting advantages of Hewlett-Packard noise figure measuring equipment, Models 340B and 342A, when used with coaxial and waveguide noise sources.

Model 340B Noise Figure Meter, when used with an hp noise source, automatically measures and continuously dis-



340B

plays the noise figure of IF or rf amplifiers tuned to 30 or 60 mc and of radar or microwave receivers with intermediate frequencies of 30 and 60 mc. Collectively, hp noise sources cover frequencies from 10 mc to 18 gc.

Five-frequency operation

Model 342A Noise Figure Meter is similar to hp 340B, except that it operates on five frequencies between 30 and 200 mc. Four of these frequencies are normally 60, 70, 105 and 200 mc; the fifth is the basic 342A tuned amplifier frequency of 30 mc.

In operation, a noise source, either a gas discharge tube or a diode, is connected to the input of a device under test. The IF amplifier output of the device is connected to the 340B or 342A. The noise figure meter gates the noise source on and off. When the source is on, the noise level is that of the device, plus the noise source. When the source is off, the noise level is that of the device and its termination. The noise figure meter automatically compares these two conditions and presents noise figure directly on a front-panel meter. Rate of response is such that changes in noise figure are constantly indicated on the meter.

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 mc with 50-ohm source impedance and low swr.

Hewlett-Packard 345B IF Noise Source: Operates at either 30 or 60 mc, as selected by a switch; another selector permits matching 50-, 100-, 200-, and 400-ohm impedances.

Hewlett-Packard 347A Waveguide Noise Sources: Argon gas discharge tubes mounted in waveguide sections; for waveguide bands 2.6 through 18 gc, 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 mc; also available with neon gas tubes.

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 30 db; (for stated accuracy with 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 mc, selected by switch; 342A: 30, 60, 70, 105, and 200 mc, selected by switch; other frequencies available.

Bandwidth: 1 mc 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: nominally 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 cps, 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 43 lbs (19,4 kg), shipping 54 lbs (24,3 kg) (cabinet); net 40 lbs (18 kg), shipping 51 lbs (23 kg) (rack mount).

Accessories furnished: one 340A-16A Cable Assembly, connects noise figure meter to 347A or 349A Noise Source.

Price: hp 340B, $715 (cabinet); hp 340BR, $700 (rack mount); hp 342A, $815 (cabinet); hp 342AR, $800 (rack mount); not available in Western Europe.

Specifications, 343A

Frequency range: 10 to 600 mc.

Excess noise: 5.2 db ±0.1 db, 10 to 200 mc; 5.2 db ±0.25 db, 200 to 400 mc; 5.2 db ±0.35 db, 400 to 600 mc.

Source impedance: 50 ohms; swr less than 1.2, 10 to 400 mc, and less than 1.3, 400 to 600 mc.

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, $100.

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 mc, selected by switch.

Excess noise: 5.2 db into conjugate load.

Source impedance: 50, 100, 200 or 400 ohms, ±4%, as selected by switch; less than 1 pf shunt capacitance.

Price: hp 345B, $125 (for operation at any two frequencies between 10 and 60 mc in lieu of 30 and 60 mc, add $25).

Specifications, 347A

hp Model	Range (gc)	Excess noise (db)	Approx. length (in.)	Approx. length (mm)	Price
S347A	2.60— 3.95	15.1 ±0.5	22½	572	$390
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	15.7 ±0.5	16	406	$275
X347A	8.20—12.4	15.9 ±0.5	14¾	375	$225
P347A	12.4 —18.0	16.0 ±0.5	14¾	375	$275

SWR for all models, fired or unfired, 1.2 maximum.

Specifications, 349A

Frequency range: 400 to 4000 mc, usable to 200 mc, with correction supplied.

Excess noise: 15.6 db ±0.6 db, 400 to 1000 mc; 15.7 db ±0.5 db, 1000 to 4000 mc.

SWR: <1.35 (fired), <1.5 (unfired) up to 2600 mc; <1.5 (fired or unfired), 2600 to 3000 mc; <2.0 (fired), <3.0 (unfired) 3000 to 4000 mc.

Dimensions: 3" wide, 2" high, 15" long (76 x 51 x 381 mm).

Weight: net 3¼ lbs (1,4 kg); shipping 6 lbs (2,7 kg).

Price: hp 349A, $325.

IMPEDANCE, SWR, REFLECTION COEFFICIENT MEASUREMENT

Impedance-matching a load to its source is one of the most important considerations in microwave transmission systems. If the load and source are mismatched, 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 to exist along the line. The ratio of standing-wave maxima to minima is directly related to the impedance mismatch of the load. The standing-wave ratio (swr), therefore, provides a valuable means of determining impedance and mismatch.

Slotted line measurements

Standing-wave ratio can be measured directly at discrete frequencies using a slotted line. The slotted line is placed immediately ahead of the load in test as shown in Figure 1, and the source adjusted for 1 kc 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 then read directly on the standing-wave indicator. Additional measurements of the standing-wave null position will yield phase information which may be entered onto a Smith Chart for determination of actual load impedance.

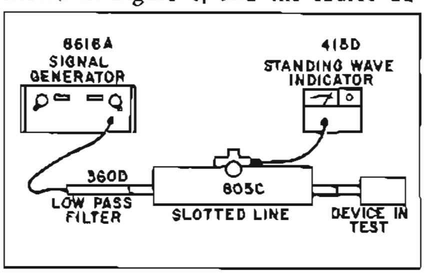


Figure 1. Typical set-up for swr and impedance measurements in coax using hp 805C Slotted Line.

Because the probe must not be allowed to extract any appreciable power from the line, high sensitivity and low noise are required in the detector and indicator. To this end, the indicator is sharply tuned to the 1 kc modulation frequency of the source, thereby reducing noise and allowing the use of a high-gain audio amplifier and voltmeter circuit.

Other considerations relative to accurate slotted line measurements include elimination of harmonics from the source prior to entering the slotted line, low FM in the source and low residual swr in the slotted line itself. Sources of error in slotted line measurement are discussed in detail in Application Note 65, "Microwave Impedance Measurement," available on request through hp sales offices.

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. Improved reflectometers, such as described on pages 160 and 161 of this catalog, permit continuous oscilloscope displays or permanent x-y recordings of reflection coefficient across complete operating bands. Oscilloscope displays, such as shown in Figure 2, allow rapid go no-go tests or monitoring of broadband circuit performance during critical adjustments.

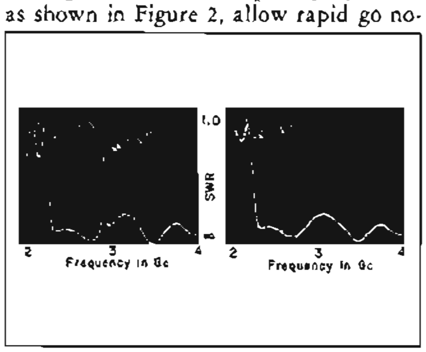


Figure 2. Oscilloscope displays of low-pass filter reflections.

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.

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 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 hp Application Note 61. Calibration procedures and instructions for use of these overlays are included in the note, which is available from Hewlett-Packard.

Reflectometer calculator

Time-consuming calculations of return loss and conversion of ρ to swr may be eliminated by using an hp 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 waveguide specifications are included on the calculator, which may be obtained from your hp field engineer upon request.

Reflectometer errors

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. For 20 db directivity, ambiguity is ± 0.1, etc. 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 values 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 non-linearity, instability and resolution are factors which must be considered. When using hp 130C or 140A Oscilloscopes for measuring small ratios ($\simeq 1$), accuracies of 2% are reasonable. Ratios of 30 db ($\rho \simeq 0.03$) can be determined with about 4% accuracy.

The total effects of these errors can be conservatively estimated as follows for leveled reflectometers using the hp equipment mentioned:

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 included in hp Application Note 65 on microwave impedance measurements.

Coaxial swept-frequency measurements

Coaxial devices may be swept-frequency tested with good accuracy up to about 4 gc in coaxial reflectometers. At frequencies much above 4 gc, the low directivity of coaxial directional couplers limits the usefulness of reflectometers considerably. While directivities of better than 30 to 40 db are available from 1 to 4 gc (hp 776D, 777D), coax couplers designed for operation around 10 gc exhibit directivities of only 15 db. This results in ambiguities of ± 0.18 in the measured ρ or an equivalent swr of about 1.44:1. If one simply uses waveguide couplers (for their high directivity) and a waveguide-to-coax adapter, the system would still have an ambiguity of about 0.11 (swr = 1.25) due to the reflection of the adapter.

The new hp X8440A Reflection Coefficient Bridge allows swept-frequency testing of coax devices from 8.2 to 12.4 gc with high accuracy. The bridge retains the high directivity of waveguide couplers while cancelling the residual effects of waveguide-to-coax adapters through unique design and careful selection of components. Figure 3 shows the bridge configuration with a leveled sweep oscillator connected. The two signal paths from the source to the detector are shown by the dashed and dotted lines. The E field in one path is rotated by 180° in the lower waveguide twists, whereas the E field in the other path remains in the same phase (note the upper twist rotates 90° then back 90°). Coupling characteristics of the directional couplers and the impedance of the adapters are carefully matched over the 8.2 to 12.4 gc band in production. The path lengths of the two signals are made equal by placing shims between certain of the waveguide flanges. As a net result, the two signals at the detector are equal in amplitude and 180° out of phase, producing a null in the detector reading and effectively cancelling adapter reflections. The output of the detector then is directly proportional to the reflection coefficient of any test device connected at the bridge's measuring arm. Matched coax adapters are provided at each arm of the bridge so either male or female Type N connectors may be tested. Accuracy of the system is better than $\Delta\rho = \pm(0.03 + 0.16\,\rho^2)$, where ρ is the reflection coefficient of the load in test. This represents a major improvement in accuracy for swept-frequency testing in coax where conventional reflectometers are seriously limited. Equipment using Type N coax connectors (male or female) with a swr of 1.5 can be tested with the X8440A with an swr ambiguity of 1.08 or less. Electrical tests of newly manufactured Type N connectors can be made with better accuracy, in most cases, than if slotted line techniques were used. Request Application Note 66 from your hp sales office for complete information on coax testing in X-band with the X8440A.

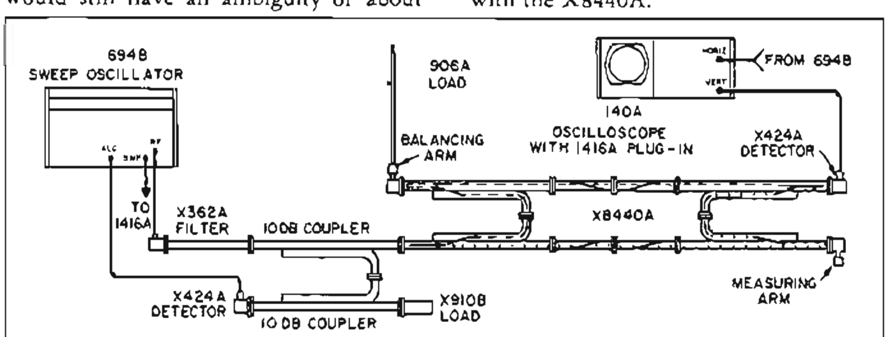


Figure 3. Measurement of reflection coefficient in coax 8.2 to 12.4 gc, with the hp X8440A.

415D SWR METER

Useful for swr, reflection coefficient, attenuation, AF null measurements

Advantages:

- Increased resolution with expand, offset provisions giving full-scale expansion for any 2.5 db increment — no "blind" spots
- Tunable amplifier to match source modulator
- Variable bandwidth for optimum swept-frequency or high-sensitivity testing
- Built-in bolometer protection
- Solid state, compact, low power consumption; portable operation optional

The hp 415D consists of a high-gain, low-noise solid-state amplifier operating at a tuned audio frequency and a voltmeter calibrated for square-law detectors to read directly in swr. The normal db scale covers 0 to 10 db, with a range attenuator covering 60 db in 10 db steps. The "expand-offset" feature activates the proper offset current and gain change to normalize the meter reading automatically. Four separate expand ranges cover the complete 10 db scale in 2.5 db sections. Concentric controls present direct readout on expanded, as well as unexpanded scales.

A front-panel screwdriver adjustment permits tuning the amplifier over a 50 cps range for ease in matching the signal source. Normal tuned frequency is 1000 cps, but frequencies between 400 and 2500 cps are available on special order. (Tuning frequency, however, should not be harmonically related to power line frequency.)

Another front-panel screwdriver control permits continuous adjustment of instrument bandwidth from 13 to 130 cps to increase sensitivity with narrow bandwidths or increase bandwidth for swept-frequency testing. The 415D is designed to operate with bolometers or crystals. The 200-ohm bolometer input provides bias of 8.7 or 4.3 ma for barretters or instrument fuses. A rear-panel control adjusts the bias ±10% of nominal value, the bias readable on the meter face. A 200-ohm crystal rectifier input is provided, as well as a high-impedance input (200 K) for crystal rectifiers when operating the instrument as a null detector. The bolometer bias is peak-limited.

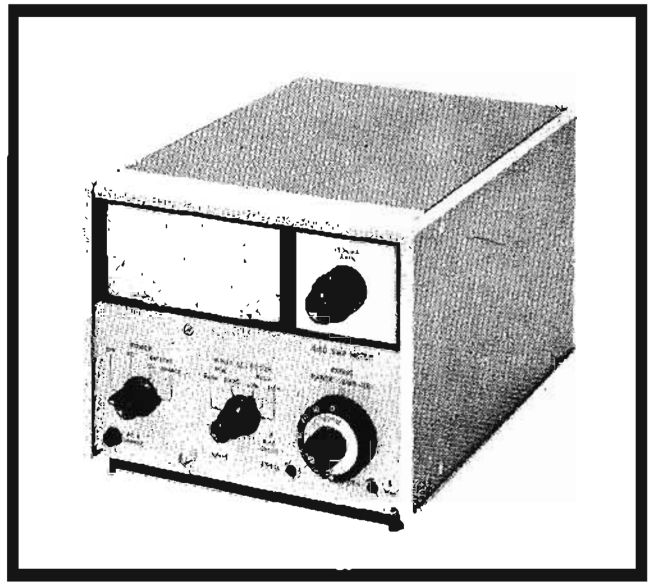
Both ac and dc outputs are provided for use of the 415D as a high-gain tuned amplifier and with recorders. The solid-state 415D may be operated with an internally mounted battery pack (optional extra) for completely portable use or to eliminate ground loops.

Specifications

Input: crystal: 200 ohms and 200 K input impedance; bolometer: 200 ohms input impedance; bias, variable ±10%, provided for 8.7 and 4.3 ma bolometers, positive bolometer protection; BNC input connector.

Sensitivity: 0.04 μv rms at minimum bandwidth, 0.1 μv rms at 30 cps bandwidth, 25° to 55° C (decreases to approx. 0.2 μv rms at 30 cps bandwidth at 0° C).

Noise: at least 7.5 db below full scale with 0.1 μv rms sensitivity and min. bandwidth, at least 5 db below full scale with 0.1 μv rms sensitivity and 30 cps bandwidth.



Frequency: 1000 cps, adjustable 5%; other frequencies beteween 400 and 2500 cps available on special order.

Bandwidth: variable, nominally 13 to 130 cps.

Range: 70 db in 10 and 2.5 db steps.

Accuracy: ±0.1 db/10 db step, maximum cumulative ±0.2 db; ±0.1 db when switching from any 10 db step (Norm) to any 2.5 db step (Expand), except ±0.05 db when switching to 0.0 (Expand); ±0.02 db linearity on Expand scales.

Output: dc: 0 to 1 ma into 1500 ohms maximum at the recorder jack (one side grounded); ac: 0 to approx. 0.5 v rms (Norm), 1 v rms (Expand) across 10 K min. at the amplifier output terminals (one side grounded).

Meter scales: calibrated for square-law detectors; swr: 1 to 4, 3.2 to 10, 1 to 1.3 (Expand); db: 0 to 10, 0 to 2.5 (Expand); Bolo Bias.

Meter movement: taut-band suspension, mirror-backed scale, with expanded db and swr scales greater than 4¼" (108 mm) long; tracking linearity 0.25% of full scale.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 2 watts; power line frequency or multiples thereof must not be at the tuned amplifier frequency; optional rechargeable battery provides up to 36 hours' continuous operation.

Dimensions: 7-25/32" wide, 6-3/32" high, 11" deep from front panel (190 x 155 x 279 mm).

Weight: net 8 lbs (3,5 kg), 11 lbs (5 kg) with batteries; shipping 11 lbs (5 kg), 15 lbs (6,8 kg) with batteries.

Accessories available: 415C-95A Rechargeable Battery and installation kit, $100; 10501A Cable Assembly, $3.50; 10503A Cable Assembly, $6.50.

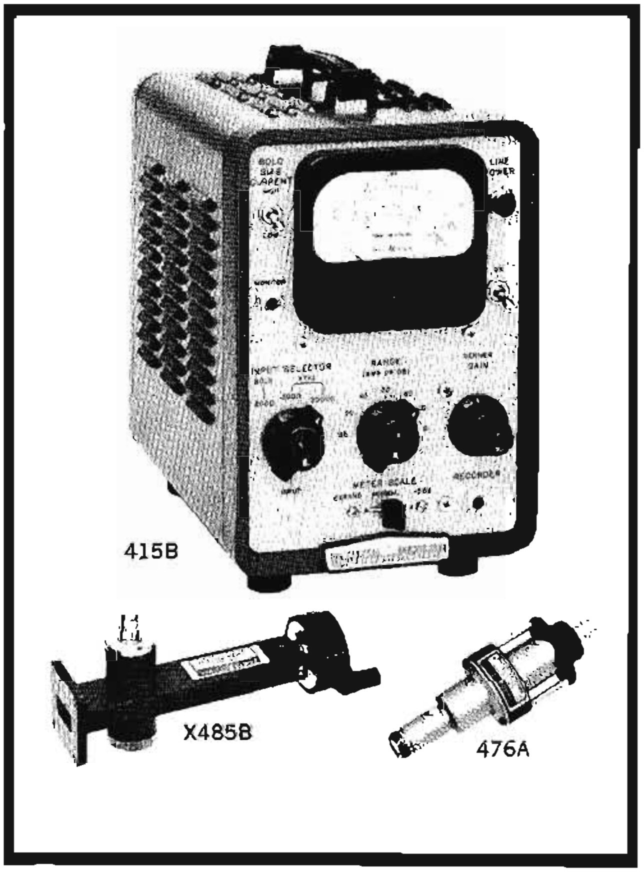
Price: hp 415D, $350.

Options

01. Rechargeable battery installed, add $100.
02. Rear input connector wired in parallel with front-panel input connector, add $15.

415B STANDING WAVE INDICATOR, 476A, 485B MOUNTS

For convenient swr measurements



415B Standing Wave Indicator

Similar to the hp 415D, 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 K 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 K 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 K) high impedance for crystal rectifier as null detector; BNC connector.

Sensitivity: 0.1 μvolt 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 cps $\pm$2%; other frequencies, 315 to 2020 cps, available on special order; should not be harmonically related to power line frequency.

Bandwidth: 30 cps (nominal).

Range: 70 db; input attenuator provides 60 db in 10 db steps, accuracy $\pm$0.1 db per 10 db step; maximum accumulative error, $\pm$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 $\pm$10%, 50 to 60 cps, 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 13 lbs (5,9 kg), shipping 16 lbs (7,2 kg) (cabinet); net 17 lbs (7,7 kg), shipping 27 lbs (12,2 kg) (rack mount).

Accessories available: plug-in filters (specify frequency): 415B-42B (315 to 699 cps), $60, and 415B-42C (700 to 2020 cps), $50; 10501A Cable Assembly, $3.50; 10503A Cable Assembly, $6.50.

Price: hp 415B, $250 (cabinet); hp 415BR, $255 (rack mount).

476A Bolometer Mount

Model 476A Bolometer Mount covers the 10 mc to 1 gc frequency range with very low standing wave ratio. 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.

Maximum swr: $<$1.15, 20 to 500 mc; $<$1.25, 10 mc to 1 gc.

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 each.

Weight: net 1 lb (0,5 kg); shipping 2 lbs (0,9 kg).

Price: hp 476A, $85.

485B Detector Mounts

The hp 485B Detector Mounts (3.95 to 12.4 gc) 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

hp Model	Frequency range (gc)	Maximum swr[1]	Fits waveguide size (in.)	Fits waveguide size (EIA)	Length (in.)	Length (mm)	Price
G485B[2]	3.95 - 5.85	1.25	2 x 1	WR187	9-5/16	237	$120
J485B[2]	5.85 - 8.2 5.50 - 5.85 5.30 - 5.50	1.25 1.35 1.50	1½ x ¾	WR137	8¼	210	$105
H485B[2]	7.05 - 10	1.25	1¼ x ⅝	WR112	6⅝	168	$ 85
X485B[2]	8.2 - 12.4	1.25	1 x ½	WR90	6-7/16	163	$ 75

[1]With Narda N821 barretter
[2]May use 1N21 or 1N23 for maximum detection sensitivity where swr is not critical
Detector elements are not supplied

416B RATIO METER

Ease, accuracy for reflection coefficient measurements

Advantages:

Eliminates amplitude-variation error

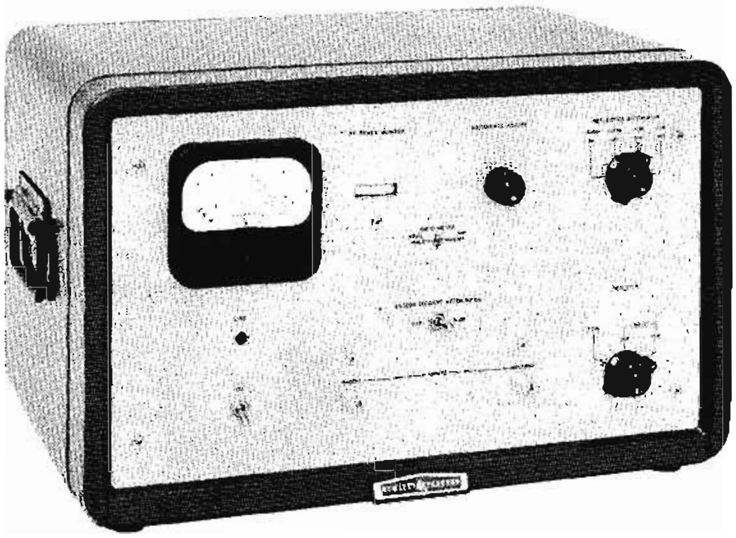
Operates accurately over 20/1 incident power range

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.



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 cps ±40 cps (±20 cps 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 K; bolometer, approximately 500 ohms (High Bolo) or 1000 ohms (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 K; 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 assure proper operating range for the instrument and for crystal detectors.

Power: 115 or 230 volts ±10%, 50 to 60 cps, 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).

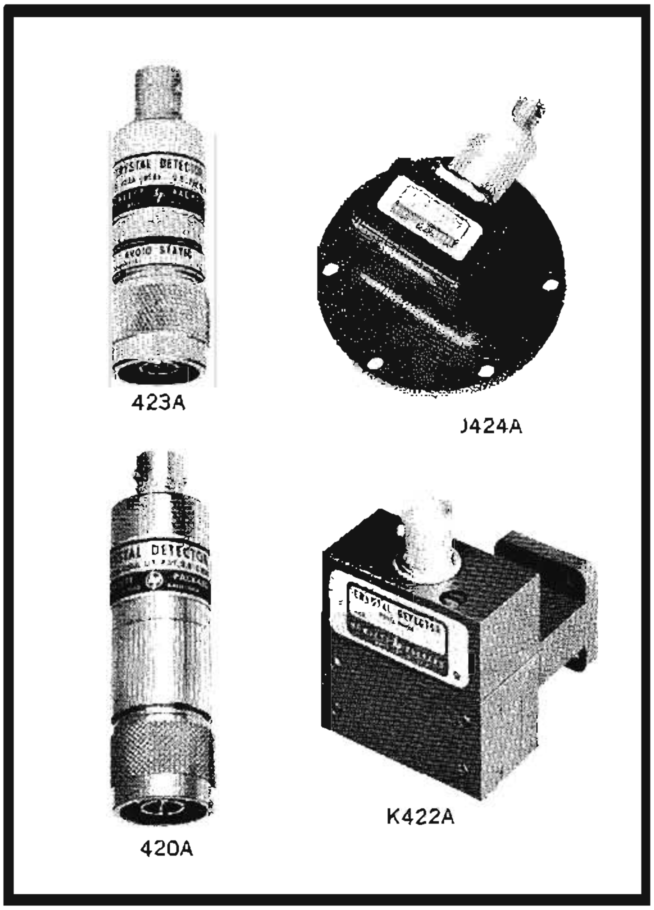
Weight: net 36 lbs (16,2 kg), shipping 45 lbs (20,3 kg) (cabinet); net 28 lbs (12,6 kg), shipping 41 lbs (18,5 kg) (rack mount).

Accessories available: 10503A Cable Assembly, $6.50; 11001A Cable Assembly, $5.50.

Price: hp 416B, $590 (cabinet); hp 416BR, $575 (rack mount).

423A, 424A, 420A,B, 422A, CRYSTAL DETECTORS

Flat response, high sensitivity, low swr



423A J424A 420A K422A

The hp 423A and 424A Crystal Detectors advance the state of the art in crystal video detectors by combining extremely flat frequency response with high sensitivity and very low swr. Such performance is due to a new crystal diode package developed by Hewlett-Packard, in which a superior diode is incorporated in a unique sealed capsule to provide best microwave characteristics. This approach also facilitates diode replacement, which can be made easily in the field. The flat frequency response and low swr of these detectors make them extremely useful as the detecting element in closed-loop leveling systems.

Matched pairs

For reflectometer applications in which both frequency response and square law characteristics are important, matched pairs of 423A and 424A detectors can be supplied with video loads for optimum square-law conformance. The low output capacitance of these detectors makes them ideal for detecting fast rf pulses; working into a low-capacitance 50-ohm load, their rise time is in the nanosecond region. Good pulse response permits their use in peak power measurement where the detected pulse is compared against a known cw level on a sensitive dc-coupled oscilloscope (such as hp 140A, page 277, or 175A, page 283).

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 mc to 12.4 gc, 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 gc range. Price: hp 420A, $50; hp 420B, $75.

hp Model	Frequency range (gc)	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 (lbs)	Shipping weight (kg)	Price
423A	0.01-12.4	±0.2 per octave, 0.01-8 gc; ±0.5 overall	>0.4	1.2, 0.01-4.5 gc; 1.35, 4.5-7 gc; 1.5, 7-12.4 gc	Type N male	yes[2]	yes[3]	2-15/32	63	1	0,5	hp 423A, $125
S424A	2.60-3.95	±0.2	>0.4	1.35	Wave-	yes[4]	yes[3]	2-7/16	62	2	0,9	hp S424A, $175
G424A	3.95-5.85	±0.2	>0.4	1.35	guide	yes[4]	yes[3]	2-1/16	52	2	0,9	hp G424A, $165
J424A	5.30-8.20	±0.2	>0.4	1.35	cover	yes[4]	yes[3]	1-7/8	48	1	0,5	hp J424A, $165
H424A	7.05-10.0	±0.2	>0.4	1.35	flange	yes[4]	yes[3]	1-9/16	40	1	0,5	hp H424A, $155
X424A	8.20-12.4	±0.3	>0.4	1.35		yes[4]	yes[3]	1-3/8	35	1	0,5	hp X424A, $135
M424A	10.0-15.0	±0.5	>0.3	1.5		yes[4]	yes[3]	1	25	1	0,5	hp M424A, $250
P424A	12.4-18.0	±0.5	>0.3	1.5		yes[4]	yes[3]	15/16	24	1	0,5	hp P424A, $175
K422A[7]	18.0-26.5	±2	≈0.1	2.5		yes[5]	furnished[6]	2	51	1	0,5	hp K422A, $250
R422A[7]	26.5-40.0	±2	≈0.1	3		yes[5]	furnished[6]	2	51	1	0,5	hp R422A, $250

For all models
Maximum input: 100 mw peak or average.
Output polarity: negative (positive output available with 423A, 424A; specify Option 03.; no additional charge).
Output connector: BNC female.
Detector element: supplied.

[1] As read on a 416 Ratio Meter (page 234) or 415 SWR Meter (page 233) calibrated for square law detectors.
[2] Frequency response characteristics (excluding basic sensitivity) track within ±0.2 db per octave from 10 mc to 8 gc, ±0.3 db from 8 to 12.4 gc; specify Option 01.; add $40 per pair.
[3] <±0.5 db variation from square law up to 50 mv peak output into >75 K; 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] Frequency response characteristics (excluding basic sensitivity) track within ±1 db for power levels less than approx. 0.05 mw; specify Option 01.; add $40 per pair.
[6] <±0.5 db variation from square law up to 50 mv peak output into >75 K.
[7] Circular flange adapters: 11515A (UG-425/U) for K-band, $35 each; 11516A (UG-381/U) for R-band, $40 each.

750, 752 DIRECTIONAL COUPLERS; X8440A REFLECTION COEFFICIENT BRIDGE

Easy-to-use, precision instruments simplify microwave measurements

X8440A Reflection Coefficient Bridge

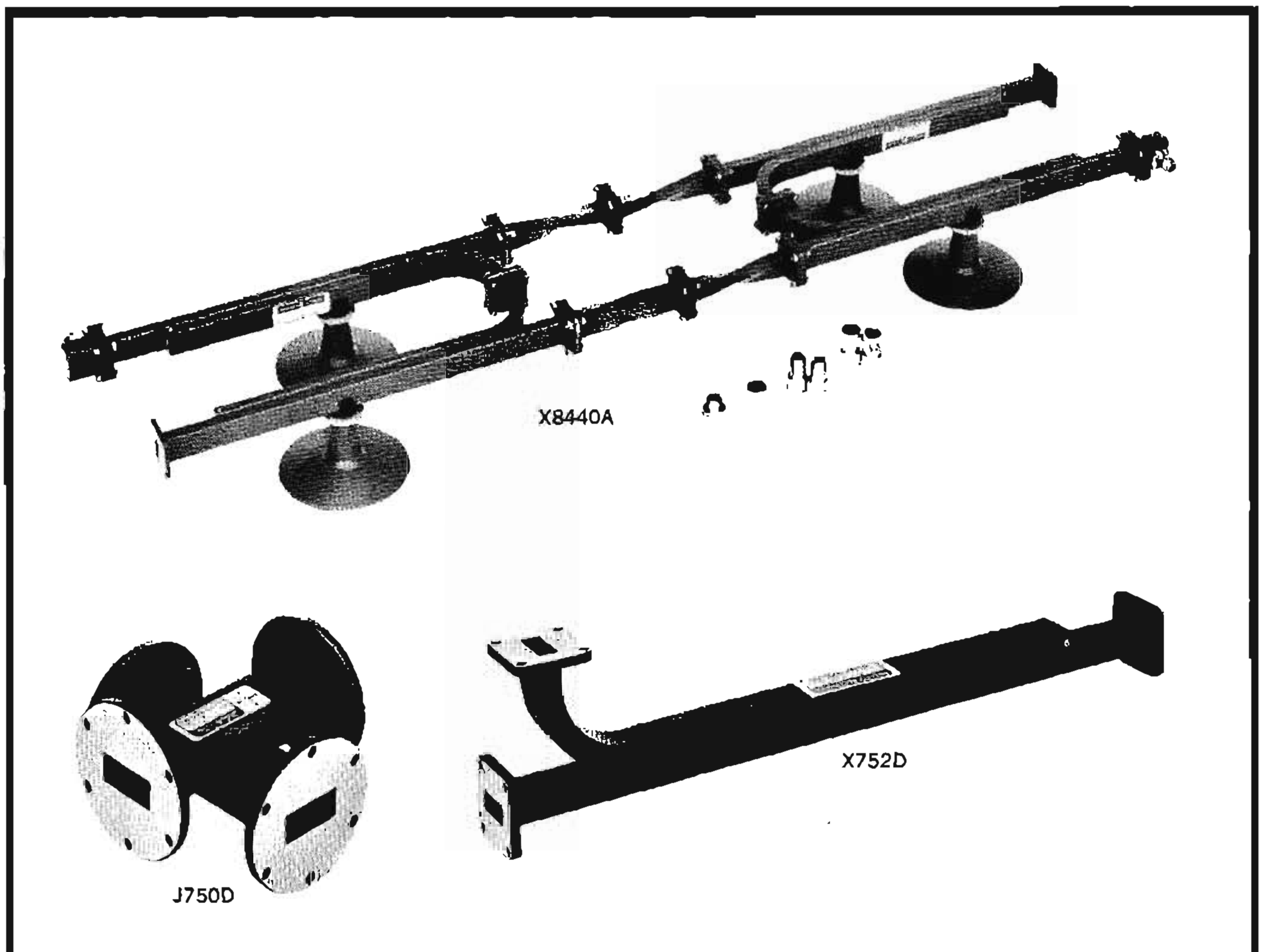
Full-range swept-frequency testing of coaxial devices in X-band (8.2 to 12.4 gc) can now be done with equal or greater accuracy than with the previously standard fixed-frequency slotted-line technique! This breakthrough came about with the advent of the hp X8440A Reflection Coefficient Bridge. Maximum measurement error using the bridge is $\pm(0.03 + 0.16\rho^2)$, which, for low values of reflection coefficient (ρ), corresponds to a residual swr of 1.06. Coaxial slotted lines, on the other hand, typically exhibit a residual swr of 1.1 between 10 and 12.4 gc (corresponding to a maximum error of ± 0.05 in the measurement of reflection coefficient) and 1.06 between 8 and 10 gc.

The X8440A consists of four waveguide directional couplers in a bridge configuration (waveguide couplers are used for their high directivity) with waveguide-to-coax adapters on opposite sides of the bridge. A 180° phase shift in one side of the bridge cancels the swr of the adapters. The bridge is easily and quickly calibrated; its output is then a direct indication of the reflection coefficient of the coaxial component under test, which is connected to one of the adapters. The results can be viewed on an oscilloscope (hp 140A with 1416A plug-in; see page 277) or recorded permanently with an x-y recorder. Application Note 66, available from your hp field engineer, describes the theory and operation of the bridge.

752 Directional Couplers

High directivity makes the 752 Directional Couplers particularly well suited for measuring small reflections, for rapidly adjusting transmission line flatness over the entire frequency range of the guide, or for broadband reflectometer applications. Signal or power monitoring and signal mixing are additional uses for these precision devices.

Used together and connected back to back, two couplers are most useful with the hp 690 Sweep Oscillators (pages 199-201) 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.

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).

750 Cross-Guide Directional Couplers

For many applications an inexpensive yet high quality, compact directional coupler is valuable; this is true for laboratory tests, as well as factory tests, or in permanent system installations. The hp 750 Cross-Guide Directional Couplers are ideal for such purposes. They consist of two waveguide sections joined at right angles across their broad faces. Coupling factors of 20 or 30 db are available, and connections may be made to both ends of the main and auxiliary guides. This provides a "four-port" network of maximum usefulness and versatility. The units are well suited for power monitoring, for isolation and for mixing powers.

Specifications, X8440A

Frequency range: 8.2 to 12.4 gc.

Max. error in measurement of reflection coefficient (ρ): $\pm (0.03 + 0.16\rho^2)$.

Accessories furnished: four 24 Waveguide Stands; four X25 Waveguide Clamps; 11511A Type N Female Shorting Jack; 11512A Type N Male Shorting Plug; matched pair of precision Type N male-to-male adapters; matched pair of precision Type N male-to-female adapters.

Price: hp X8440A, $1200.

* See Application Note 61, "Leveled Swept-frequency Measurements with Oscilloscope Display," available upon request from your Hewlett-Packard field engineer.

Specifications, 750 Series

hp Model	Coupling (db)	Frequency range (gc)	Fits waveguide size (in.)	(EIA)	Dimensions (in)	(mm)	Shipping weight (lbs)	(kg)	Price
S750D	20	2.6–3.95	3 x 1½	WR284	9 x 9	229 x 229	14	6,3	$150
S750E	30	2.6–3.95	3 x 1½	WR284	9 x 9	229 x 229	14	6,3	$150
G750D	20	3.95–5.85	2 x 1	WR187	6 x 6	152 x 152	6	2,7	$120
G750E	30	3.95–5.85	2 x 1	WR187	6 x 6	152 x 152	6	2,7	$120
J750D	20	*5.85–8.2	1½ x ¾	WR137	5 x 5	127 x 127	4	1,8	$100
J750E	30	*5.85–8.2	1½ x ¾	WR137	5 x 5	127 x 127	4	1,8	$100
H750D	20	7.05–10	1¼ x ⅝	WR112	4 x 4	102 x 102	2	0,9	$ 75
H750E	30	7.05–10	1¼ x ⅝	WR112	4 x 4	102 x 102	2	0,9	$ 75
X750D	20	8.2–12.4	1 x ½	WR90	3 x 3	76 x 76	1	0,45	$ 60
X750E	30	8.2–12.4	1 x ½	WR90	3 x 3	76 x 76	1	0,45	$ 60

Directivity: approximately 20 db or more with good terminations such as hp 914A.
Coupling accuracy: less than ±1.7 db variation from nominal value over entire frequency range of guide.

*J750 couplers usable to 5.3 gc; directivity same as above; coupling with ±3 db of nominal value.

Specifications, 752 Series

Band[1,2] (prefix)	Frequency (gc)	Fits waveguide size (in)	Mean coupling accuracy (db)[3,4]	SWR[5,6] main guide 752A	SWR[5,6] main guide 752C,D	Average power aux. guide load (w)	Length (in) A	Length (in) C	Length (in) D	Shipping weight (lbs)	Shipping weight (kg)	Price
S	2.6–3.95	3 x 1½	±0.4	1.1	1.05	2	50¼	48	48	38	17,1	$450
G	3.95–5.85	2 x 1	±0.4	1.1	1.05	2	34½	33	33	16	7,4	$300
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	18⅝	17½	17½	4	1,8	$150
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	$125
M	10–15	850 x .475	±0.4	1.1	1.05	1	16-5/16	15-11/16	15-11/16	3	1,4	$225
P	12.4–18	.702 x .391	±0.4	1.1	1.05	1	13¾	12¼	12¼	2	0,9	$150
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: S-band, 3 db coupling, Model S752A).
[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 gc with reduced performance.
†Circular flange adapters: K-band (UG425/U), hp 11515A, $35 each; R-band (UG-381/U), hp 11516A, $40 each.

770 DUAL-DIRECTIONAL COUPLERS, 780 DIRECTIONAL DETECTORS, 790 DIRECTIONAL COUPLERS

Increase coax reflectometer accuracy

770 Dual-Directional Couplers

The high directivity of the hp 770 Series Dual-Directional Couplers leads to more accurate results using reflectometers in coaxial systems. Reflectometers can save appreciable engineering and production test time in the design and manufacture of broadband apparatus (such as antennas, transceivers, etc.), while insuring that all portions of the frequency range of interest are examined. The couplers also are capable of materially improving the speed and accuracy of power measurements on coaxial vhf/uhf systems because of their accurate coupling attenuation characteristic and low swr over relatively wide frequency ranges.

The couplers are specifically designed to furnish maximum versatility and ease in use. Each covers a frequency spread of more than two-to-one, and its coverage is centered on one of the important vhf/uhf bands. The units are capable of handling fairly high amounts of power and have a low insertion loss, so that they can be permanently installed in coaxial lines for power monitoring. Since they are dual devices, a power meter or detector can be connected alternately to the "incident" and "reflected" auxiliary terminals to aid in system adjustment for maximizing forward power.

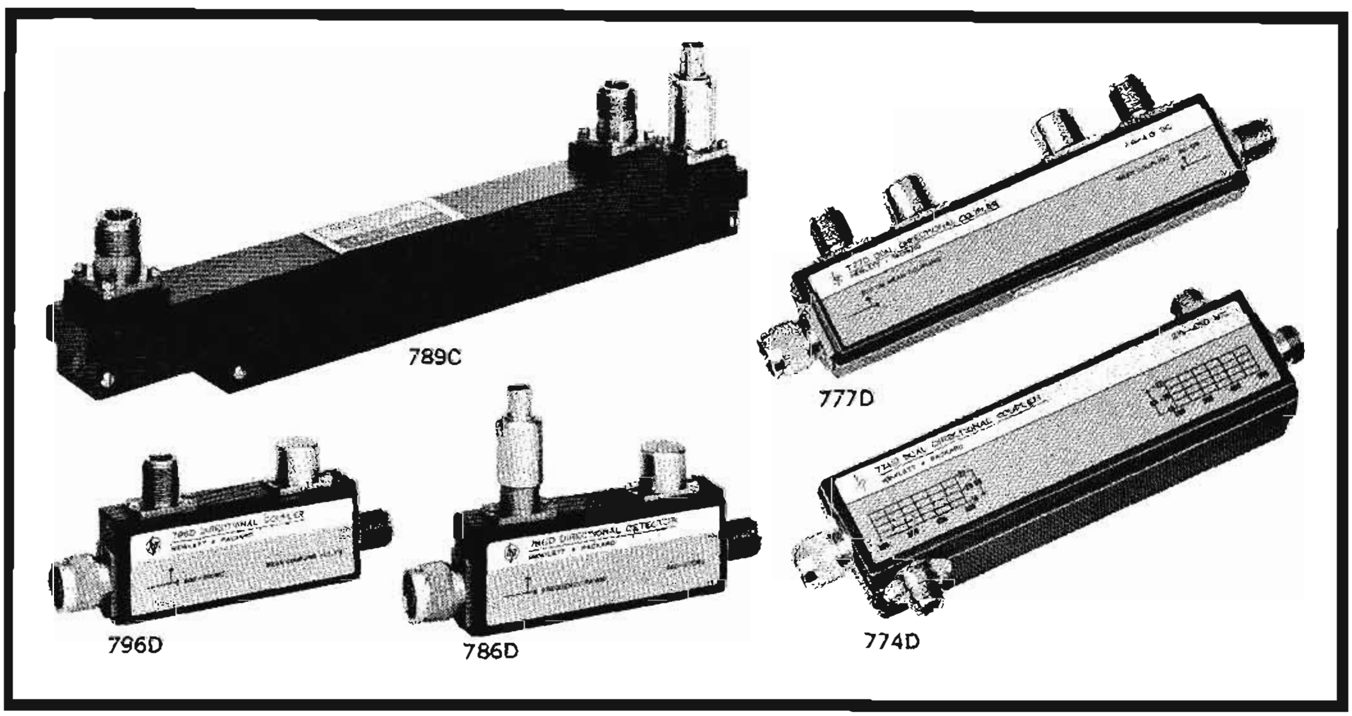
780 Directional Detectors

The hp 780 Directional Detectors are directional couplers with built-in crystal detectors. In each case the coupler itself has extremely flat frequency response and good directivity, while the detector also has very good frequency response plus high sensitivity. The configuration of the directional detector reduces the number of ambiguities over the standard system of separate directional coupler and detector and makes possible tighter correlation between main-arm power and detected signal.

The directional detector is well suited for closed-loop leveling applications, particularly with sweep oscillators such as the hp 690 Series (pages 199-201), for it permits the establishment of a leveled-power point anywhere in a system. Thus, leveled power can be applied to a load regardless of the characteristics of cables, connectors, etc., between the rf source and directional detector. The 786D through 789C are coaxial devices; X781A has a coaxial input and X-band waveguide output for working into WR90 waveguide systems. All have good equivalent source match. The detector element is a newly developed hp diode which embodies advanced microwave and solid-state techniques in a small, sealed capsule.

790 Directional Couplers

The 790 Directional Couplers are ultra-flat couplers which nevertheless have high directivity, making them ideal for power-monitoring applications in coaxial systems. For these couplers, output coupling (ratio of output power from main and auxiliary arms) is specified, rather than coupling factor. Thus, no correction factor is required to account for insertion and coupling losses in the main arm. With a power meter such as the hp 431B (page 220, 221) connected to the auxiliary arm, a calibrated, absolute power level can be conveniently established at any point in a system. The output of the 431B Power Meter can be used as a leveling signal for sweep oscillators. Thus, the 790 Directional Couplers, which have good equivalent source match, permit the easy assembly of a swept-frequency rf source which is both leveled and calibrated.



Specifications, 774D — 777D

hp Model	774D	775D	776D	777D
Frequency range	215 to 450 mc	450 to 940 mc	940 to 1900 mc	1900 to 4000 mc
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	approx. 0.15 db	approx. 0.2 db	approx. 0.25 db	approx. 0.6 db
Primary line connectors	precision Type N, one male, one female			
Auxiliary arm connectors	precision Type N, female			
Accessories available	11511A Type N Female Shorting Jack, $4; 11512A Type N Male Shorting Plug, $4.50			
Length	9-1/16" (230 mm)	9-1/16" (230 mm)	6-5/16" (161 mm)	8-7/8" (225 mm)
Shipping weight	4 lbs (1,8 kg)	4 lbs (1,8 kg)	3 lbs (1,4 kg)	3 lbs (1,4 kg)
Price	hp 774D, $200	hp 775D, $200	hp 776D, $200	hp 777D, $250

[1]Measured with hp 905A Sliding Termination or K01-770D Line Length Set.
[2]Maximum change in the coupling curve of one auxiliary arm relative to the other.

Specifications, 780 Series

hp Model	Frequency range (gc)	Freq. resp. (db)[1,2]	Low-level sens. (μv/μw)	Directivity (db)[1]	Equiv. source match[1,3]	Max. swr	Max. input (w, peak or avg.)	Insertion loss (db)[4]	Length (in)	Length (mm)	Shipping weight (lbs)	Shipping weight (kg)	Price
786D	0.96 to 2.11	±0.2	>4	30	1.13	1.15[1]	10	0.25	6	152	2	0,9	$300
787D	1.9 to 4.1	±0.2	>4	26	1.16	1.15[1]	10	0.35	4⅞	124	2	0,9	$300
788C	3.7 to 8.3	±0.3	>40	20	1.25	1.20	1	0.6	4⅞	124	2	0,9	$325
789C	8.0 to 12.4	±0.5	>20	17	1.25	1.40	1	0.7	11⅝	295	2	0,9	$350
X781A	8.0 to 12.4	±0.5	>20	17	1.07	1.25[1]	1	0.7	15¾	400	2	0,9	$350

[1]Swept-frequency tested.
[2]As read on a 416 Ratio Meter or 415 SWR Meter calibrated for square-law detectors.
[3]The apparent swr at the output of an rf generating system, such as the output of a directional detector when it is used in a closed-loop leveling system.
[4]Includes loss due to coupling.

For all models

Detector output impedance: 15 K 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: precision Type N, one male (input), one female (789C: both female; X781A: input, precision 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 from low level up to 50 mv peak output (working into external load >75 K); sensitivity typically one-fourth of unloaded sensitivity; add $20.

03. Positive polarity detector output; no additional charge.

Specifications, 790 Series

hp Model	Frequency range (gc)	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)	Insertion loss (db)[4]	Length (in)	Length (mm)	Shipping weight (lbs)	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	0.25	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	0.35	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	0.6	4⅞	124	2	0,9	$225

For all models: rf connectors: primary line: precision Type N, one male (input), one female; auxiliary arm: precision Type N female.

[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.

INSTRUMENTS WITH GPC-7 PRECISION COAX CONNECTORS

Increased accuracy for coax measurements to 18 gc

Precision measurements in coaxial systems have historically been restricted to the lower portions of the microwave spectrum primarily due to the measurement ambiguities and lack of repeatability that resulted from the coaxial connectors themselves. The practical extension of coaxial techniques to 18 gc is now possible with the introduction of the Amphenol* GPC-7 Precision 7 mm Coaxial Connectors.

These connectors, originally conceived by Hewlett-Packard with further development carried on jointly by Hewlett-Packard and Amphenol, offer the following outstanding characteristics: extreme broadband useability (to 18 gc), low swr, quick-connect coupling with positive and precise alignment, clearly defined reference plane, low rf leakage and low contact resistance. In addition, the connectors are sexless, and all categories, i.e., GPC-7, LPC-7 and FPC-7 series of the Amphenol 7 mm connector class will mate.

Hewlett-Packard has embarked on an extensive program to apply these new precision connectors to all types of coaxial test instruments, particularly where overall performance can be materially enhanced, either by improving measurement accuracy or extending the frequency range of measurement. Shown on these pages are some of the new coaxial test instruments that are equipped with the GPC-7 connector, along with brief descriptions of the major performance characteristics.

281B Series Waveguide-to-Coaxial (GPC-7) Adapters

Transformation from waveguide systems into precision 7 mm coax is achieved with the 281B Series Waveguide-to-Coaxial Adapters. Similar to the 281A Series (page 174), adapters covering all standard waveguide sizes from 2.60 to 18.0 gc are offered. Especially noteworthy are the M281B and P281B, which permit adaptation to 7 mm coax of higher frequency instruments with waveguide outputs such as hp 626A Signal Generator (pages 196, 197) and hp 695A Sweep Oscillator (pages 199-201).

hp Model	Frequency range	Waveguide port EIA designation
S 281B	2.60–3.95 gc	WR 284
G 281B	3.95–5.85 gc	WR 187
J 281B	5.30–8.20 gc	WR 137
H 281B	7.05–10.0 gc	WR 112
X 281B	8.20–12.4 gc	WR 90
M 281B	10.0–15.0 gc	WR 75
P 281B	12.4–18.0 gc	WR 62

Loads and terminations

Important constituents in measurement systems are low-reflection terminations, and hp has developed a coaxial sliding load, Model 907A, for use with GPC-7 precision coaxial systems. The 907A Sliding Load operates to 18 gc with less than 1.05 load swr; this reflection can be shifted in phase to permit its separation from other reflections in the system under test.

The hp 909A is a fixed coaxial termination for GPC-7 coax systems with less than 1.04 swr over its full dc to 18 gc range.

Crystal detectors and thermistor mounts

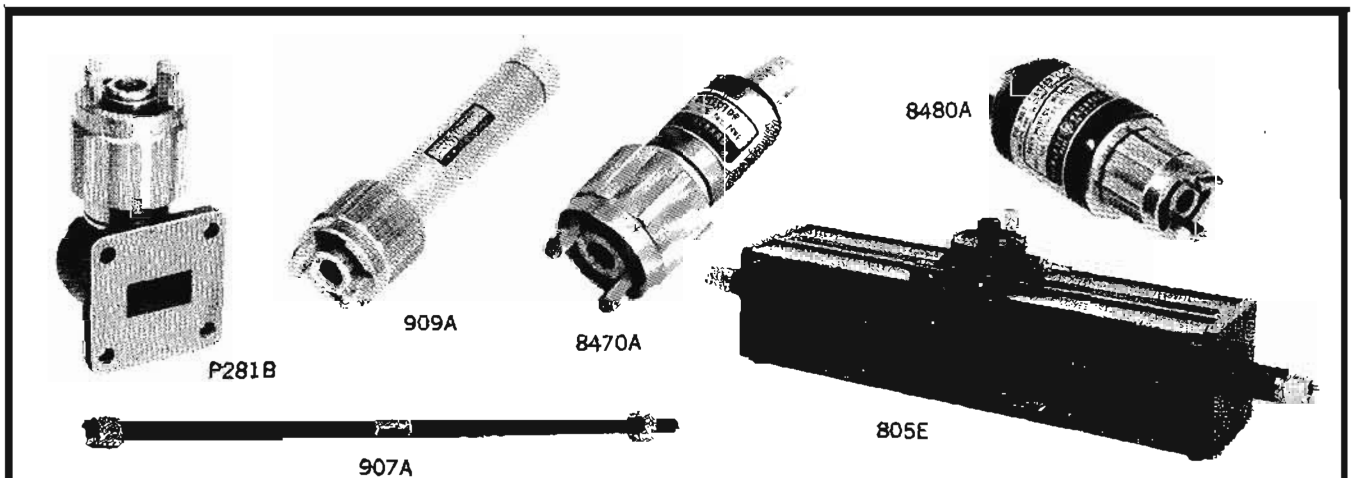
The superior performance of the hp 423A Crystal Detector (page 235) has been incorporated in the new hp 8470A Crystal Detector for GPC-7 coaxial systems. Low vswr, high sensitivity and flat response as high as 18 gc are among the major features.

The hp 8480A Coaxial Thermistor Mount is the GPC-7 connector version of the familiar hp 478A Thermistor Mount (page 220) for use with the hp 431B Power Meter. This temperature-compensated thermistor mount provides a good impedance match and high efficiency, resulting in accurate rf power measurements in the 100 mc to 12.4 gc frequency range.

Slotted lines, 500 mc to 18 gc

Hewlett-Packard offers two new slotted lines which provide accurate vswr measurements in 7 mm coaxial systems equipped with GPC-7 connectors. The Model 805E covers the frequency range from 500 mc to above 4 gc with less

*Amphenol RF Division, a Division of Amphenol-Borg Electronics Corporation, Danbury, Connecticut.



than 1.02 residual vswr. The 805E, derived from the familiar Type N hp 805C Slotted Line (page 244), features a GPC-7 connector on one end for connection to the 7 mm device under test. The other end of the 805E is equipped with a Type N connector for simple connection to the signal source.

To cover the important frequency range from 3.5 to 18 gc, the new hp Model 816A has been developed. This integral carriage and slotted line, with GPC-7 connectors on both ends, exhibits less than 1.02 residual swr over its entire frequency range. The Model 447A Untuned Probe, featuring low noise and high sensitivity, has been specifically designed for use with the 816A Slotted Line to provide greatest overall measurement capability.

Other instruments

To extend measurement capabilities within the 3.5 to 18 gc frequency range, the hp 873A Slide Screw Tuner can be employed to tune out other system discontinuities.

Coaxial dual-directional couplers, directional detectors and flat directional couplers, derived from their Type N counterparts, hp 770, 780 and 790 Series (page 238), are instruments that contribute additional measurement flexibility in 7 mm coaxial systems. While the input and auxiliary ports are Type N, the output port is a GPC-7 connector, thereby facilitating use of levelled sweep oscillators (hp 690 Series, pages 199-201) and coaxial reflectometer techniques.

Dual-directional couplers

hp Model	Frequency
8774D	215 to 450 mc
8775D	450 to 940 mc
8776D	940 to 1900 mc
8777D	1 9 to 4 0 gc

Directional detectors

hp Model	Frequency
8786D	0.96 to 2.11 gc
8787D	1.9 to 4.1 gc
8788C	3.7 to 8 3 gc
8789C	8.0 to 12 4 gc

Flat directional couplers

hp Model	Frequency
8796D	0 96 to 2.11 gc
8797D	1.9 to 4.1 gc
8798C	3.7 to 8.3 gc

K07-999 Connector Evaluation Set

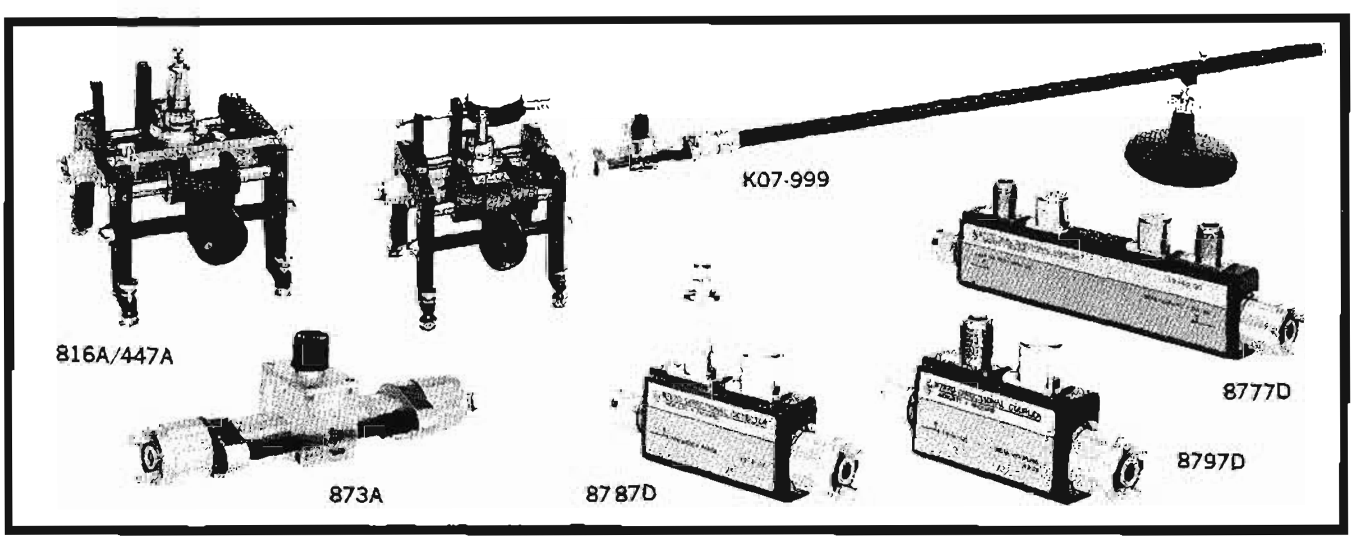
The Hewlett-Packard K07-999 Connector Evaluation Set has been developed to permit equipment designers to evaluate the performance of the new Amphenol 7 mm precision connector series.

The set consists of the 816A Precision Coaxial Slotted Line with integral carriage and 447A Broadband Probe Assembly, 873A Slide Screw Tuner and 907A Low Reflection Coaxial Sliding Load, all equipped with GPC-7 coax connectors and precision-manufactured to ensure exact measurements. Frequency range of the set is 3.5 to 18 gc, and the minimum measurable swr, using the half-wavelength substitution technique, is 1.003.

Other equipment

For the convenience of equipment designers and measurement laboratories, Hewlett-Packard can supply the Amphenol 7 mm components that might be needed for system tests, measurement and evaluation applications. Of course, these items also are available through the Amphenol RF Division organization.

hp Part No.	Description	Amphenol No.
1250-0745	GPC-7 General Precision Connector	131-1100
1250-0746	7 mm Airline Assembly—5.900" (fitted with one GPC-7 each end)	131-5001
1250-0747	7 mm Airline Assembly—4.215" (fitted with one GPC-7 each end)	131-5000
1250-0748	7 mm Airline Assembly—3.278" (fitted with one GPC-7 each end)	131-5002
1250-0749	Adapter; GPC-7 to N male	
1250-0750	Adapter; GPC-7 to N female	
1250-0751	Adapter; GPC-7 to TNC male	
1250-0752	Adapter; GPC-7 to TNC female	
8710-0037	GPC-7 assembly tool kit	131-2025



PROBE CARRIAGES, SLOTTED LINES, PROBES, DETECTORS

Low-cost precision tools for microwave measurements to 40 gc

809B, 814B Carriages

Model 809B Carriage is a precision mechanical assembly which operates with six hp 810B Waveguide Slotted Sections (3.95 to 18 gc) and with hp 806B Coaxial Slotted Section (3 to 12 gc). The carriage eliminates the cost of a probe carriage for each frequency band. Sections can be interchanged in seconds. The 809B is designed for use with either the hp 444A Untuned Probe or the hp 442B Broadband Probe. The carriage has a centimeter scale with a vernier reading to 0.1 mm, and provision also is made for mounting a dial gauge if more accurate probe position readings are required.

The hp 814B Carriage, also a precision assembly, is designed for use with the hp K and R815B Waveguide Slotted Sections (18 to 40 gc) and hp 446B Untuned Probe. The carriage is equipped with a dial indicator for accurate readings. Slotted sections are easily interchanged.

Specifications, 809B

Carriage: mounts all 810B Waveguide Slotted Sections and 806B Coaxial Slotted Section.
Probe required: 444A Untuned Probe or 442B Broadband Probe.
Probe travel: 10 cm.
Calibration: metric; vernier permits readings to 0.1 mm; provision for dial gauge.
Dimensions: 8⅞" long, 6¾" wide, 5¾" high (226 x 172 x 146 mm).
Price: hp 809B, $175.

Specifications, 814B

Carriage: mounts 815B Waveguide Slotted Sections.
Probe required: 446B Untuned Probe.
Calibration: metric; dial gauge with 0.01 mm division.
Size: 6¼" long, 6¼" wide, 6½" high (159 x 159 x 165 mm).
Price: hp 814B, $225.

806B, 810B, 815B Slotted Sections

Designed for use with the 809B Carriage, the 806B Coaxial Slotted Section provides continuous coverage from 3 to 12 gc. Impedance is 50 ohms, and the Type N connectors are a precision type for minimum swr when mated with standard Type N connectors.

The 810B Waveguide Slotted Sections also are designed for use with the 809B Carriage. Each is a precision-manufactured section of waveguide in which a small longitudinal slot is cut. A traveling probe on the 809B 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, 806B

Carriage: fits 809B Carriage.
Frequency range: 3 to 12 gc.
Residual swr: less than 1.04, 3 to 8 gc; approximately 1.06, 8 to 10 gc; approximately 1.1, 10 to 12 gc.
Impedance: 50 ohms
Connectors: Type N, one male, one female; special fittings provide minimum swr; either end may be connected to load; includes shorting connectors, male and female, for phase measurements.
Pick-up error: probe pick-up variation along line is less than 0.1 db except at extreme ends, where it is less than 0.4 db.
Length: 10" (254 mm).
Price: hp 806B, $200.

Specifications, 810B

hp Model	Frequency range (gc)	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
M810B	10.0–15.0	0.850 x 0.475	WR75	—	$175
P810B	12.4–18.0	0.702 x 0.391	WR62	UG419/U	$110

Carriage: fits 809B 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 (gc):	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:	$265	$265

*Circular flange adapters: K-band (UG425/U) 11515A, $35 each; R-band (UG381/U) 11516A, $40 each.

S810A Waveguide Slotted Section

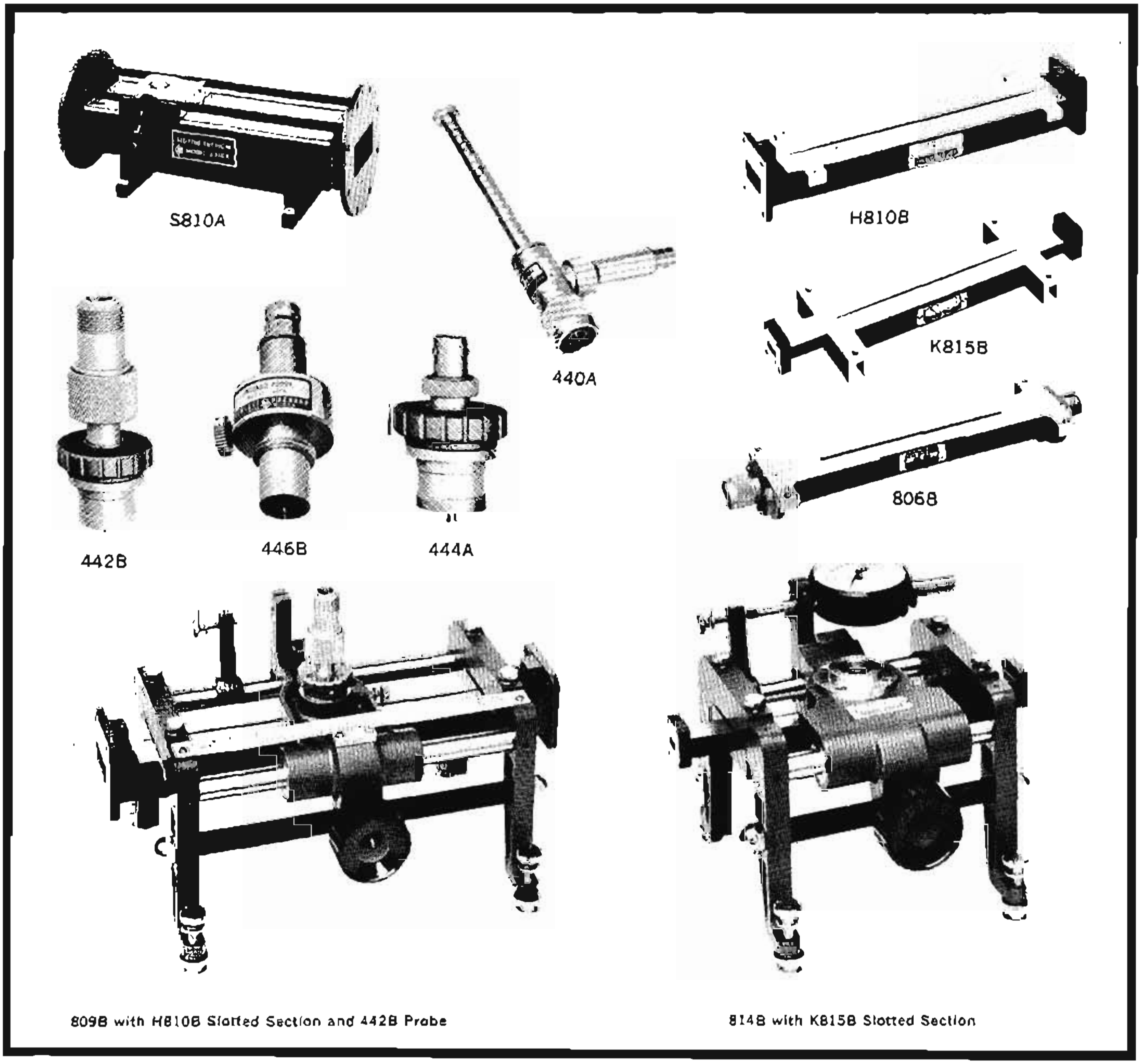
This instrument is a conventional slotted waveguide complete with probe carriage mounted directly on the section. It is available only in the 3" x 1½" (WR284) size covering 2.6 to 3.95 gc. The carriage accepts the hp 444A Untuned Probe or hp 442B Broadband Probe.

Specifications, S810A

Conventional waveguide slotted section with probe carriage mounted directly on waveguide; will accept 444A or 442B Probes.
Frequency range: 2.6 to 3.95 gc.
Residual swr: less than 1.01.
Fits waveguide size: nominal OD, 3" x 1½"; EIA, WR284.
Length: 12¾" (324 mm).
Price: hp S810A, $450.

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 gc) 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.



809B with H810B Slotted Section and 442B Probe

814B with K815B Slotted Section

Specifications, 440A

Frequency range: 2.4 to 12.4 gc.

Detector: 1N21 or 1N23 silicon crystals or 821 series barretter (not supplied)

Tuning: single stub.

Connectors: UG21B/U (rf input); BNC female (detector output).

Price: hp 440A, $85.

442B, 444A, 446B 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, permitting direct connection to a receiver, spectrum analyzer or other instrument. It can be connected to a 440A Detector Mount to form a sensitive and convenient tuned rf detector for slotted waveguide sections. The 442B fits the 809B Carriage. Price: hp 442B, $50.

The 444A Untuned Probe 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 809B Carriage or other carriages with a 3/4" (19 mm) mounting hole.

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.

Specifications, 444A

Frequency range: 2.6 to 18 gc.

Output connector: BNC female.

Detector: supplied

Price: hp 444A, $55.

Specifications, 446B

Carriage: mounts in 814B.

Frequency range: 18 to 40 gc.

Detector: modified 1N53 silicon diode, installed.

Price: hp 446B, $145.

805C,D SLOTTED LINES; 870A, 872A, 880A,B TUNERS

Match microwave impedances

805C,D Slotted Lines

The Hewlett-Packard 805C,D Slotted Lines employ two parallel planes and a rigid center conductor, offering important advantages over the conventional coaxial slotted section. Besides providing greater structural stability, this configuration results in improved electrical characteristics, such as negligible slot radiation and less effect from variations in probe depth or centering. The probe circuit is tunable 500 to 4000 mc, and depth of probe penetration can be adjusted quickly and easily. Two versions of the 805 are offered: the 805C for Type N systems, and the 805D for use with RG-44/U stub-supported rigid coaxial lines (⅞" OD).

Specifications, 805C,D

Frequency range: 500 to 4000 mc; minimum frequency determined by usable length of 14½" (368 mm).

Characteristic impedance: 805C: 50 ohms (for use with any 50-ohm cable using Type N connector); 805D: 46.3 ohms (for use with rigid coaxial lines, ⅞" outside diameter).

Connectors: 805C: Type N (one male, one female; special fittings designed to mate with Type N connectors, provide a minimum swr; either end may be connected to the load); 805D: one male, one female.

Residual swr: 1.04.

Calibration: metric, calibrated in cm and mm; vernier permits reading to 0.1 mm.

Detector probe: tunable probe provided for entire frequency range; detector element may be 1N21B crystal (supplied with instrument) or 821 series barretter or selected 1/100-amp instrument fuse.

Weight: net 18 lbs (8,1 kg); shipping 28 lbs (12,6 kg).

Accessories furnished: 805C: 11511A Shorting Jack; 11512A Shorting Plug; 805D: 11513A Shorting Plug; 11514A Shorting Jack.

Accessories available: 805C: 11501A Cable Assembly, $15; 11500A RF Cable Assembly, $15; both models:10503A Cable Assembly, $6.50; 11510A Carrying Case, 29" long, 9½" high, 9½" wide (737 x 241 x 241 mm), $65; 475B-34V Barretter Adapter, $3.

Price: hp 805C, $525; hp 805D, $600.

870A Slide-Screw Tuners

Slide-screw tuners are used to match loads, terminations, etc., to the characteristic impedance of the transmission system. The Hewlett-Packard 870A tuners consist of a waveguide slotted section with a precision carriage that supports an adjustable probe. The position and penetration of the probe is adjusted to set up a reflection which cancels an existing reflection in the system. An swr of 20 can be corrected to 1.02, and small swr's may be corrected exactly. Nine models cover the 2.6 to 40 gc range. Price: hp 870A, $130 to $300.

872A Coaxial Slide-Screw Tuner

This tuner consists of a parallel plane line and a precision probe carriage and exhibits exceedingly low insertion loss. Carriage travel is at least one-half wavelength at 500 mc, so any phase of reflection can be cancelled. Phase can be adjusted independent of magnitude, making the 872A much more convenient than double-stub tuners. Both probe penetration and position can be logged, so that settings may be repeated easily.

Specifications, 872A

Frequency range: 500 to 4000 mc.

Correctable swr: 5.

Insertion loss at maximum correctable swr: 0.5 db or less.

Impedance: 50 ohms (Type N connectors, one male, one female).

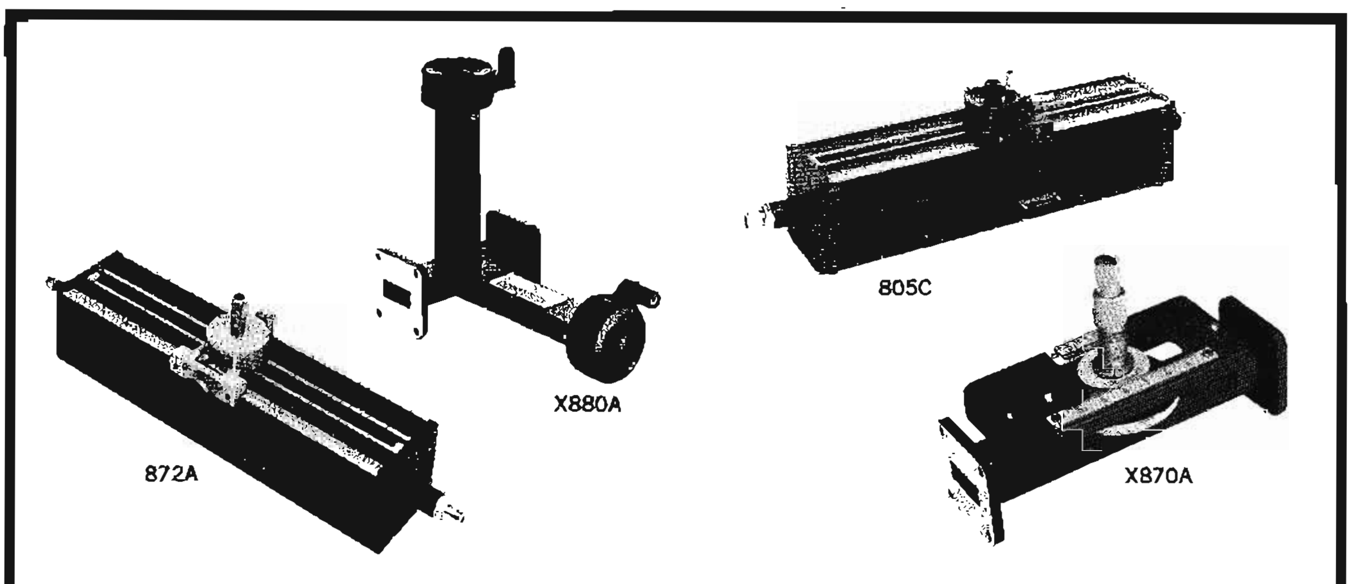
Weight: net 17 lbs (7,7 kg); shipping 27 lbs (12,2 kg).

Accessories available: 11511A Shorting Jack, $4; 11512A Shorting Plug, $4.50.

Price: hp 872A, $525.

880 E-H Tuners

The 880A,B tuners (8.2 to 18 gc) consist of a straight section of waveguide to which series and shunt tuning arms are attached. Each arm has a movable short circuit. Tuners of the E-H configuration are particularly useful where rf leakage is undesirable or where high power precludes the use of a slide-screw tuner. Standing wave ratios as high as 20 can be reduced to less than 1.02. Price: hp X880A, $130; hp P880B, $150.



WAVEGUIDE, COAXIAL TERMINATIONS, LOADS, WAVEGUIDE SHORTS

Versatile, convenient microwave instruments

906A, 914 Loads, 916 Standard Reflections

The hp 906A Coaxial Sliding Load is a movable, low-reflection termination for Type N 50-ohm systems. It covers the frequency range of 1 to 12.4 gc and can be moved at least one-half wavelength at 1 gc. Load swr is less than 1.05 from 1.5 to 12.4 gc, less than 1.1 from 1 to 1.5 gc. Price hp 906A, $325.

Model 914 Moving Load consists of a section of waveguide in which is mounted a sliding, tapered low-reflection load. A plunger controls the position of the load, moving it at least one-half wavelength at the lowest waveguide frequency. Thus, the phase of the residual load reflection can be reversed, so that this reflection can be separated from the other small reflections in the system.

The waveguide sections of the moving loads are manufactured to very close tolerances to minimize the waveguide swr. All but S-band units are broached, for broaching is a linear cutting stroke which does not have the irregularities of milling cutters, etc. In addition, the guide dimensions are checked with precision gauges — air gauges from X- through R-bands. Nine models cover from 2.6 to 40 gc; each has a locking mechanism which prevents accidental movement of the load. Hewlett-Packard 914 prices range from $60 to $250.

Model X916 Standard Reflections, available in 4 models, are precision loads used to set up exact reflections for standardizing swr measuring systems. Nominal reflection coefficients for the four models (X916B through X916E) are 0.05, 0.1, 0.15 and 0.2. Price hp X916, $125 each.

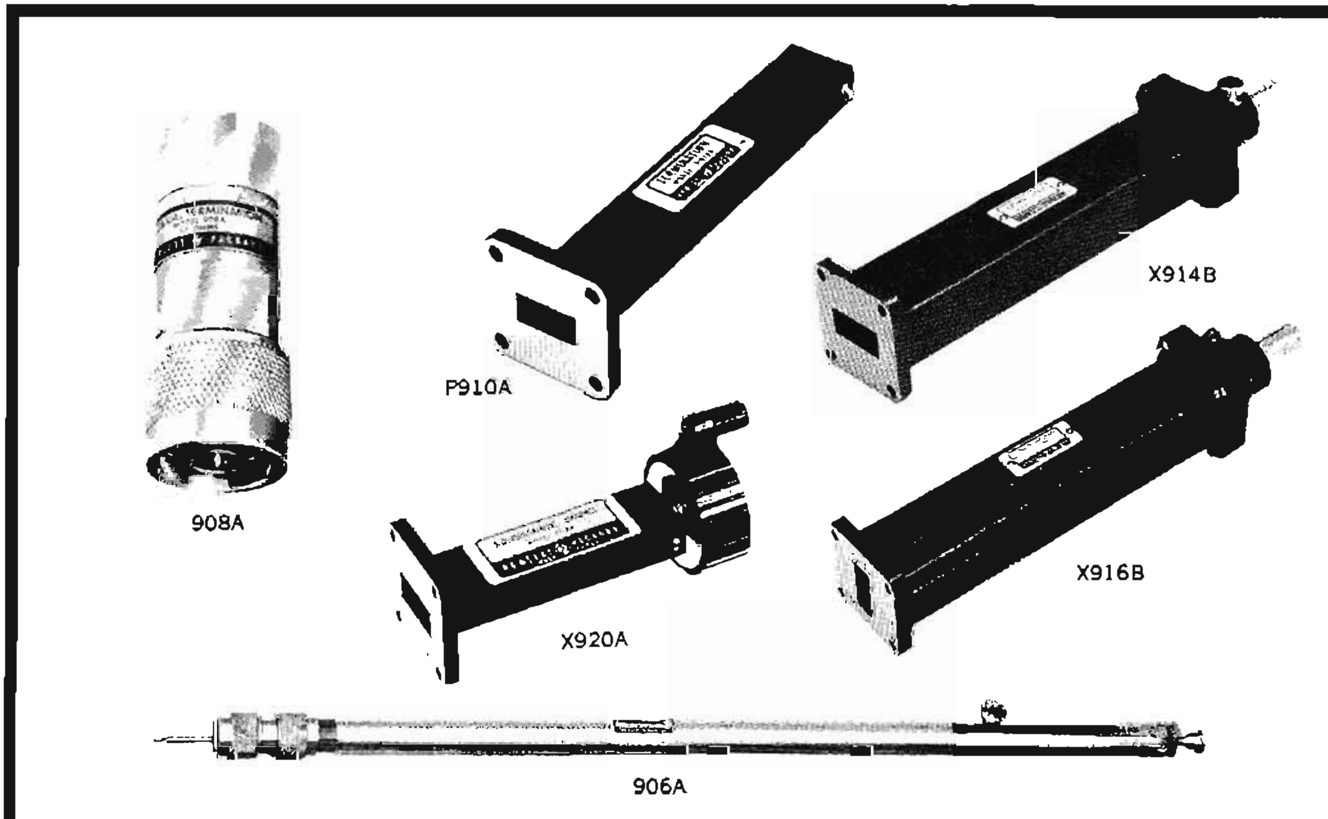
908A, 910 Terminations

The Model 908A is a low-reflection load for terminating 50-ohm coaxial systems in their characteristic impedance. Frequency range is dc to 4 gc, and swr of the coaxial termination is less than 1.05 over the entire range. Power rating is 0.5 watt average. Price hp 908A, $35.

The 910 Series is designed for terminating waveguide systems operating at average powers up to about 1 watt (1 kw peak). They may be used wherever a matched load is required, as in the measurement of reflection, discontinuities or obstacles in waveguide systems. Featuring low swr, the 910 Series covers the frequency range of 2.6 to 18 gc in six models. Price hp 910 Series, $35 to $75.

920A,B Waveguide Shorts

Model 920A,B Waveguide Shorts, available in 9 bands covering 2.6 to 40 gc, are convenient instruments for introducing a variable element in waveguide systems. They can be used to provide a variable short-circuit reference point. The waveguide sections are broached and checked to close tolerances to insure uniform reflection as the reference point is shifted. Price hp 920A,B, $75 to $155.



532 SERIES, 536A FREQUENCY METERS, 885A PHASE SHIFTERS

Precision instruments for general-purpose or lab use

532, 536A Frequency Meters

The hp 532 Series and 536A Frequency Meters are wideband, direct-reading instruments offering ease of operation, plus high resolution. Frequency is read directly in gc with extremely high accuracy, which means that no interpolation or charts are required.

The instruments comprise a special transmission section with a high Q resonant cavity that is tuned by a choke plunger. No sliding contacts are used, and the section transmits virtually full power off resonance. A 1 db or greater dip in output indicates resonance. There are no spurious responses. 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" (1956 mm) and is calibrated in 5 mc increments. Resettability is extremely good. All frequency calibrations are visible, so you can tell at a glance the specific portion of the band you are measuring.

The 532 Series are waveguide instruments which cover the frequency range from 3.95 to 40 gigacycles. The 536A, a frequency meter for coaxial systems, covers the frequency range from 0.96 to 4.2 gigacycles.

Specifications, 532A,B and 536A

hp Model	Frequency range (gc)	Dial accuracy (%)	Overall accuracy[1] (%)	Calibration increment (mc)	Price
536A	0.96–4.20	0.10 [2]	0.17 [3]	2	$500
G532A	3.95–5.85	0.033	0.065	1	$375
J532A	5.30–8.20 [4]	0.033	0.065	2	$350
H532A	7.05–10.0	0.040	0.075	2	$300
X532B	8.20–12.4	0.050	0.08	5	$200
M532A	10.0–15.0	0.053	0.085	5	$300
P532A	12.4–18.0	0.068	0.10	5	$275
K532A [5]	18.0–26.5	0.077	0.11	10	$350
R532A [5]	26.5–40.0	0.083	0.12	10	$400

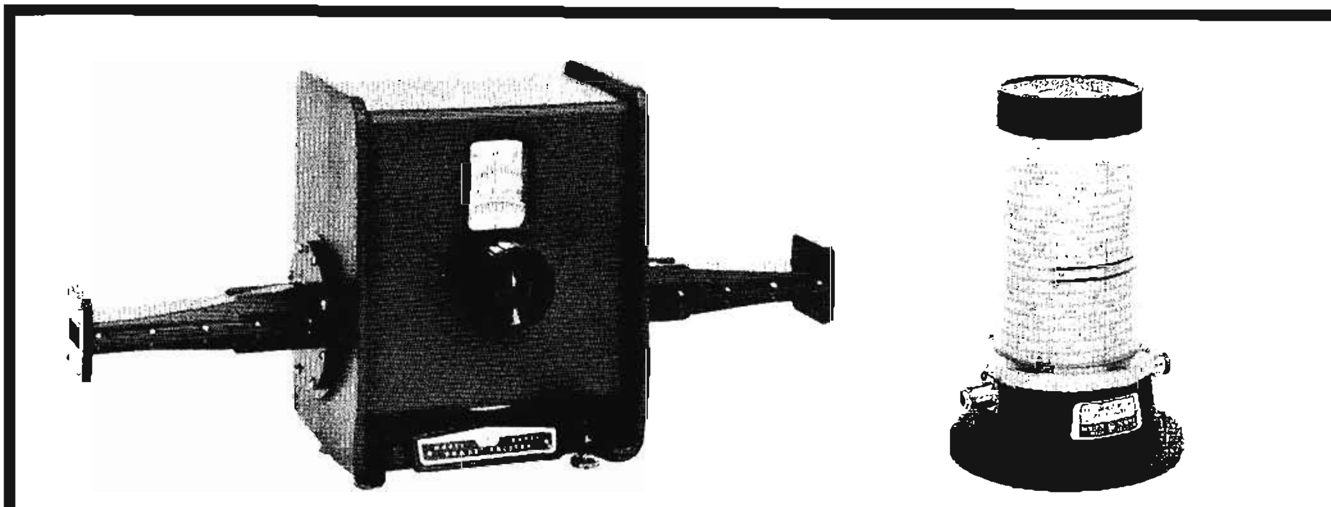
[1] Includes allowance for 0 to 100% relative humidity, temperature variation from 13°C to 33°C and backlash.

[2] 0.15, 0.96 to 1 gc.

[3] 0.22, 0.96 to 1 gc.

[4] Because of the wide frequency range of the J532A, frequencies from 7.6 to 8.2 gc can excite the TE_{11} mode when the dial is set between 5.3 and 5.6 gc.

[5] Circular flange adapters: K-band (UG-425/U) 11515A, $35 each. R-band (UG-381/U) 11516A, $40 each.



X885A   536A

885A Waveguide Phase Shifters

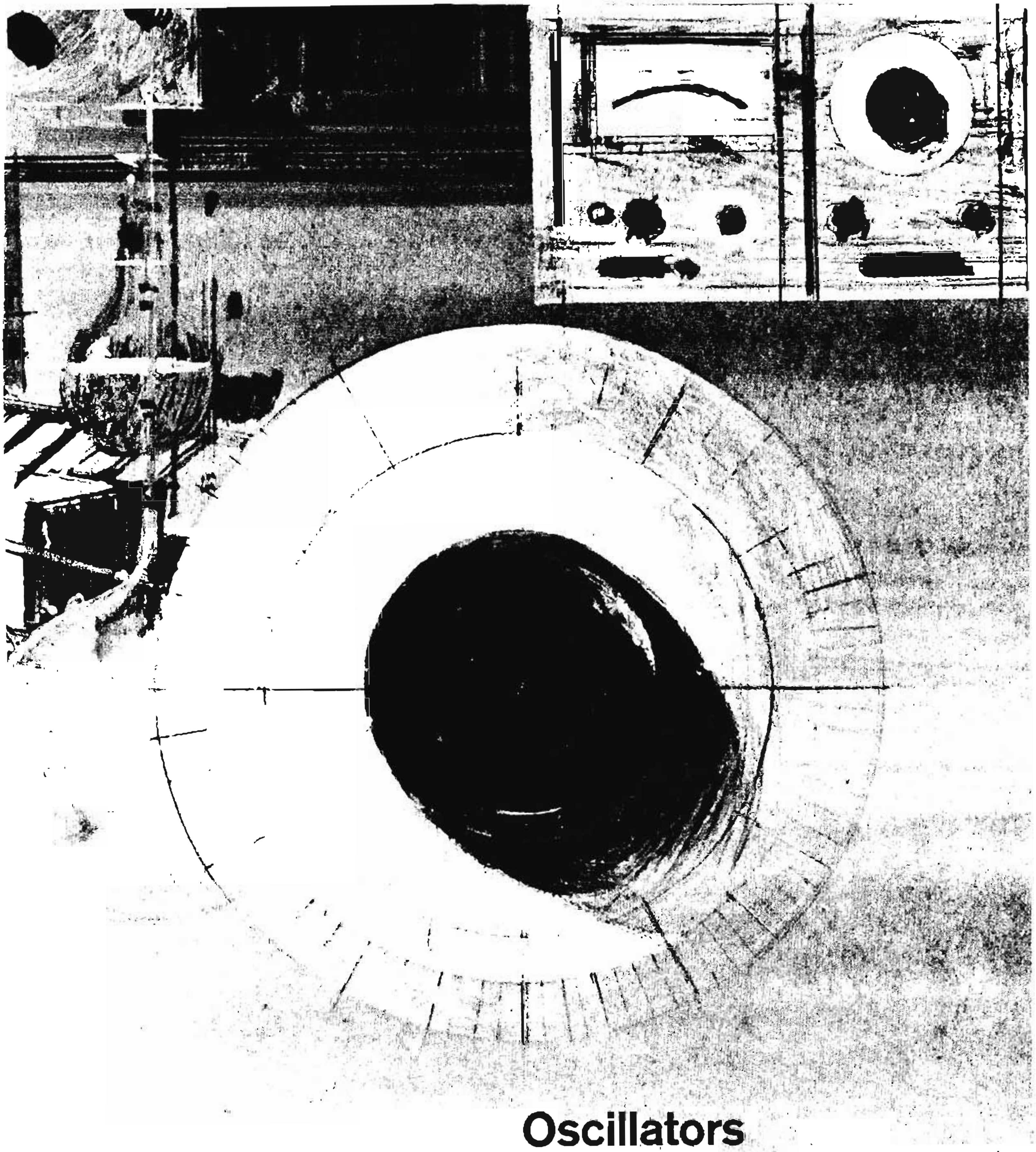
Hewlett-Packard 885A Phase Shifters provide accurate, controllable phase variation in the J-, X- and P-band frequency ranges. They are particularly useful in microwave bridge circuits, where phase and amplitude must be adjusted independently. They also are used in the study of phased arrays.

The instruments 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

hp Model	Frequency range (gc)	Accuracy	Maximum insertion loss	Power (rating watts)	Price
J885A	5.30–8.20	3°	2 db	10	$550
X885A	8.20–12.4	2°, 8.2–10 gc 3°, 10–12.4 gc	1 db, 8.2–10 gc 2 db, 10–12.4 gc	10	$425
P885A	12.4–18.0	4°	3 db	5	$600

All Models: maximum swr, 1.35; for small phase differences, accuracy is as tabulated or 10%, whichever is less.



Oscillators

OSCILLATORS AND AUDIO SIGNAL GENERATORS

Oscillators *generate sine-wave signals* of known frequency and amplitude for test and performance measurements on electronic circuits. These tests include gain, frequency response, attenuation, impedance and distortion. Signal generators fundamentally are oscillators, too, but they are distinguished from oscillators by having wide-range, precision output attenuators and output meters for accurately measuring the voltage supplied to the load.

General-purpose oscillators generate a broad range of frequencies at a variety of power levels for many different load impedances. Table 1 illustrates the frequency range and power output of Hewlett-Packard oscillators. The hp 200CD, for instance, covers a frequency range from 5 cps to 600 kc for a variety of test purposes.

Basic oscillator requirements

In selecting a test oscillator or signal *generator, the user will be most inter*ested in its frequency coverage. The question to be answered here is: will the instrument supply both the lowest and highest frequencies of interest in anticipated tests? As shown on the chart, Hewlett-Packard manufactures a broad range of oscillators and audio frequency generators covering the frequency spectrum from 0.00005 cps to 10 mc.

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 an hp oscillator capable of delivering several volts' output into a high-impedance load or supplying several watts of power into lower-impedance loads.

Available output power also is related to the oscillator's output impedance. Most Hewlett-Packard oscillators have low internal impedances, which means that they are capable of supplying power into a wide variety of loads. In most cases, transformer coupling is used for a low-impedance 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 a 600-ohm variable T-pad on the output side of the transformer. Some low-power oscillators, intended for tests requiring extremely low distortion and exceptionally flat frequency response, have RC output coupling.

Besides frequency range and power output, the user will be interested in the *oscillator's stability, its dial resolution* and the amount of distortion (hum and noise) in the output signal.

Dial resolution

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 precision 6 inch dials calibrated over 300 degrees with 15 or more inches of calibration marks for each range of the instrument. Most dial accuracies of Hewlett-Packard oscillators are within $\pm 2\%$. One instrument, the 200J Interpolation Oscillator, has band switching on a 3.3-to-1, rather than a 10-to-1, basis to spread the tuning scale 3 times farther for more precise settings.

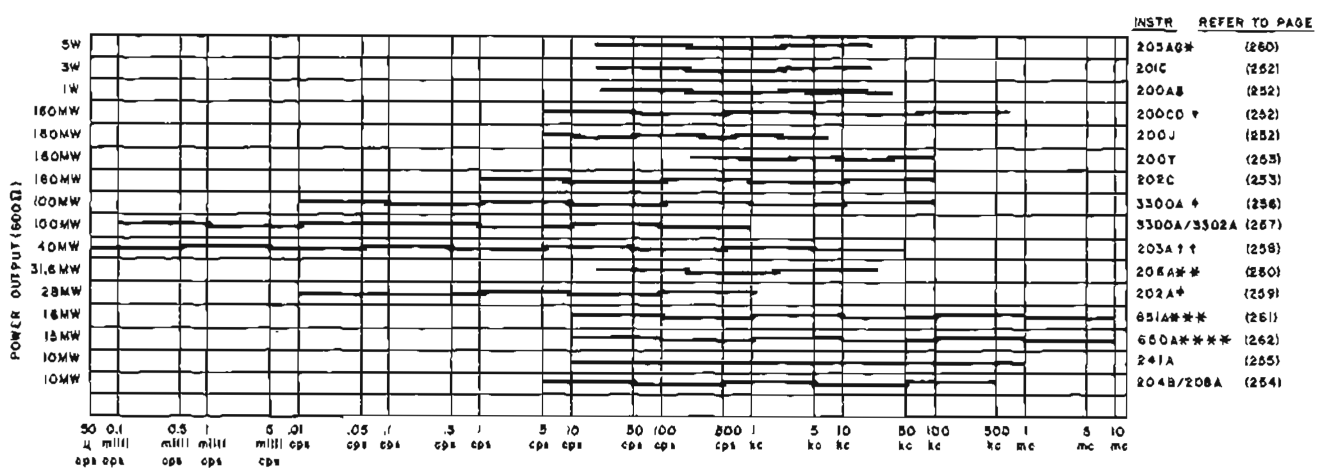
The accuracy with which the frequency tracks the tuning dial also enters into the overall accuracy figure.

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 hp-designed RC oscillator circuits, described later, assure stability by using large amounts of negative feedback. Carefully chosen components, such as Hewlett-Packard precision resistors and variable capacitors in the frequency-determining networks, contribute to long-term stability. *Oscillator stability is included in the* overall 2% accuracy figure.

Amplitude stability

Amplitude stability is important in certain oscillator applications, such as



* 3 WATTS MAX. INTO 50, 200, 600 AND 6KΩ

** 15dbm INTO 50, 150 AND 600Ω

*** ALSO 200MW INTO 50Ω (OTHER Z ABOVE 50Ω AVAILABLE ON SPECIAL ORDER)

**** 300 OR 6Ω WHEN USING HP11047A

† HP 200SR SPECIAL VERSION OF 200CD OUTPUT: 5VRMS INTO 50Ω

†† FOUR OUTPUTS: REFERENCE AND VARIABLE SINE WAVE, REFERENCE AND VARIABLE SQUARE WAVE TWO SINE AND SQUARE WAVES OUTPUT IDENTICAL EXCEPT ONE SINE AND SQUARE WAVE CONTAINS A 0 TO 360° PHASE-SHIFTER

♦ SINE, SQUARE, TRIANGULAR OUTPUTS

Table 1. Frequency range and power output of hp oscillators. Line segments show span of each range.

the driving source in bridge measurements or in magnetic amplifier circuits. Amplitude stability is inherent in the hp RC oscillator circuit because of the large negative feedback factor and the amplitude stabilizing technique. Amplitude stability of the hp 651A Test Oscillator is typically ±0.01% per day.

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. Frequency response of Hewlett-Packard oscillators varies less than 1 db throughout the mid-frequency range, though this may increase slightly at the extreme ends of the oscillator's range. Frequency stability at fixed frequencies of hp oscillators (204B, 208A and 651A) is typically ±0.02% per day.

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. Besides, 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 inherently a low-distortion sine-wave generator; all Hewlett-Packard Wien bridge oscillators have less than 1% distortion, typically 0.25%. Oscillator-amplifier operating levels are set so that the second harmonic, introduced by small non-linearities in the transfer characteristic of one stage, is cancelled by the following stage (second harmonic distortion of a sine wave in an amplifier usually results in flattening of one peak and stretching of the other). 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.

Hum and noise

Hum and noise are introduced at a variety of points in oscillator circuits; but when the circuit operates at a relatively high level, generally 20 to 25 volts in Hewlett-Packard RC oscillators, the amount of hum and noise introduced into the oscillator circuits is usually negligible. However, hum and noise, introduced by a power amplifier following the amplitude control, remain constant as the output signal amplitude is diminished. Hence, even though the hum and noise power is quite small compared to rated output, these spurious signals may 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 proportionately with the signal when low-level signals are desired for test purposes.

Theory of operation

The Hewlett-Packard-pioneered Wien bridge RC oscillator has become the standard oscillator circuit for variable 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 oscillator circuit, shown in Figure 1, is a two-stage amplifier with both negative and positive feedback loops. Positive feedback for sustaining

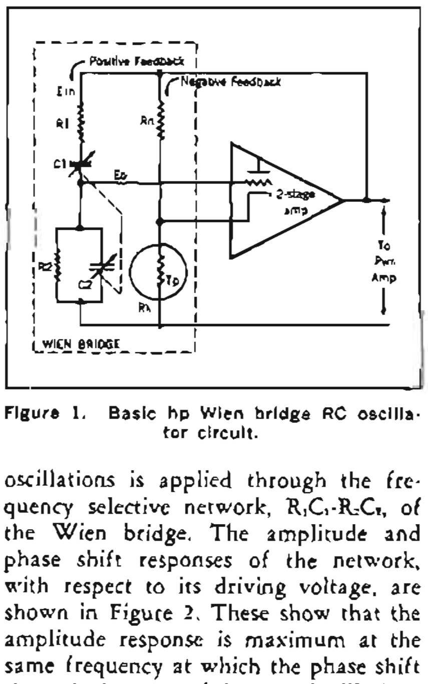


Figure 1. Basic hp Wien bridge RC oscillator circuit.

oscillations is applied through the frequency selective network, R_1C_1-R_2C_2, of the Wien bridge. The amplitude and phase shift responses of the network, with respect to its driving voltage, are shown in Figure 2. These show that 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: $f_0 = \frac{1}{2\pi RC}$, when $R_1 = R_2$ and $C_1 = C_2$.

Unlike LC circuits, where the frequency varies inversely as the square root of C, the frequency of the Wien bridge oscillator varies inversely as C. Thus, 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

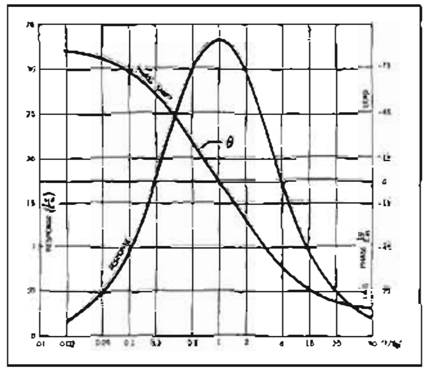


Figure 2. Characteristics of frequency-determining network.

the other pair of bridge arms, R_n and R_k. R_k is 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. In crystal and LC oscillators, amplifier saturation usually causes limiting, so that any further increase in the oscillator-amplifier input results in no further increase in the output signal. Amplifier waveforms in these circuits are highly distorted, and the output signal is usually taken from the resonant circuit to minimize output distortion. The hp Wien bridge RC oscillator, however, depends on the temperature-sensitive resistor for amplitude control. This means that the amplifier may be operated entirely within the linear portion of its transfer characteristic, resulting in purer sine-wave output.

The Wien bridge RC oscillator is capable of stable oscillations with low distortion output. 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 just such an arrangement.

A different type of amplitude stabilization is used in the solid-state hp 204B and 208A Oscillators because the current drawn by a lamp would be incompatible with long-term battery operation. These instruments use a voltage comparison system which continuously compares the output voltage to a reference fixed by a zener diode and adjusts the amount of negative feedback accordingly.

Pushbutton tuning

Pushbutton oscillator tuning is possible with a modified Wien bridge as shown in Figure 3. Here, the resistive

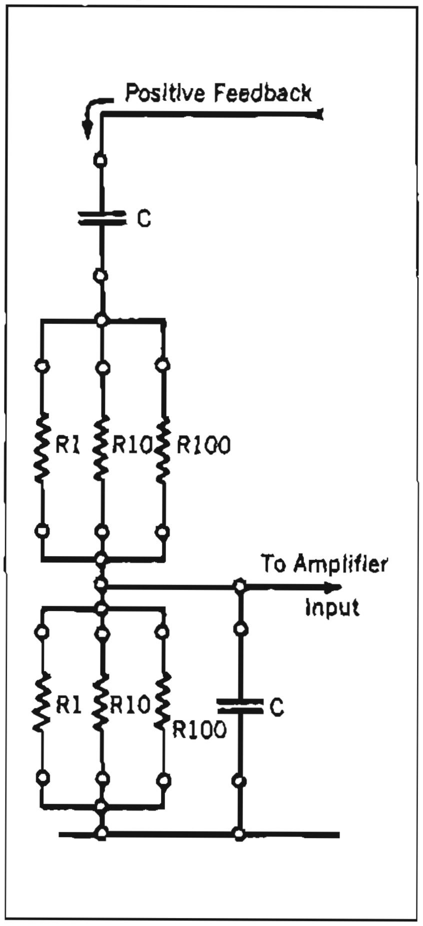


Figure 3. Frequency-selective network for pushbutton oscillator.

branches of the frequency-selective network are made up of parallel combinations of resistors. Through algebraic reduction substitution of the parallel combination of R_1, R_{10} and R_{100} for R in the basic frequency determining equation,

$$f = \frac{1}{2\pi RC},$$ results in:

$$f = \frac{1}{2\pi R_1 C} + \frac{1}{2\pi R_{10} C} + \frac{1}{2\pi R_{100} C}$$

or, $f_{total} = f_{units} + f_{tens} + f_{hundreds}$

Thus, frequency increments chosen by any pair of resistors are not affected by settings of the other two pairs.

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 cps to 1 mc 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.

Push-pull RC oscillator

A more refined circuit, the push-pull Wien bridge RC oscillator, is shown in Figure 4. Although increasing the cost and complexity of the instrument, this circuit provides several advantages over the basic single-ended oscillator circuit. For one, the circuit is operating in a push-pull mode, which means that push-pull output may be obtained directly from the oscillator-cathode followers without use of a transformer.

The circuit has zero output impedance because of positive feedback added from each output tube plate 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_0 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.

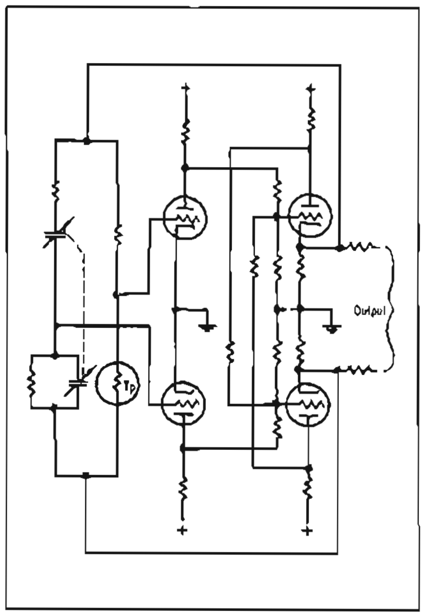


Figure 4. Push-pull RC oscillator.

In the push-pull 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. This improved circuit is used in the 200CD Wide-Range Oscillator, the 202C Low-Frequency Oscillator, and 200J Low-Distortion Interpolation Oscillator.

Low-distortion signal generator

Distortion can be reduced further by a tuned filter following the oscillator circuit. The 206A Audio Signal Generator has a selective amplifier between the oscillator and power output circuit. This amplifier has a negative feedback loop which includes an RC rejection filter. The capacitors of the rejection filter are ganged on the same shaft with the oscillator capacitors, so that the rejection filter and oscillator are always tuned to the same frequency.

The oscillator's fundamental frequency does not pass through the amplifier's negative feedback loop because of the rejection filter; therefore, amplifier gain at this one frequency is not reduced by negative feedback. All other frequencies do pass through the negative feedback loop; as a result, amplifier gain is reduced at all harmonic frequencies. A 10 db improvement in the ratio of the fundamental to its harmonics is obtained with this arrangement.

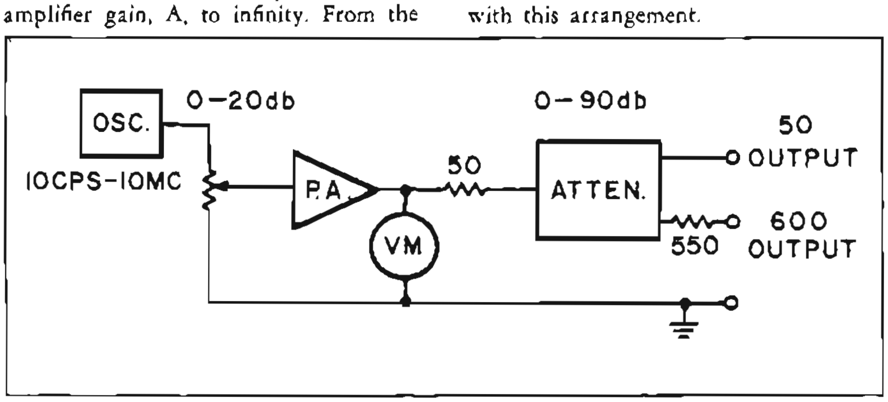


Figure 5. High-frequency oscillator.

High-frequency oscillator

The high-frequency limits of the RC oscillator usually are imposed by the amplitude and phase characteristics of the oscillator-amplifier, which calls for compensating RC networks if oscillations are to be sustained. An amplifier phase shift of just a fraction of a degree causes 1% error in calibration. The hp Model 651A Test Oscillator, described on page 261, overcomes the difficulty of phase shift at high frequencies. A modified Wien bridge oscillator is used on all the ranges of the hp 651A, instead of phase shift oscillators which are commonly used above 100 kc. The Wien bridge in the hp 651A differs from the conventional Wien bridge circuit in the design of the resistive voltage divider network. Oscillation at the selected frequency is made possible by the use of both regenerative and degenerative feedback. An impedance converter provides a high impedance in series with the input impedance of a differential amplifier on the first four frequency ranges (X10 to X10 K). The high impedance added prevents the RC bridge circuit from being loaded by the low input impedance of the differential amplifier on lower frequency ranges. The impedance converter is bypassed on the X100 K and X1 M range due to lower resistance values in the RC bridge. A complementary symmetry circuit is used to provide power gain and to increase the dynamic voltage range of the oscillator. The basic circuit of the hp solid-state 10 cps to 10 mc oscillator is shown in Figure 5.

Low-frequency oscillator

Low-frequency limit of an RC oscillator circuit is usually set by the thermal characteristics of the temperature-sensitive resistance. At very low frequencies, the incandescent lamp has time to heat and cool during each cycle. This change of resistance during each cycle introduces serious amounts of distortion in the output.

For very low frequencies, an entirely different approach is used in the 3300A Function Generator. (This instrument is called a function generator because it delivers sine, triangular and square waves.) The circuit of this instrument, outlined in Figure 6, uses a dc-coupled flip-flop circuit to generate a square wave. The output of the flip-flop is passed through the upper current source to a Miller integrator, whose triangular wave output is coupled back to the voltage comparitor.

Circuit operation of the 3300A is as follows: The integrator converts the flip-flop step voltage to a ramp. When the ramp reaches a preset amplitude level, it triggers the flip-flop into its other stable state. The ramp then reverses slope and continues until the other trigger level is reached. Adjustment of the current driving the integrator controls the ramp slope, which, in turn, controls the multivibrator frequency.

The circuit produces low-frequency square and triangular waves. The triangular wave is synthesized into a sine

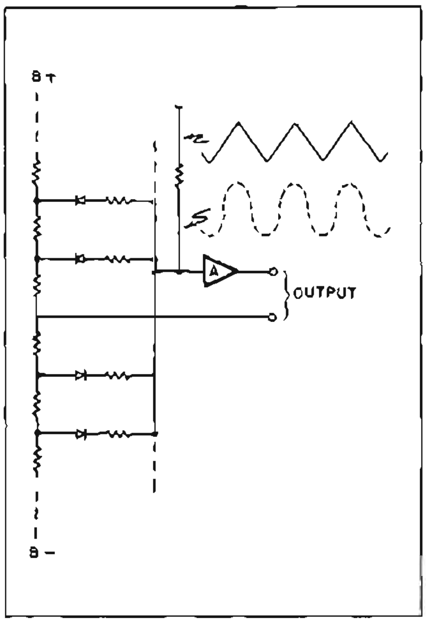


Figure 7. Non-linear shaping network.

wave by a diode-resistance network. The synthesizing circuitry of Figure 7 shows how the slope of the triangular wave is altered as its amplitude changes, resulting in a remarkably pure sine wave. In practice, twelve diodes are used for shaping.

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 (see page 256) is two output amplifiers that provide simultaneous outputs of any of the three waveform functions—sine, triangular or square.

Another hp low-frequency oscillator is the Model 203A Variable-Phase Function Generator (this instrument is called a variable-phase function generator because it offers a referenced 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 contain a 0-to-360-degree phase shifter). The circuit of this instrument is a beat-frequency oscillator which, by mixing two high-frequency signals, generates signals in the frequency range of 0.00005 cps to 60 kc. One of the high-frequency signals is a fixed frequency; the other is variable. The fixed-frequency signal is generated by a crystal oscillator which is applied to both channels and routed to a modulator through an RF amplifier within each channel. The variable-frequency signal is applied directly to the modulator of each channel. These two signals are mixed in the modulator, and the difference in frequency between the two signals is the output frequency of the hp Model 203A (see page 258).

The RC Oscillator circuits described here are used in Hewlett-Packard's broad line of oscillators and audio signal generators. These span a frequency range of 0.00005 cps to 10 mc, covering the subsonic, audio, ultrasonic, video and low rf ranges. All of the hp oscillators and audio signal generators 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 an hp oscillator and signal generator are available to meet your application. If special needs arise, modification of standard hp instruments to meet a specific application may be practical. Contact your local hp sales office for additional information.

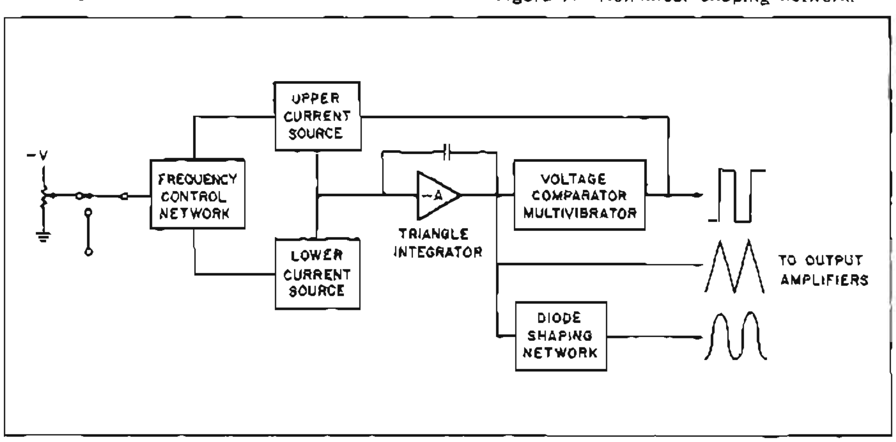


Figure 6. Low-frequency oscillator.

200 SERIES AUDIO OSCILLATORS

Exceptional value, highest quality

Advantages:

- No zero setting, high stability
- Constant output
- Wide frequency range
- Logarithmic scale
- Low distortion
- Compact, lightweight
- 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 cps to 40 kc

This basic oscillator is a compact, convenient source of precision audio test voltages, which is offered at an extremely low price. Frequency coverage is 20 cps to 40 kc in four overlapping bands. The 63" effective scale length and 72 dial divisions insure accurate, direct frequency setting. Output is balanced for dependable driving of transmission systems. The 200AB is ideal for amplifier testing, as a bridge voltage source, for testing transmitter modulator response, modulating signal generators and making loudspeaker resonance tests. hp 200AB, $165 (cabinet); hp 200ABR, $170 (rack mount).

200CD Wide-Range Oscillator, multi-purpose, 5 cps to 600 kc

One of the most popular of all hp oscillators, Model 200CD covers the range 5 cps to 600 kc and 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. hp 200CD, $195 (cabinet); hp 200CDR, $200 (rack mount).

200J Interpolation Oscillator, maximum band spread, 6 cps to 6 kc

This ultra-precision instrument is engineered for interpolation and frequency measurements where frequencies must be known with extreme accuracy. Covering the range 6 cps to 6 kc, Model 200J offers an output of 160 mw or 10 volts into 600 ohms, or 20 volts open circuit, balanced to ground. Distortion is less than 0.5%, and frequency stability is ±2% or 0.2 cps. The instrument has 6 spread scale frequency ranges, and an effective scale length of 80" for maximum resettability. Calibration accuracy is ±1%, and frequency response is ±1 db full range. Hum voltage is less than 0.1% of output. hp 200J, $350 (cabinet); hp 200JR, $355 (rack mount).

200T Telemetry Oscillator, high stability, resolution; 250 cps to 100 kc

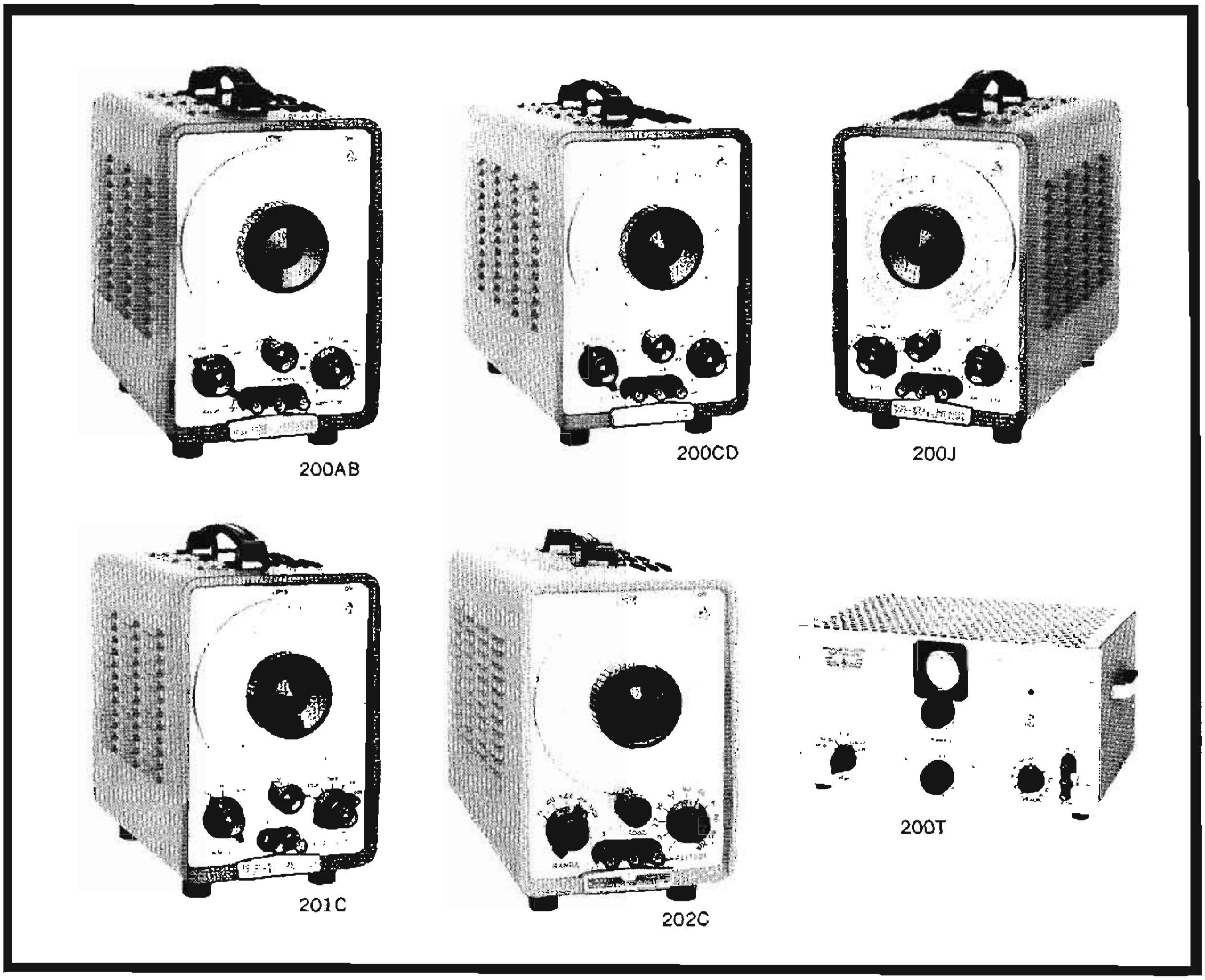
Model 200T provides the highest possible frequency stability in a wide-range, convenient commercial audio oscillator. It is particularly useful for precise, high-resolution frequency-checking applications such as the evaluating of telemetering circuit, determination of carrier current equipment operation and measurement of characteristics of sharply tuned filters. Model 200T covers frequencies 250 cps to 100 kc in 5 ranges, with good overlap between bands; output is 160 mw or 10 volts into 600 ohms, or 20 volts open circuit. Calibration accuracy ±1% long term, frequency response ±1 db full range. High stability, distortion less than 0.5% full range. Hum and noise less than 0.03% of rated output. The instrument is compact, versatile, simple to operate. It covers IRIG (RDB) channels 1 through 18, and no channel is split by band switching. hp 200T, $500 (cabinet); hp 200TR, $505 (rack mount).

201C Audio Oscillator, high power, 20 cps to 20 kc

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 cps to 20 kc, 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 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 cps is less than 0.5%. hp 201C, $250 (cabinet); hp 201CR, $255 (rack mount).

202C Low-Frequency Oscillator, excellent waveform 1 cps to 100 kc

Model 202C brings to the low-frequency spectrum the accuracy and stability you associate with audio measurements. It provides excellent waveform throughout its broad frequency range of 1 cps to 100 kc and has unique usefulness in industrial, field or laboratory work. Model 202C is extremely convenient for vibration, stability, electro-cardiograph, electro-encephalograph and other measurements in the subsonic, audio and ultrasonic fields. Distortion is less than 0.5%; hum voltage is less than 0.1%, and recovery time is extremely short—5 seconds at 1 cps. hp 202C, $325 (cabinet); hp 202CR, $330 (rack mount).



200AB 200CD 200J 201C 202C 200T

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 cps to 40 kc (4 bands)	±2%	1 w (24.5 v)	75 ohms	1% 20 cps to 20 kc 2% 20 kc to 40 kc	0.05%	70	15 (5,3)	20 (9)	7½ x 11½ x 12 (191 x 292 x 305)	$165
200CD	5 cps to 600 kc (5 bands)	±2%	160 mw (10 v)	600 ohms	0.5% below 500 kc 1% 500 kc and above	0.1%	75	22 (9,9)	27 (12,2)	7⅜ x 11½ x 14⅜ (187 x 292 x 365)	$195
200J	6 cps to 6 kc (6 bands)	±1%	160 mw (10 v)	600 ohms	0.5%	0.1%	110	22 (9,9)	27 (12,2)	7⅜ x 11½ x 14⅜ (187 x 292 x 365)	$350
200T	250 cps to 100 kc (5 bands)	±1%	160 mw (10 v)	600 ohms	0.5%	0.03%	160	27 (12,2)	36 (16,2)	18¾ x 9-3/16 x 11¾ (476 x 233 x 299)	$500
201C	20 cps to 20 kc (3 bands)	±1%†	3 w (42.5 v)	600* ohms	0.5%‡	0.03%	75	16 (7,2)	23 (10,4)	7½ x 11½ x 12½ (191 x 292 x 318)	$250
202C	1 cps to 100 kc (5 bands)	±2%	160 mw (10 v)	600 ohms	0.5%§	0.1%	75	27 (12,2)	34 (15,3)	7½ x 11½ x 14½ (191 x 292 x 368)	$325

*Internal impedance approx. 600 ohms with output attenuator at 10 db or more, approx. 75 ohms below 5000 cps with attenuator at zero. †Internal non-operating controls permit precise calibration of each band. ‡0.5% cps, 50 cps to 20 kc at watt output; 1% over full range at 3 watts output. §Above 5 cps. ¶Measured with respect to full rated output.

General:

Frequency response: flat ±1 db over instrument range; reference level at 1 kc.

Size and weight: maximum overall size and weights are given for cabinet models; 19" rack models also available.

Power: 115 or 230 volts ±10% at 50 to 1000 cps.

Accessories available: 11000A Cable Assembly, $4.50; 11001A Cable Assembly, $5.50; 11004A, 11005A Line Matching Transformers, see pages 263, 264.

204B PORTABLE OSCILLATOR, 208A TEST OSCILLATORS

Solid-state, battery-operated, 5 cps to 560 kc, floating output

Fully solid-state and battery-operated hp 204B and 208A Oscillators are extremely useful for both field and laboratory work. Internal heat production is small, resulting in unusually low warm-up drift. Stable, accurate signals are instantly available over a frequency range from 5 cps to 560 kc.

Balanced and unbalanced loads, plus loads referenced either above or below ground, can be driven by these versatile oscillators; their output is fully floating and isolated from power line ground when battery operated. Completely balanced output is easily obtained with a simple external matching network. There is excellent frequency stability, even with rapidly changing loads; low-impedance circuits drive the 600-ohm output, effectively isolating the oscillator stage.

Figures 1 and 2 show the excellent frequency and amplitude stability characteristics of these oscillators. Typical frequency stability is better than 5 parts in 10^4, even at the least stable frequency (560 kc). Output amplitude stability is held extremely constant by

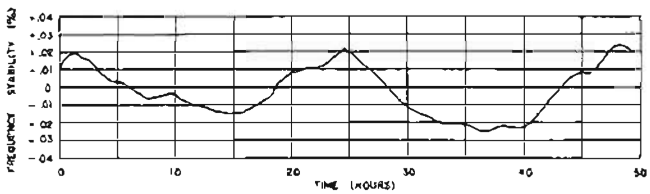


Figure 1. Typical frequency stability characteristics at 500 kc.

a thermally self-compensating peak detector control circuit, which is virtually insensitive to mechanical shock or temperature changes. Flat frequency response provides further convenience of operation. At all dial and range switch settings the output is flat within ±3%.

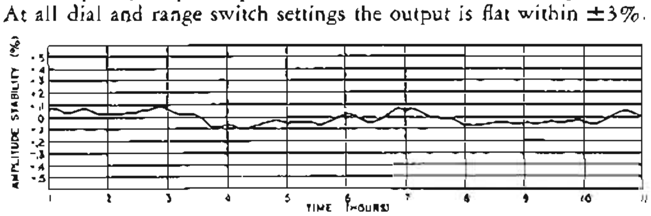


Figure 2. Typical amplitude stability

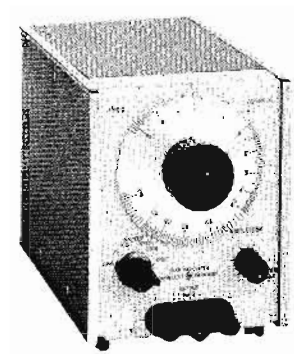
The solid-state design, light weight, modular construction, and battery operation of these oscillators contribute to their portability. Rapid attenuation selection and monitored oscillator levels ideally suit the 208A Oscillator to transmission line work, production line tests and similar situations, where output levels must be known.

Model 208A is calibrated in volts and has a 6-position attenuator (Meter Scale Value switch) with 10:1 steps from 0.01 mv to 1 v. Another attenuator (Multiplier switch) changes the output by a factor of 2.5, increasing maximum output to 2.5 v rms. The 208A (Option 01.) is calibrated in dbm and has a 110 db attenuator adjustable in 1 db steps.

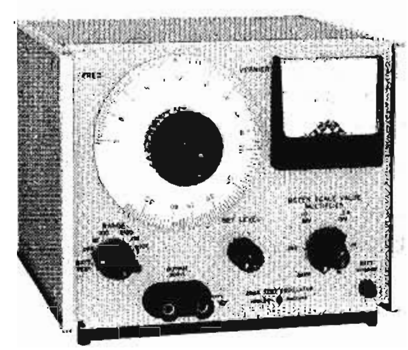
Specifications, 204B

Frequency range: 5 cps to 560 kc, in 5 ranges; 5% overlap between ranges, vernier control.
Dial accuracy: ±3%.
Frequency response: ±3%, with rated load.
Output impedance: 600 ohms.
Output: 10 mw (2.5 v rms) into 600 ohms; 5 v rms open circuit; completely floating.
Output control: continuously variable bridged "T" attenuator with at least 40 db range.
Distortion: less than 1%.
Noise: less than 0.05% at maximum output.
Power: 4 batteries at 6.75 v each, 7 ma drain, life at least 300 hours.
Dimensions: 6-3/32" high, 5⅛" wide, 8" deep (155 x 130 x 203 mm).
Weight: net 7 lbs (3 kg); shipping 11 lbs (5 kg).
Price: hp 204B (with mercury batteries), $315.
Options

01. AC power supply installed in lieu of batteries, add $35.
02. Up to 40 hours' operation per recharge with furnished rechargeable batteries (self-contained recharging circuit functions automatically when instrument is connected to ac line; 115 or 230 v ±10%, 50 to 1000 cps, approx. 3 w); oscillator may be used during recharge from ac line; expected battery life 20,000 hours, add $75.



204B



208A

Specifications, 208A

(Same as 204B, except:)

Output attenuator: meter scale value, 0.01 mv to 1 v full scale in 6 steps; X2.5 multiplier, concentric with Meter Scale Value switch, to obtain 0.025 mv to 2.5 v.
Output attenuator accuracy: 5 cps to 100 kc; error is less than ±3% at any step; from 100 kc to 560 kc, error is less than 5% at any step; specifications include multiplier accuracy.
Output monitor: solid-state 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.
Operating temperature range: 0°C to +50°C.
Power: up to 30 hours' operation per recharge with furnished rechargeable batteries (self-contained recharging circuit functions automatically when instrument is connected to ac line; 115 or 230 v ±10%, 50 to 1000 cps, approx. 3 w); oscillator may be used during recharge from ac line; expected battery life, 20,000 hours.
Dimensions: with feet 6½" high, 7-25/32" wide, 8" deep (165 x 198 x 203 mm).
Weight: net 8¼ lbs (3.5 kg); shipping, approximately 10 lbs (4.5 kg).
Price: hp 208A, $525.

Specifications, 208A (Option 01.)

(Same as 208A, except:)

Output attenuator: 0 to 110 db in 1 db steps.
Accuracy, 10 db section: from 5 cps to 100 kc, error is less than ±0.125 db at any step; from 100 kc to 560 kc, error is less than ±0.25 db at any step.
Accuracy, 100 db section: from 5 cps to 100 kc, error is less than ±0.25 db at any step; from 100 kc to 560 kc, error is less than ±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.), $535.

241A PUSHBUTTON OSCILLATOR

Three-digit frequency resolution, 10 cps to 1 mc

Advantages:

- Three-digit frequency resolution
- Simple, rapid, accurate frequency selection
- Compact, lightweight, portable
- Flat frequency response, 10 cps to 1 mc
- Accurate repeatability

Uses:

- Production line and repetitive testing
- Standard source for calibrating ac-to-dc converters
- Response testing at audio and communication frequencies; narrow- or wideband devices
- Low distortion source in the presence of shock, vibration or hf radiation.

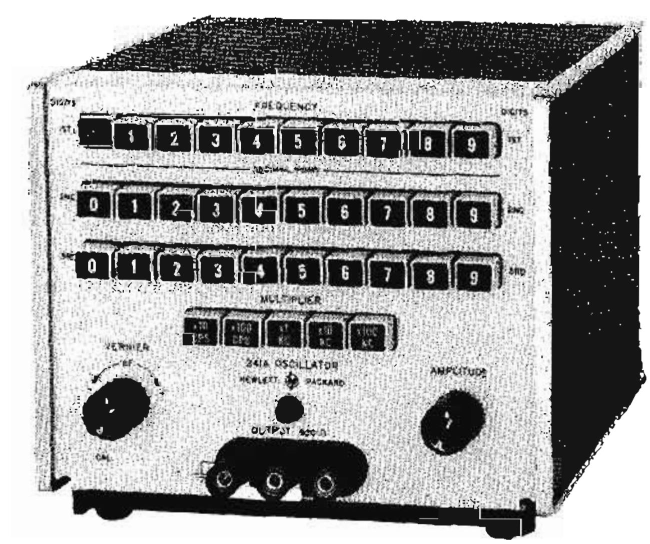
Pushbutton convenience and repeatability for selecting frequencies from 10 cps to 999 kc make the hp 241A Oscillator ideal for supplying stable test signals for laboratory or production work. Simple depression of three frequency buttons and one of five decade multipliers selects any of 4500 discrete frequencies. Accuracy is ±1%, and repeatability is typically better than 0.02%.

Three-digit frequency resolution is provided, with interpolation possible with a vernier control that extends the upper frequency to 1 mc. 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. Frequency response is flat ±2% over the entire range at any attenuator setting. Hum and noise are reduced below 0.05% of the output.

Adaptations available

Several adaptions for communications work are featured in the hp Models H30- and H48-241A. The output circuit includes a combined L and T pad which has two outputs to match either 600- or 900-ohm loads and to provide equal power to each. Both outputs are balanced to ground. Output power may be adjusted over a 40 db range (+10 to −30 dbm) in 1 db steps with an accuracy of 0.1 db. Frequency range is 100 cps to 10 kc, 2 ranges, 1800 frequency increments with vernier overlap. Frequency accuracy is ±0.2%, and frequency response is within 0.2 db over the entire range.

These special 241A oscillators are arranged to operate from the standard 48 volt (H48-241A) or 30 volt (H30-241A) (positive ground) telephone equipment battery supply. Contact your local hp sales office for additional information.



Specifications

Frequency range: 10 cps to 1 mc, 5 ranges, 4500 frequency increments per range, with vernier overlap.

Calibration accuracy: ±1%.

Frequency response: ±2% into rated load.

Output impedance: 600 ohms.

Distortion: 1% maximum.

Hum and noise: 0.05% of output.

Output: +10 to −30 dbm into 600 ohms (2.5 volts maximum).

Power: 115 or 230 volts, 50 to 1000 cps, 1 watt.

Dimensions: 6-18/32" high, 7-25/32" wide, 8⅛" deep (167 x 197 x 206 mm).

Weight: net 8 lbs (3,6 kg); shipping 13 lbs (5,85 kg).

Price: hp 241A, $490.

3300A FUNCTION GENERATOR, 3301A AUXILIARY PLUG-IN, 3302A TRIGGER/PHASE LOCK PLUG-IN, 3303A DIVIDER PLUG-IN

Plug-ins, multiple outputs achieve maximum versatility

Maximum versatility and usefulness with 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, covering all frequencies from 0.01 cps to 100 kc, continuously variable in seven decade ranges. This solid-state, multi-purpose source provides simultaneous signals of any two waveforms, with constant amplitude over the entire frequency range.

Plug-ins, which insert directly into the front panel, include the hp 3301A Auxiliary Plug-in, hp 3302A Trigger Plug-in and hp 3303A Divider Plug-in. The 3302A provides single-and multiple-cycle operation with variable start/stop phase. A phase lock loop in the 3302A permits synchronizing the 3300A with an external signal and provides variable phase control. The 3303A divides the 3300A frequency by 100, offering waveform frequencies of 0.0001 cps to 1 kc. The 3300A Function Generator with plug-in versatility provides a compact, convenient multi-purpose source of test waveforms useful for testing servo, geophysical and medical equipment, and for the electrical simulation of mechanical phenomena.

Electronic frequency control

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. An input voltage of —0.5 to —10 volts will linearly control the frequency over any one range.

Output system

The output system of the 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. Separate connectors on the rear panel provide terminals for circuit ground, shield ground and power line ground. The operator may connect a dc supply to the rear terminals and obtain any dc offset voltage on the output up to ±250 volts with respect to power line ground.

The 3300A may be used to supply a balanced output, using both output amplifiers. Each output amplifier will deliver 35 volts p-p into an open circuit.

This instrument is rugged and is constructed with quality components. It is simple to operate, and it is adaptable to a wide variety of low-frequency field or laboratory work.

3301A Auxiliary Plug-in

The hp 3301A Auxiliary Plug-in provides internal connections for basic unit operation.

3302A Trigger/Phase Lock Plug-in

The 3302A is designed to provide 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.

Single-cycle operation

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. The output starts and stops at the same phase, which is adjustable from —90 degrees to +90 degrees with the front-panel start/stop phase control. The input trigger circuit is dc coupled and may be actuated with either polarity of applied voltage.

In the single-cycle mode, a variable phase output can be obtained by triggering with an external sine wave tuned to the same frequency as the 3300A, using the input phase switch and the start/stop phase control. This is particularly useful at frequencies below 10 cps where a phase lock system is not practical.

In addition, when an external trigger is applied, the instrument can be used as a low-frequency pulse generator using the square wave output. The pulse repetition rate is determined by the repetition rate of the applied trigger voltage; the pulse width is controlled by the 3300A frequency control, and the pulse delay is adjustable using the start/stop phase control. Pulses can also be obtained by using the manual trigger.

Multiple-cycle operation

In the multiple-cycle mode of operation, any number of complete cycles of any function can be obtained by pushing the manual trigger to start and stop or by applying an external gate voltage. The output signal will start and stop at the same phase, adjustable from —90 degrees to +90 degrees with the start/stop phase control. The 3302A is useful for generating waveform bursts or pulse trains for transient response and coding system measurements.

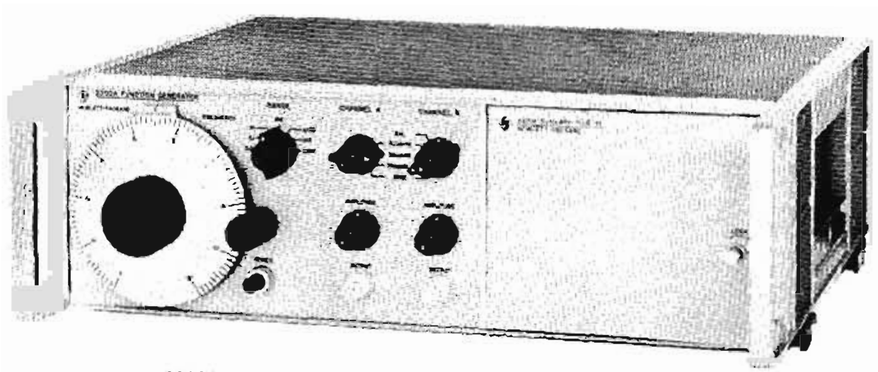
Phase-lock operation

The 3300A may be phase-locked to any periodic signal with a frequency from 10 cps to 100 kc. A meter, located on the plug-in front panel, indicates when phase lock is achieved. The phase shift between the input signal and the 3300A can be adjusted over a 360 degree range using the phase control and the input phase switch. This feature is particularly useful for generating a variable phase output at frequencies greater than 10 cps.

The instrument also may be phase-locked to a harmonic of an externally applied signal, making it useful for synthesis of complex waveforms. In addition, the 3300A may be phase-locked to an external source to obtain sine, triangle and square wave outputs with frequency characteristics of the externally applied signal.

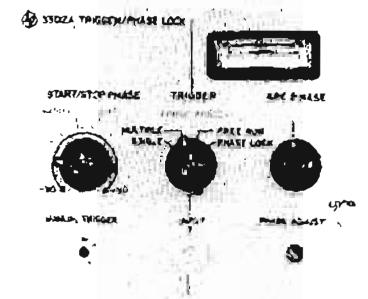
3303A Divider Plug-in

Available soon for use with the 3300A Function Generator, the hp 3300A/3303A combination is suited for very



3300A Function Generator with 3301A Auxiliary Plug-in

AVAILABLE
LATE 1965



3302A Trigger/Phase Lock Plug-in

low-frequency applications. This divider unit is used to divide the main-frame frequency of the 3300A by 100, offering accurate quadrature signals at frequencies from 0.0001 cps to 1 kc. Triangle, sine or square waves at 1/100 of the 3300A frequency are available at Channel A and Channel B. In addition, all of the Channel A waveforms may be shifted 90° in phase with respect to Channel B. Multiple combinations of waveforms are available from the divider plug-in such as sine-cosine, sine-sine, sine-triangle, sine-triangle shifted 90° and many others.

Tentative specifications, 3300A
(basic unit)

***Available plug-in units**
3301A Auxiliary Plug-in
3302A Trigger Plug-in
3303A Low-Frequency Plug-in

Output waveforms: sinusoidal, square and triangular selected by panel switch (any two outputs available simultaneously).

Frequency range: 0.01 cps to 100 kc in seven decade ranges.

Frequency response: ±1%, 0.01 cps to 10 kc; ±3%, 10 kc to 100 kc.

Dial accuracy: ±1% of maximum dial setting, 0.01 cps to 10 kc; ±2%, 10 kc to 100 kc.

Maximum output per channel: >35 volts peak to peak open circuit; 15 volts peak to peak into 600 ohms; 2 volts peak to peak into 50 ohms.

Output attenuator: continuously variable, >40 db range.

Output impedance: 600 ohms, nominal.

Sine wave distortion: <1%, 0.01 cps to 10 kc; <3%, 10 kc to 100 kc.

Square wave response: <250 nsec rise and fall time on all ranges; <1% sag, <5% overshoot.

Triangle linearity: <1%, 0.01 cps to 50 kc; <2%, 50 kc to 100 kc; <1% symmetry error.

Sync pulse output: >+10 volts peak, open circuit; <5 μsec duration; sync pulse occurs at crest of sine and triangular wave output.

DC stability: drift <±0.5% of peak-to-peak amplitude.

Remote frequency control: −0.5 to −10 volts will linearly change frequency over 1 decade within a single range; frequency linearity with respect to voltage ±1% of maximum frequency on range selected.

Power: 115 or 230 volts, ±10%, 50 to 1000 cps, approximately 50 watts.

Dimensions: standard full module; 5" high, 16" wide, 11" deep (127 x 406 x 279 mm).

Weight: net 20 lbs (9 kg); shipping 24 lbs (10.8 kg).

Price: on request.

*3300A requires a plug-in to operate

Specifications, 3302A

Modes of operation: single cycle, multiple cycle, phase lock, free run.

Trigger requirements

Single cycle: manual or external; dc coupled; requires at least 1 volt to trigger externally; may be triggered with positive or negative input voltage.

Multiple cycle: manual or external start/stop; dc coupled; requires at least 1 volt to start, 0 volts to stop; may be triggered with either positive or negative input voltage.

Phase lock: dc coupled; requires at least 1 volt peak to peak to lock, 10 volts peak to peak for specified accuracy with sine wave input.

Phase accuracy: ±10° from 100 cps to 100 kc; ±20° from 10 cps to 100 cps.

Price: on request.

203A VARIABLE-PHASE FUNCTION GENERATOR

Variable-phase sine- and square-wave test signals, 0.00005 cps to 60 kc

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 cps to 60 kc is covered in 7 overlapping bands (2 additional ranges available on special order, offering frequency range to 0.00005 cps). Accurate ±1% frequency setting is provided by 180 dial divisions. A vernier drive allows precise adjustment.

30 volt output

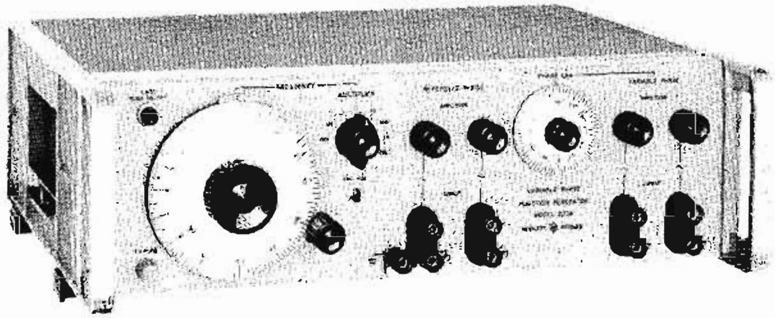
The 203A provides a maximum output voltage of 30 volts peak-to-peak for all waveforms. The sinusoidal signals have a distortion that is less than 0.06% and provide virtually transient-free outputs when frequency and operating conditions are varied rapidly. The four output circuits of the 203A have individual 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 with either 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.

NEW



Specifications

Frequency range: 0.005 cps to 60 kc in seven decade ranges.*

Dial accuracy: ±1% of reading.

Frequency stability: within ±1%, including warmup drift and line voltage variations of ±10% (typical short term 1 part in 10^4).

Output waveforms: 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.

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.

Maximum output voltage: at least 30 volts peak to peak open circuit for sinusoidal and square waveforms.

Output power: 5 volts into 600 ohms (40 mw); at least 40 db continuously variable attenuation on all outputs.

Distortion: total harmonic distortion hum and noise >64 db below fundamental (<0.06%).

Output system: direct-coupled output is isolated from ground and may be operated floating or with either side grounded (sine wave only).

Amplitude stability: (with respect to frequency) ±1% referenced to 1 kc.

Square wave response: rise and fall time, <200 nsec; flatness, flat to within ±0.5% from 10% to 90% of half period.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 25 watts.

Dimensions: cabinet: 5¼" high, 16¾" wide, 11¼" deep (133 x 425 x 286 mm); rack mount kit (203A-00203) furnished with instrument.

Weight: net 19 lbs (8,7 kg); shipping approximately 25 lbs (11,3 kg).

Price: hp 203A, $1200; Option 01., add $40; Option 02., add $80.

*Two lower ranges of 0.0005 (Option 01.) and 0.00005 cps (Option 02.) are available on special order.

202A LOW-FREQUENCY FUNCTION GENERATOR

Transient-free voltage, 0.008 cps to 1200 cps; sine-square-triangular waveforms

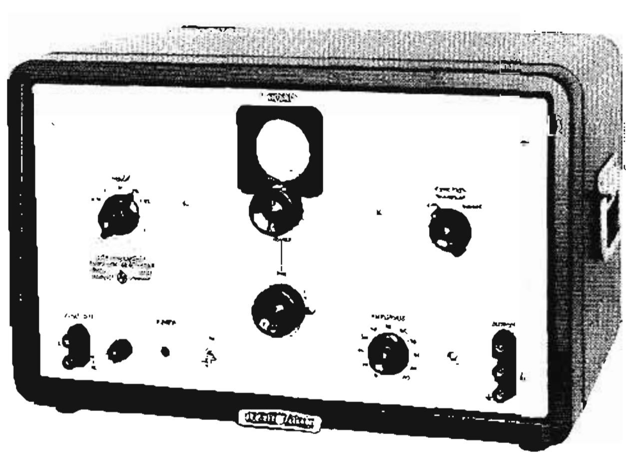
The hp 202A Low-Frequency Function Generator is a compact, convenient, multi-purpose source of transient-free test voltages. It is particularly useful for testing servo, geophysical and medical equipment and for the electrical simulation of mechanical phenomena.

Output frequency is continuously variable from 0.008 cps to 1200 cps in 5 bands. Model 202A offers exceptional stability and distortion of less than 1% over most of the band. Any of three desired waveforms — sine, square or triangular — may be selected by a front-panel switch. Output is high — 30 volts peak to peak — for all three waveforms and is essentially constant over the entire frequency range.

The hp 202A differs from conventional low-frequency oscillators in that the sine wave is electronically synthesized. A controlled bi-stable circuit generates a rectangular wave. This wave is passed through a special integrator, providing a true triangular wave.

The triangular wave then enters a shaping circuit designed exclusively for this equipment. In this circuit, 12 crystal diodes modify or "shape" the wave and provide a sine wave. This sine wave has a distortion of less than 1%, and the synthesizing circuit provides virtually transient-free output even when frequency and operating conditions are rapidly varied. It is not necessary to wait long periods for the circuits to stabilize, as is the case with conventional low-frequency oscillators. The circuit inherently maintains constant amplitude over the entire frequency range.

The output system of the 202A is fully floating with respect to ground and may be used to supply a balanced voltage or an output voltage with either output terminal grounded. The equipment will deliver 10 volts rms into a load of 4000 ohms or greater. Internal impedance is only 40 ohms. There are no coupling capacitors in the output system, and a high degree of dc balance is achieved.



Specifications

Frequency range: 0.008 to 1200 cps in five decade ranges.

Dial accuracy: 2% from 1.2 to 12; 3% from 0.8 to 1.2.

Frequency stability: within 1%, with line voltage variations of ±10%.

Output waveforms: sinusoidal, square and triangular.

Maximum output voltage: at least 30 volts peak to peak across rated load (4000 ohms) for all three waveforms (10.6 volts rms for sine wave).

Internal impedance: approx. 40 ohms over entire range.

Sine wave distortion: less than 1% on X0.01, X0.1, X1, and X10 ranges; less than 2% on X100 range.

Output system: output is isolated from ground and may be operated balanced or with either side grounded; output system is direct-coupled; dc level of output remains stable over long periods of time and can be adjusted to zero by a front-panel control.

Frequency response: constant within 0.2 db.

Hum level: less than 0.05% of maximum output.

Sync pulse: 10 volts peak negative, less than 5 μsec duration; sync pulse occurs at crest of sine and triangular wave output.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 150 watts.

Dimensions: cabinet: 20¾" wide, 12¾" high, 14⅝" deep (528 x 324 x 372 mm); rack mount: 19" wide, 10-15/32" high, 13" deep (483 x 266 x 330 mm).

Weight: net 42 lbs (18,9 kg), shipping 52 lbs (23,4 kg) (cabinet); net 37 lbs (16,6 kg), shipping 46 lbs (20,7 kg) (rack mount).

Accessories available: 11000A Cable Assembly, $4.50; 11001A Cable Assembly, $5.50.

Price: hp 202A, $550 (cabinet); hp 202AR, $535 (rack mount).

205AG, 206A AUDIO SIGNAL GENERATORS

Versatile instruments, 20 cps to 20 kc

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 cps to 20 kc in three decade ranges.

Calibration accuracy: ±2% under normal temperature conditions.

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 cps to 20 kc at output levels up to +30 dbm with output meter reading held constant at +37 db; ±1.5 db, 20 cps to 20 kc at output levels above +30 dbm with output meter reading held constant at +37 db (reference 1000 cps)

Internal impedances: approximately 1/6 of the 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 cps.

Hum level: more than 60 db below the output voltage or 90 db below 0 dbm, 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.

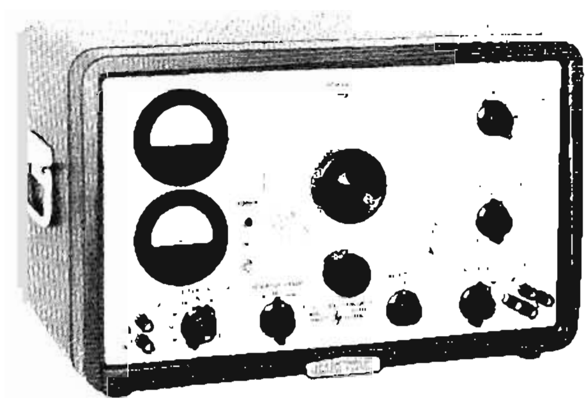
Output attenuator: 110 db in 1 db steps.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 150 watts.

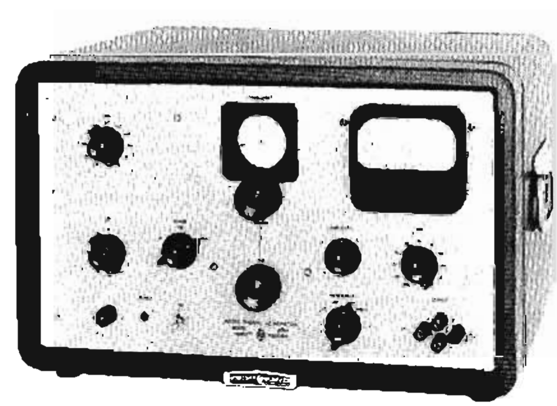
Dimensions: cabinet: 20¾" wide, 12¾" high, 15½" deep (527 x 324 x 394 mm); rack mount: 19" wide, 10½" high, 14" deep behind panel (483 x 267 x 356 mm).

Weight: net 56 lbs (25.2 kg), shipping 67 lbs (30,2 kg) (cabinet). net 49 lbs (22,1 kg), shipping 63 lbs (28,3 kg) (rack mount).

Price: hp 205AG, $600 (cabinet); hp 205AGR, $585 (rack mount)



205AG



206A

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.

Specifications, 206A

Frequency range: 20 cps to 20 kc in three decade ranges.

Calibration accuracy: ±2% including warm-up drift.

Output: +15 dbm into impedances of 50, 150 and 600 ohms; approximately 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 cps to 15 kc, when the output meter reading is held constant.

Distortion: less than 0.1% at frequencies above 50 cps and less than 0.25% from 20 cps to 50 cps.

Hum level: at least 75 db below the output signal or more than 100 db below zero level, whichever is larger.

Output meter: calibrated in dbm and also in volts; readability at least 0.2 db at all points above a 50% scale reading (0 dbm equals 1 mw in 600 ohms).

Output attenuators: 111 db in 0.1 db steps.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, 140 watts.

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 67 lbs (30,2 kg) (cabinet); net 50 lbs (22,5 kg), shipping 63 lbs (28,3 kg) (rack mount).

Price: hp 206A, $900 (cabinet); hp 206AR, $885 (rack mount).

651A TEST OSCILLATOR

Solid-state, 10 cps to 10 mc, 50- and 600-ohm oscillator

The solid-state hp Model 651A Test Oscillator provides accurate, stable test signals for laboratory or production measurements. This instrument covers a wide frequency range from 10 cps to 10 mc, continuously variable across six bands.

Two output impedances are available from the front panel, providing 200 mw into 50 ohms or 16 mw into 600 ohms. This capacitance-tuned oscillator delivers a flat output throughout the entire frequency range. Once warmed up, and in a normal lab environment, where ambient temperature does not change more than 3 or 4°C over 24 hours, frequency stability at 5 mc is typically ±10 ppm.

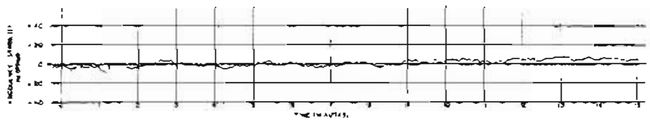


Figure 1. Typical frequency stability characteristics at 5 mc for 15 minutes.

An indication of the overall frequency stability under the above conditions is shown in Figure 1, which illustrates the behavior over a 15-minute period. The typical frequency stability for a 24-hour period at 5 mc is ±0.02%. The frequency stability at lower frequencies is typically better than those shown in the top frequency band.

Typical amplitude stability over a 17-hour period is ±0.1%, as shown in Figure 2.

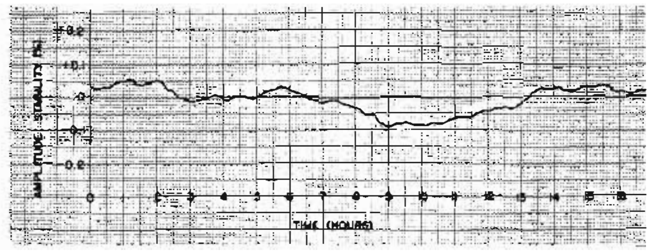
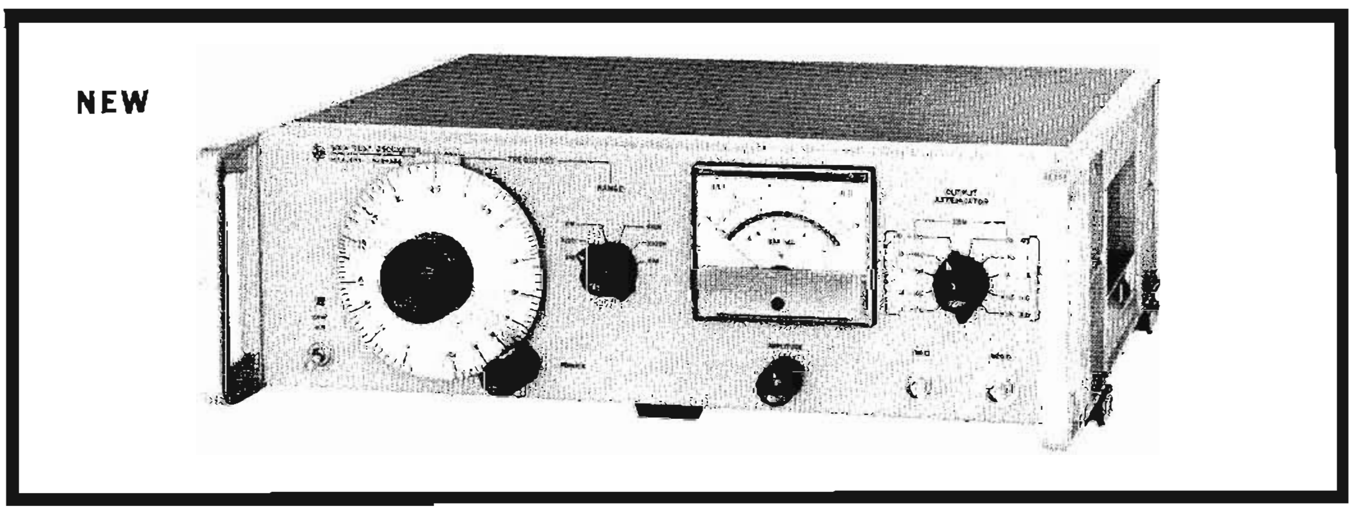


Figure 2. Typical amplitude stability at mid-band frequencies for 17 hours.

A high-impedance voltmeter measures the output of the power amplifier. The meter is calibrated to read volts or dbm into a 50-ohm load. For any attenuator setting, true output is obtained by subtracting the attenuator reading from the output voltmeter reading. The output attenuator has a 90 db range, adjustable in 10 db steps with a 20 db vernier. Two outputs, 50- and 600-ohm, are available on the front panel. The standard 651A output monitor is calibrated to read dbm for 50 ohms (0 dbm = 1 mw into 50 ohms). The Model 651A (Option 01.) is calibrated to read dbm for 600 ohms (0 dbm = 1 mw into 600 ohms). The 651A (Option 02.) has a 75-ohm and 600-ohm output. The output monitor is calibrated to read dbm for 75 ohms (0 dbm = 1 mw into 75 ohms). Output impedances not listed are available to meet your requirements. Discuss your application with your hp sales engineer.



Specifications

Frequency range: 10 cps to 10 mc, 6 bands; dial calibration, 1 to 10.

Dial accuracy: ±2%, 100 cps to 1 mc; ±3%, 10 cps to 10 mc (including warm-up drift and ±10% line variation).

Frequency stability: typically 10 ppm/minute.

Output: 200 mw (3.16 v into 50 ohms); 16 mw (3.16 v into 600 ohms); 6.32 v open circuit.

Distortion: <1%, 10 cps to 5 mc; approximately 2% at 10 mc.

Hum and noise: less than 0.05% of maximum rated output.

Output monitor: voltmeter monitors level at input of attenuator in volts or db; top scale calibrated in volts; bottom scale calibrated in db; accuracy ±2% at full scale; flatness: ±1% at full scale, 20 cps to 4 mc; ±2% at full scale, 10 cps to 10 mc.

Frequency response: flat within ±2%, 100 cps to 1 mc; ±3%, 10 cps to 100 cps; ±4%, 4 mc to 10 mc.

Amplitude control: 20 db range (nominal).

Attenuator: range 90 db in 10 db steps; overall accuracy, ±0.1 db; Z_o = 50 ohms and 600 ohms (*Z_o = 75 ohms and 600 ohms, Option: 02.).

Temperature range: 0°C to +50°C.

Dimensions: 5-7/32" high, 16¾" wide, 13¼" deep (133 x 425 x 367 mm); rack mount kit (5060-0075) furnished with instrument.

Weight: net 17 lbs (7.7 kg); shipping 22 lbs (9.9 kg).

Power: 115 v or 230 v ±10%, 50 to 1000 cps, 20 w.

Price: hp 651A, $590.

Options

01. 651A output monitor top scale calibrated in dbm/600 ohms; bottom scale calibrated in volts; $615.
02. 651A output, 75-ohm and 600-ohm; output monitor top scale calibrated in dbm/75 ohms; bottom scale calibrated in volts; $615.

* Other output impedances above 50 ohms are available on special order.

650A TEST OSCILLATOR

Fast, accurate tests 10 cps to 10 mc

The hp 650A Oscillator brings audio-frequency speed, accuracy and ease of operation to higher frequency fields. Its wide frequency range, 10 cps to 10 mc, makes it ideal for a wide variety of measurements in audio, ultrasonic, video and rf bands. Output is flat within ±1 db throughout its frequency range. Voltage range is 30 microvolts to 3 volts, and output impedance is 600 ohms. For measurements where low source impedance is desired, an output voltage divider provides a 6-ohm impedance.

Six decade frequency ranges provide an effective scale length of 94 inches. The tuning dial is controlled directly, or with a 6-to-1 vernier microdrive for hairline adjustment.

Output monitor

The output voltage is monitored by a vacuum tube voltmeter which measures the voltage at the input to the attenuator system. The vtvm is calibrated in volts and decibels and reads actual output voltage when the attenuators are set for zero attenuation. For other attenuator settings true output voltage is obtained by subtracting the attenuator reading from the output voltmeter reading. The output attenuator is adjustable in 10 db steps, and maximum attenuation is 50 db.

Circuits of the hp 650A have been carefully proportioned, and low temperature coefficient components have been employed to assure highest frequency stability. Output voltage will remain constant over long periods of time, despite wide variations in temperature. Distortion over the low-frequency bands is kept at a minimum to increase the usefulness of the instrument for audio measurements.

Specifications

Frequency range: 10 cps to 10 mc; six decade bands.

Calibration accuracy: ±2%, 10 cps to 100 kc; ±3%, 100 kc to 10 mc (including warm-up and ±10% line voltage variation).

Output: 15 milliwatts or 3 volts rms into 600-ohm resistive load; open-circuit voltage is at least 6 volts rms.

Source impedance: 600 ohms; 300 ohms or 6 ohms when using 11047A Output Divider.

Frequency response: flat within ±1 db, 10 cps to 10 mc into 600-ohm resistive load.

Distortion: less than 1% from 20 cps to 100 kc; less than 2% from 100 kc to 1 mc; approximately 5% at 10 mc.

Output monitor: vacuum tube voltmeter monitors level at input to attenuator, in volts or db at 600-ohm level; zero db = 1 mw in 600 ohms; accuracy ±5% of full-scale reading.

Output attenuator: 0 to 50 db in 10 db steps; accuracy ±1 db into resistive load of 600 ohms.

Hum voltage: less than 0.5% of output voltage with meter at full scale.

Power: 115 or 230 v ±10%, 50 to 1000 cps, 165 w.

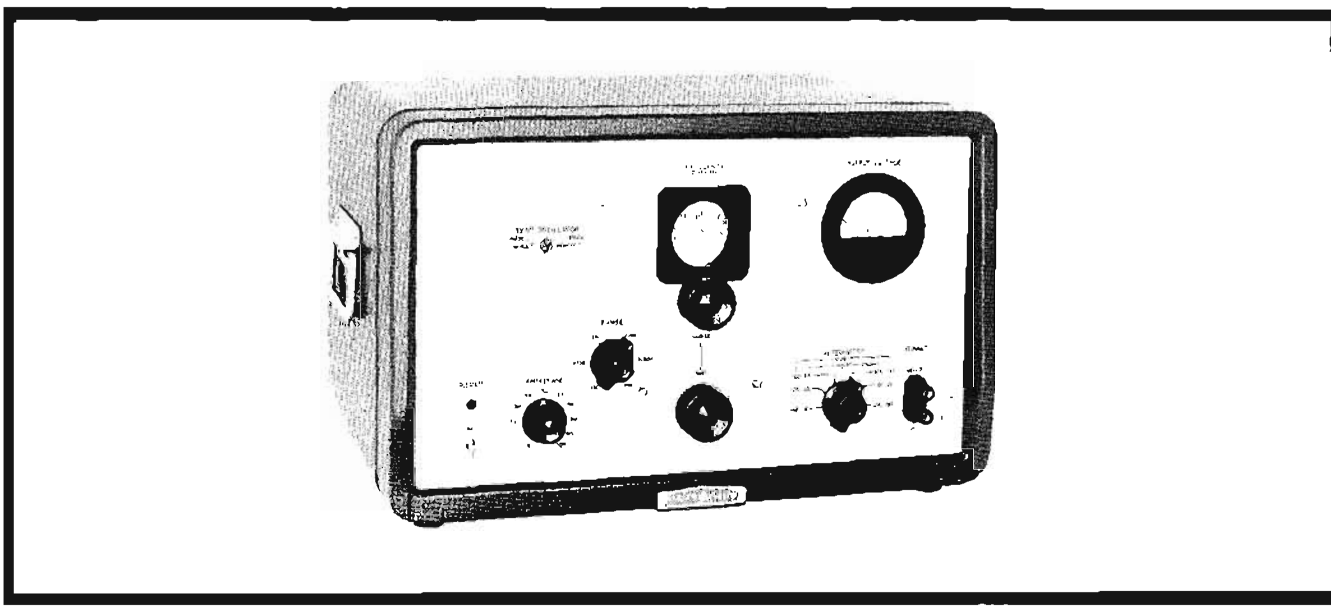
Dimensions: *cabinet:* 20¾" wide, 12¾" high, 15" deep (527 x 324 x 381 mm); rack mount: 19" wide, 10½" high, 15" deep behind panel (483 x 267 x 356 mm).

Weight: net 46 lbs (20,7 kg), shipping 55 lbs (24,7 kg) (cabinet); net 37 lbs (16,6 kg), shipping 52 lbs (23,4 kg) (rack mount).

Accessory furnished: one 11047A Output Divider.

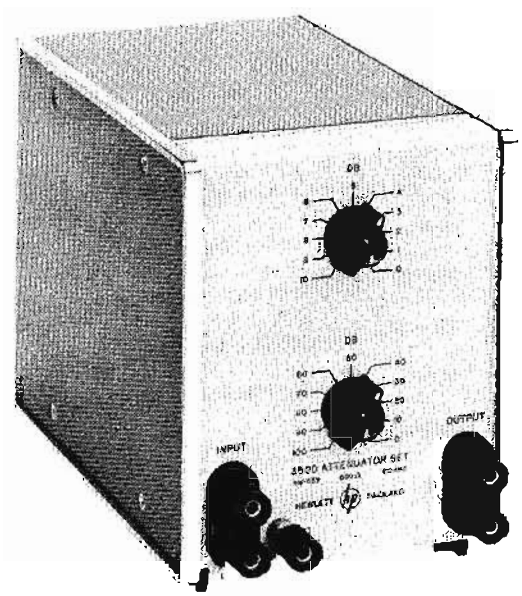
Accessories available: 11000A Cable Assembly, $4.50; 11001A Cable Assembly, $5.50; 11047A Output Divider, $25.

Price: hp 650A, $550 (cabinet); hp 650AR, $535 (rack mount).

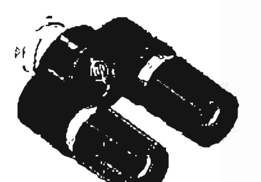


350C,D ATTENUATORS, HEWLETT-PACKARD ACCESSORIES

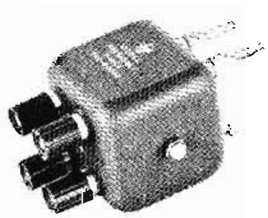
Match 500- or 600-ohm lines, 5-watt capability; useful accessories



350D

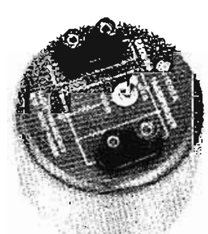


10110A

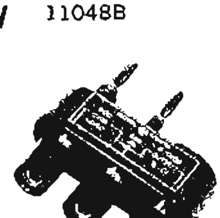


11004A

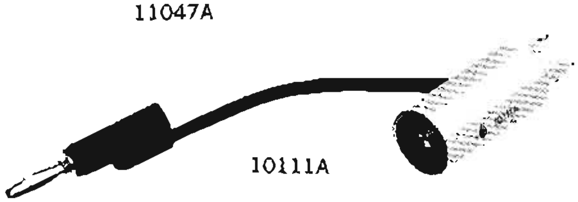
NEW 11048B



11005A



NEW 11047A



10111A

350C,D 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.

Specifications, 350C,D

Attenuation: 110 db in 1 db steps.

Accuracy, 10 db section: from dc to 100 kc, error is less than ±0.125 db at any step; from 100 kc to 1 mc, error is less than ±0.25 db at any step.

Accuracy, 100 db section: from dc to 100 kc, error is less than ±0.25 db at any step up to 70 db, less than ±0.5 db above 70 db; from 100 kc to 1 mc, error is less than ±0.5 db at any step up to 70 db, less than ±0.75 db above 70 db.

Power capacity: 350C, 500 ohms: 5 watts (50 v dc or rms) maximum, continuous duty; 350D, 600 ohms: 5 watts (55 v dc or rms) maximum, continuous duty.

DC isolation: signal ground may be ±500 v dc from external chassis.

Dimensions: 6-3/32" high, 5⅛" wide, 8" deep (155 x 130 x 203 mm).

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Accessories available: 11000A Cable Assembly, 44" of RG-58C/U 50-ohm coaxial terminated by dual banana plugs, $4.50; 11001A Cable Assembly, as above, but with one BNC male connector, $5.50.

Price: 500-ohm attenuator, hp 350C, $125; 600-ohm attenuator, hp 350D, $125.

Accessories:

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.

11004A Line-Matching Transformer

The 11004A Transformer has a frequency response between 5 kc and 600 kc, provides fully balanced 135- or 600-ohm output from single-ended input. Maximum level +22 dbm; hp 11004A, $60 each.

11005A Line-Matching Transformer

The 11005A Transformer has a frequency response between 20 cps and 45 kc, provides a fully balanced 600-ohm output from single-ended input. Maximum level is +15 dbm; hp 11005A, $80 each.

11047A Output Divider Load

Output voltage divider for 650A Test Oscillator. (Refer to page 262.) Source impedance 300 ohms or 6 ohms is provided for small test signals or a low source impedance; hp 11047A, $25 each.

11048B 50-Ohm Feed Thru

Precision 50-ohm feed thru termination with male and female BNC connectors; 11048B, $10 each.

HEWLETT-PACKARD CABLE ACCESSORIES

Cable assemblies, cabinet accessories

10501A Cable Assembly

44" of 50-ohm coaxial cable terminated on one end only with UG-88C/U BNC male connector; hp 10501A, $3.50 each.

10502A Cable Assembly

9" of 50-ohm coaxial cable terminated on both ends with UG-88C/U BNC male connectors; hp 10502A, $5.50 each.

10503A Cable Assembly

4' of 50-ohm coaxial cable terminated on both ends with UG-88C/U BNC male connectors; hp 10503A, $6.50 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, $4.50 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, $5.50 each.

11002A Test Leads

Dual banana plug to alligator clips, 5'; hp 11002A, $7.50 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, $5.50 each.

11037A Cable Assembly

44" dual banana plugs to alligator clips; hp 11037A, $6 each.

11056A Handle Kit

(for one-third module)

Handle for carrying hp instruments whose size are one-third full rack width; hp 11056A, $5 each. (Refer to pages 13 and 14.)

11057A Handle Kit

(for one-half module)

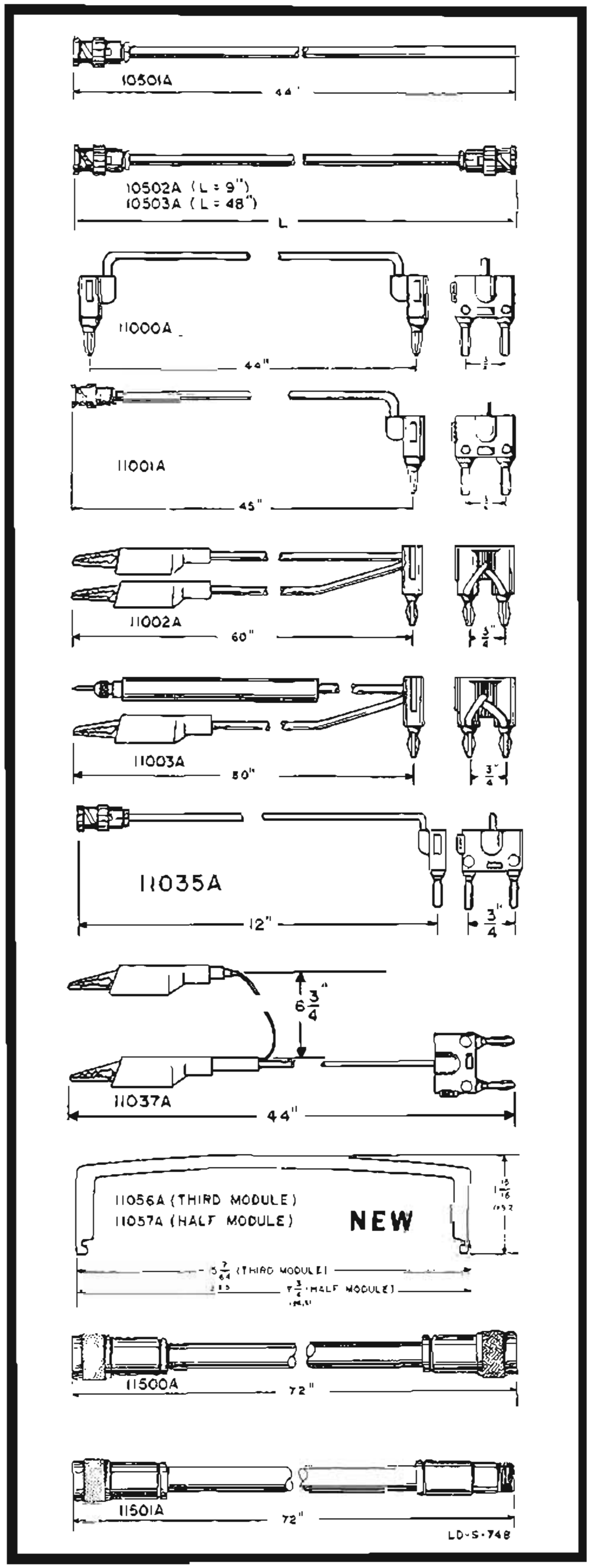
Handle for carrying hp instruments whose size are one-half full rack width; hp 11057A, $5 each. (Refer to pages 13 and 14.)

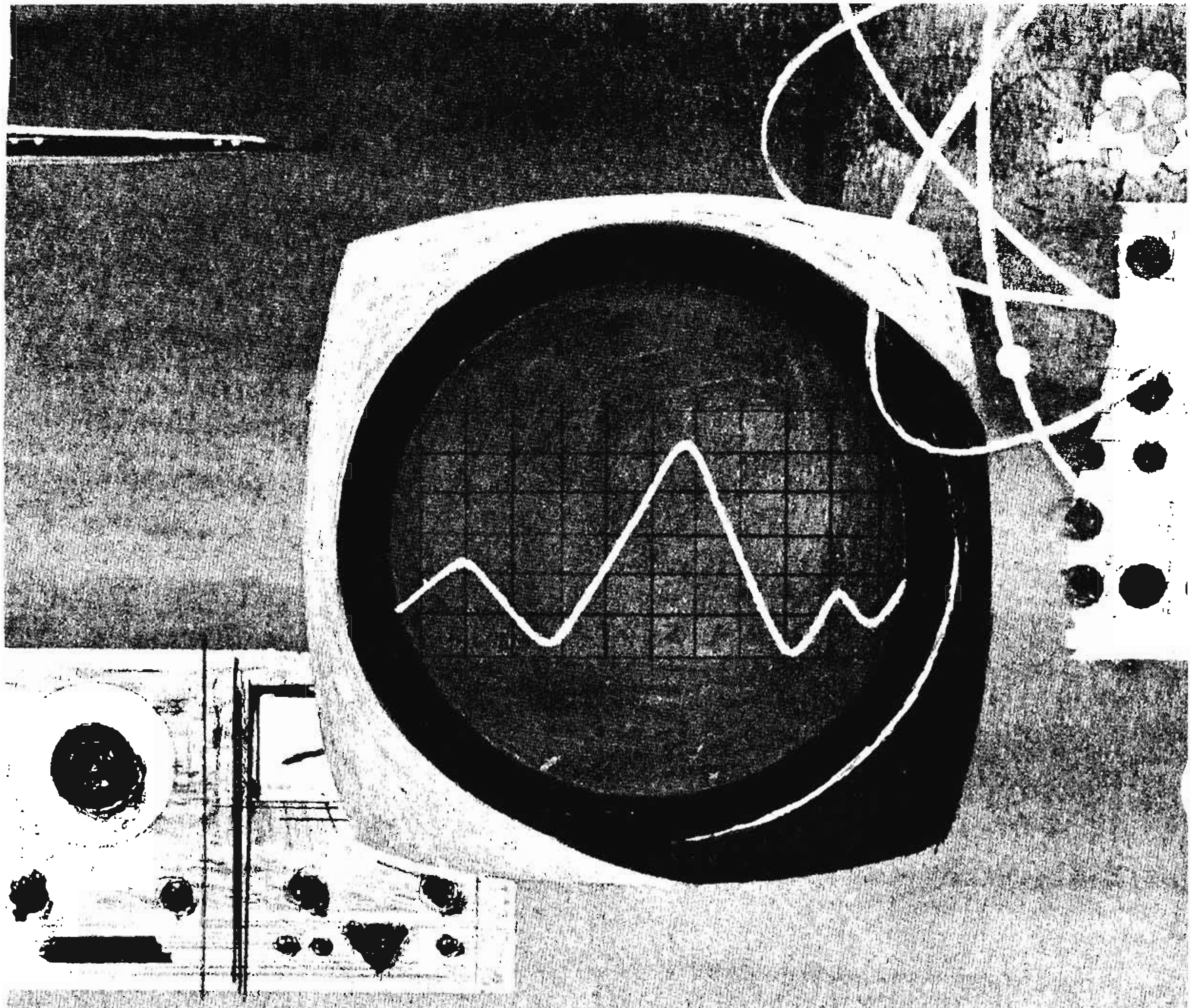
11500A Cable Assembly

6' of specially treated 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.





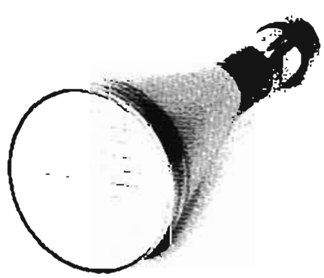
Oscilloscopes

OSCILLOSCOPES

The cathode-ray oscilloscope is an extremely fast x-y plotter which plots an input signal versus another signal or versus time. The "stylus" is a luminous spot which moves over the display area in response to input voltages. In the usual scope application, the x-axis input is an internally generated linear ramp voltage which moves the spot uniformly from left to right across the display screen. 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.

When the signal being observed is repetitive at a fast enough rate, the display appears as a steady line. The cathode-ray oscilloscope, thus, is a means of visualizing time-varying voltages. As such, it has become a universal tool in all kinds of electronic investigations. In addition to voltages, a scope can present visual representations of a wide variety of dynamic phenomena by the use of transducers for converting current, strain, acceleration, pressure and other physical quantities into voltages.

The cathode-ray tube

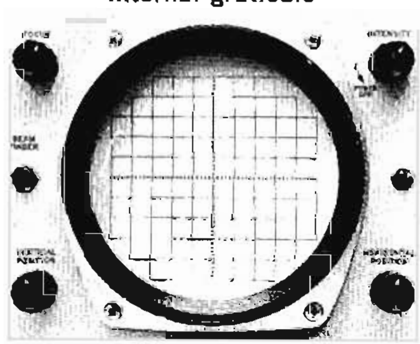


The cathode-ray tube (crt) is the heart of the cathode-ray oscilloscope, with the rest of the instrument consisting of circuitry for operating the crt. As is commonly known, this tube has an electron gun at one end and a phosphor display screen at the other end. The gun has a thermionic cathode, various accelerating electrodes for directing emitted electrons toward the display screen, and a focusing electrode. The resulting narrow beam of electrons from the gun strikes the phosphor in a small spot with enough energy to cause fluorescence.

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 moving the beam up and down and voltages on the other pair moving it from side to side. These movements are independent of each other, so that the spot may be positioned anywhere on the phosphor screen by appropriate voltage inputs.

The accuracy with which the viewed waveform corresponds to the deflection voltages depends in large measure on the performance of the cathode-ray tube. Careful design of the electrodes and the precision manufacturing techniques of the Hewlett-Packard cathode-ray tube facility insure that the beam moves linearly with respect to the deflection voltages. Hewlett-Packard's precision crt's make it possible to measure accurately the input voltage amplitude at any point on the waveform by measurement of the amount of deflection of the fluorescent spot.

Internal graticule



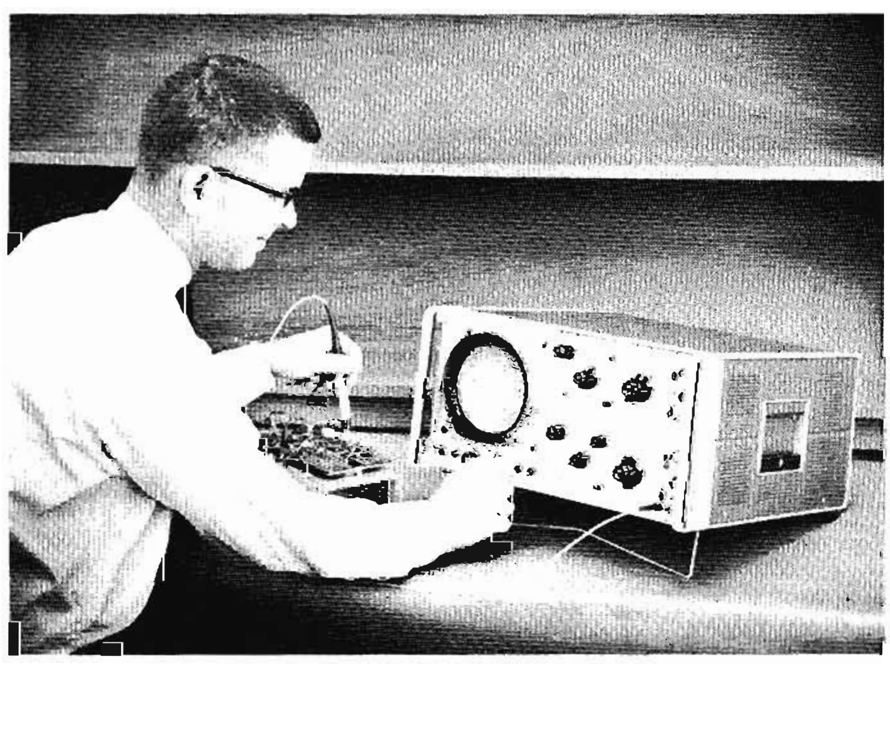
The amount of spot deflection, and, thus, the input voltage amplitude, is gauged by a rectangular graticule placed on the display area. A significant contribution to precision oscillography was made by Hewlett-Packard with the introduction of the internal graticule tube. In these tubes the graticule of fine, black lines is placed in the same plane as the phosphor. This avoids errors caused by the parallax which otherwise exists when the graticule is external to the tube, separated from the phosphor by the thickness of the glass face-plate.

CRT photography is improved by the internal graticule tube. With the proper techniques, described on page 301, the trace shows white, the graticule shows black, while the background is an intermediate gray. This results in maximum contrast between trace and graticule and at the same time obtains an increase in photographic speed.

Another feature of Hewlett-Packard's internal graticule tube is that the outer surface of the face-plate is etched slightly, thus minimizing glare and bothersome reflections. This face-plate is made of laminated glass, giving superior protection from implosion without the need for an external plastic shield.

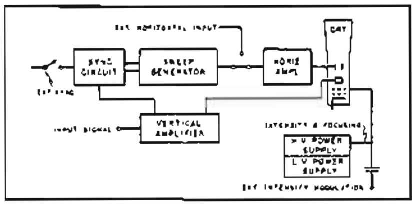
CRT phosphors

The purchaser of an oscilloscope has the option of selecting the phosphor best suited to his primary applications. The various chemical salts used in crt phosphors have different characteristics affecting the color of fluorescence and its brightness, decay and speed of response. Unless otherwise specified, most Hewlett-Packard scopes are supplied with P31 phosphor. This phosphor combines brightness and a spectral response well



suited to the eye, with ruggedness and resistance to burning. Phosphor characteristics are discussed in the table on page 268.

Basic oscilloscope circuitry



The primary subsystems of a cathode-ray oscilloscope are the crt, the vertical deflection system, the horizontal deflection system and the power supplies. The power supplies include focusing and intensity controls for adjusting the crt spot. Sampling oscilloscopes, discussed on page 294, have additional circuitry for observation of fast signals beyond the capability of ordinary real-time oscilloscopes.

The horizontal deflection system supplies drive voltages for moving the electron beam horizontally. Since so many measurements are concerned with plotting voltage versus time, the horizontal deflection system also includes sawtooth waveform generators for sweeping the beam horizontally at a uniform rate, plus synchronizing circuits for starting the horizontal sweep at a specific instant with respect to the measured waveform.

The horizontal amplifiers of all 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.

The vertical deflection system consists of an amplifier chain for amplifying low-level input signals sufficiently to drive the crt spot. Attenuators are included, so that a wide range of input signal amplitudes may be accommodated within the vertical dimension of the display area.

Selecting an oscilloscope

Choice of an oscilloscope is based largely on considerations of both performance capabilities and versatility. Versatility is greatly enhanced if the scope has plug-in capability, since the scope's performance can be altered by use of the appropriate plug-in. Plug-in capability also enables a scope's performance to be updated as new plug-ins become available. The prospective purchaser should decide, first of all, whether his applications are broad enough to require plug-in versatility.

Bandwidth and sensitivity 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. High sensitivity requires more amplifier stages and added refinements for minimizing dc drift and noise.

Detailed discussions of the various Hewlett-Packard oscilloscopes are grouped in later sections according to plug-in capability. These discussions are divided as follows: (1) general-purpose, non-plug-in scopes, useful for the majority of industrial and laboratory applications (page 269); (2) plug-in scopes, having the additional features required for high frequency or fast pulse work (page 276); (3) sampling oscilloscopes, which extend scope measurements to frequencies of 4 gc and above and to pulses with rise times measured in picoseconds while still retaining a large, bright display and high sensitivity (page 294).

The reader is referred to these sections for detailed discussions of scope characteristics. Certain other features, common to most Hewlett-Packard scopes, are described here.

Features of the vertical deflection system

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 Hewlett-Packard scopes have built-in calibrators which supply precisely controlled signals for use as calibrating test signals.

DC coupling, included on all Hewlett-Packard scopes, 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 to be examined. Hewlett-Packard scopes all have provision for inserting decoupling capacitors into the signal line when dc coupling is not desired.

A widely used option in oscilloscope vertical deflection systems is the provision for two signal channels. Dual-channel operation is obtained most conveniently by electronic switching between signal channels, resulting in alternate displays of the two signals. Switching may occur between sweeps so that the waveform of one channel is displayed during one sweep, and the other waveform is displayed on the next sweep; or switching may occur rapidly (40 kc to 1 mc) for displaying samples of both channels during one sweep. This latter method, frequently referred to as "chopped" presentation, is most often used for low-frequency waveforms which otherwise would flicker with alternate-sweep presentation.

Dual-channel presentation enables comparison studies of two signals, such as phase measurements or studies of an amplifier's output signal versus its input. The two inputs of dual-channel oscilloscopes have separate preamps and attenuators for independent adjustment of the amplitudes of the two signals. In some applications, a dual-beam oscilloscope, such as the hp Model 132A, must be used rather than a dual-trace unit. The crt of the 132A has two electron guns and two sets of deflection plates. This arrangement allows single-shot observations of events that are too fast for the "chopped" dual-trace method described above. Also, simultaneous x-y and y-t displays or two different sweep speeds are possible without expensive delay generators usually found only in elaborate high-frequency scopes.

Other features

The beam finder button, a convenience feature found on Hewlett-Packard scopes, simplifies trace centering. Pressing this button reduces the gain of both horizontal and vertical amplifiers while simultaneously brightening and defocusing the trace. In this way, the trace is brought on screen, regardless of the settings of the positioning, intensity and sweep trigger controls.

Triggering the sweep is quick and easy with hp oscilloscopes 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 absence 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. Other features of the horizontal deflection system, such as sweep delay and single-sweep operation, are discussed in later sections.

Reliability through conservative design is built into all Hewlett-Packard scopes. They are designed for ease of servicing, with all components readily accessible. Edge-on connectors, or snap-out circuit boards, as in the Model 132A Dual Beam Oscilloscope, allow easy removal of entire circuit sections for replacement or repair.

The newer hp scopes are packaged in the hp modular cabinets (pages 13, 14). These instruments can be stacked on the bench with other hp instruments or quickly converted to rack mounting. A tilting bail raises either end for easier viewing on the bench.

Phosphor characteristics, Hewlett-Packard cathode-ray tubes

Phosphor	Trace color: Under excitation	Trace color: After-glow	Low-level persistence[2]	Relative burn resistance	Relative visual brightness: 2.5 kv non-alum.	3.5 kv alum.[3]	5 kv alum.[3]	7.5 kv alum.[3]	10 kv alum.[3]	12 kv alum.[3]	Use
P1[1]	green	green	180 msec	100	100	190	420	860	1300	1600	visual observation of medium and fast repetitive signals
P2	blue	yellow	1 sec	150	130	240	550	1100	1650	2100	visual display and photographic recording of medium and slow repetitive signals
P7	blue-white	yellow	3 sec	75	60	110	300	600	900	1130	long persistence makes P7 useful for visual observation of slow transients and slow repetitive signals
P11	blue	blue	20 msec	75	20	70	170	400	660	800	best for photographic recordings of fast waveforms and transients, poor for visual work
P31	blue-green	light green	500 msec	250	190	320	740	1600	2300	3000	best general-purpose phosphor for visual and photographic use on all waveforms, most resistant to burning

[1]P1 phosphor will not fluoresce under ultra-violet excitation. Not available with internal graticule.
[2]Low-level persistence is a measure of the time for the afterglow to decrease to 10% brightness, a level of light intensity which is still visible.
[3]Aluminized crt has greater visual brightness and is less susceptible to burning.

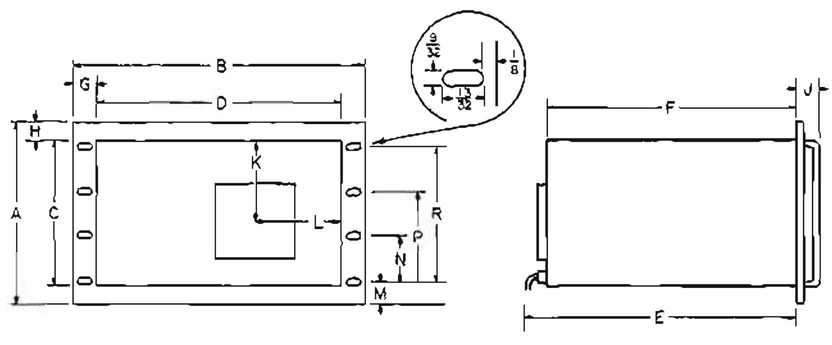
Rack mount information hp oscilloscopes
Dimensions in inches (mm)

	120B	122A	130C	132A	140A	170B	175A	180B
A[1]	6-31/32 (177)	6-31/32 (177)	6-31/32 (177)	8-23/32 (222)	8-23/32 (222)	12-7/32 (310)	12-7/32 (310)	12-7/32 (310)
B[1]	19 (483)	19 (483)	19 (483)	19 (483)	19 (483)	19 (483)	19 (483)	19 (483)
C	6-25/32 (172)	6½ (165)	6-25/32 (172)	8-17/32 (217)	8-17/32 (217)	11-21/32 (296)	12-1/32 (306)	11-21/32 (296)
D	16¾ (426)	16¾ (426)	16¾ (426)	16¾ (426)	16¾ (426)	16-15/16 (430)	16¾ (426)	16-15/16 (430)
E	17 (432)	19½ (495)	17⅞ (454)	17⅞ (454)	17⅞ (454)	22¼ (565)	23 (584)	22¼ (565)
F	16⅜ (416)	19 (483)	16⅜ (416)	16⅜ (416)	16⅜ (416)	20¼ (514)	22⅜ (568)	20¼ (514)
G	1⅛ (29)	1⅛ (29)	1⅛ (29)	1⅛ (29)	1⅛ (29)	1-1/16 (27)	1⅛ (29)	1-1/16 (27)
H	0	¼ (6)	0	0	0	5/16 (8)	0	5/16 (8)
J	2 (51)	1¼ (32)	2 (51)	2 (51)	2 (51)	2 (51)	2 (51)	2 (51)
K	—	—	—	—	4 (102)	6⅝ (168)	7 (178)	6⅝ (168)
L	—	—	—	—	9¼ (235)	11 (279)	11½ (292)	11 (279)
M[1]	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)	1-31/64 (38)
N[1]	—	—	—	—	—	3½ (89)	3½ (89)	3½ (89)
P[1]	—	—	—	—	—	5¾ (146)	5¾ (146)	5¾ (146)
R[1]	4 (102)	4 (102)	4 (102)	—	5¾ (146)	9¼ (235)	9¼ (235)	9¼ (235)
Cooling Type	C	C	C	C	F.A.	F.A.	F.A.	F.A.
Air in	B	B	B	B	R	R	R	R
Air out	S.T.R.	T.R.	S.T.R.	S.T.R.	S	S	S	S
CFM[2]	25	35	25	30	60	110	90	65

Abbreviations: C = convection, F.A. = forced air, B = bottom, R = rear, S = sides, T = top.

[1]Conform to EIA standards for rack mounts.

[2]This is the recommended volume of air, at normal ambient temperature, that should be supplied to the rack mounted instrument for cooling; the following expression may be used as a "rule of thumb" to establish the volume of air required by the entire enclosure. Q = 176 x P (kw) where Q = Cfm (vol. of air); P (kw) = kw of input power to the enclosure; additional air should be supplied if the intake air is not distributed proportionally to each instrument or if it is at a high ambient temperature.



GENERAL-PURPOSE OSCILLOSCOPES

Hewlett-Packard's general-purpose oscilloscopes make accurate voltage and time measurements on a wide variety of waveforms in the subsonic, audio, ultrasonic and low rf frequency ranges. These scopes are intended for analysis of waveforms in which little importance is attached to frequency components beyond 500 kc. The dc amplifiers and long sweep rates are suitable for medical and mechanical studies, as well as for low-frequency electrical work. At the same time, fast sweep speeds are provided in these instruments for detailed studies of transient phenomena, vibration effects, audio analysis and other higher frequency physical events.

Since these instruments have relatively simple circuitry and construction, they are the most economical type of oscilloscope. In applications such as systems, where the scope performs just one function and the added expense of plug-in flexibility is not needed, the general-purpose oscilloscope provides maximum economy.

Cathode-ray tubes

The precision cathode-ray tubes in the hp low-frequency scopes use the phosphors described on page 268 and feature parallax-free internal graticules. The graticules cover a 10 by 10 cm useful display area. A large calibrated display area such as this is especially advantageous for x-y measurements.

The cathode-ray tubes of most of these scopes are mono-accelerator types in which all electron acceleration takes place in the gun section. The electron stream is not subjected to any electrostatic fields after leaving the gun section, insuring straight-line travel to the phosphor screen. Accurate deflection factors result and the bright, clear cathode-ray trace remains sharply focused throughout the large display area.

The Model 132A Dual-Beam Oscilloscope (pages 274, 275) uses a dual electron gun crt together with two pairs of horizontal and vertical deflection plates and amplifiers to achieve two completely independent displays. This allows dual x-y measurements, simultaneous x-y and y-t plots, and displays with two different sweep speeds. The dual-beam scope is also ideal for transient study of rapidly changing signals, since a single-beam dual-trace scope cannot display two single shots at high sweep speeds.

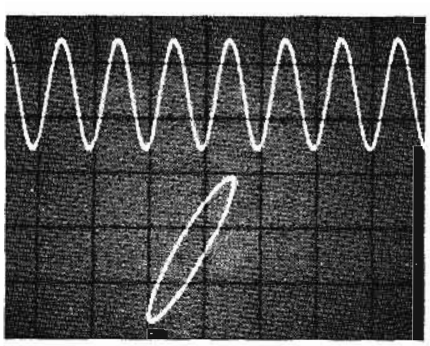


Figure 1. Two completely independent beams allow the Model 132A to make a wide variety of measurements.

Vertical amplifiers

High sensitivity is built into hp general-purpose scopes (to 200 μv/cm in the 130C and to 100 μv/cm in the 132A). High sensitivity enables transducer outputs to be connected directly to the scope, simplifying instrumentation set-ups. For instance, dynamic measurements of strain are readily made with the concise instrumentation diagrammed in Figure 2.

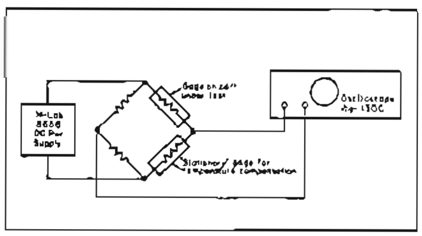


Figure 2. Dynamic strain measurements made with high-sensitivity oscilloscope.

High amplifier gain with minimum drift and noise is obtained in the hp scopes by careful circuit design. Large amounts of negative feedback, aided by the use of regulated power supplies, achieve gain stability for measurement accuracy. Excellent dc stability is maintained through the use of balanced amplifiers, regulated dc filament power, conservatively operated components with low coefficients of temperature, and, in the Model 132A, input nuvistors shock-mounted in an aluminum block for low microphonics and drift.

The balanced amplifier design also means that balanced input signals can be connected directly to these scopes. When used in the differential mode, the scope displays the voltage difference between the signals on the two input leads, while canceling "in-phase" (common mode) voltages existing on both leads. The 132A Dual-Beam Oscilloscope, for example, has a 40,000-to-1 common mode rejection ratio; this allows maximum sensitivity to be used with low-level signals such as transducer outputs.

Provision is made for ac coupling in the amplifiers when it is desirable to remove the dc component of a signal.

Horizontal amplifiers

The amplifiers for horizontal deflection in hp low-frequency scopes have phase shift characteristics which are matched to the vertical amplifiers up to and beyond 100 kc. In particular, the Model 130C features vertical and horizontal amplifiers which have identical characteristics with respect to both phase and sensitivity.

Matched amplifier characteristics enhance the precision of phase measurements in the x-y mode. A typical sine wave phase measurement is diagrammed in Figure 3. Here, horizontal and vertical amplifier gains are adjusted for equal deflection. The resulting display pattern is an ellipse whose shape indicates the phase angle between the signals at the scope's input. At one extreme this ellipse becomes a straight line slanting towards the right at 45° (0° phase shift). At the other extreme, it slants to the left at 45° (180° phase shift). Other values of phase shift lie between these extremes; 90° (or 270°) phase shift generates a circle. The phase shift is calculated from measurements of the parameters indicated on the diagram[1]. Useful voltage-current phase relationships also can be studied by using an hp current probe as one of the input signals.

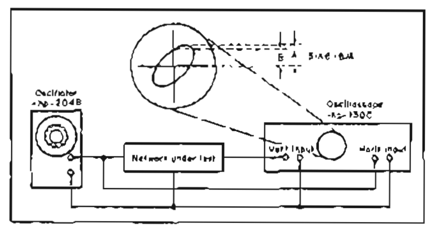


Figure 3. Phase measurement, using scope in x-y mode.

Simple operation

These scopes have been designed for "connect-and-read" convenience, as well as having the performance capabilities required for precision measurements. With automatic triggering and direct-reading controls, hp general-purpose scopes can be operated readily by inexperienced personnel. At the same time, the precision and flexibility required for laboratory use are available.

Automatic triggering is selected by a switched position on the trigger level control. This position alters the trigger circuit, so that the oscilloscope sweep cycles automatically in the absence of an input signal.

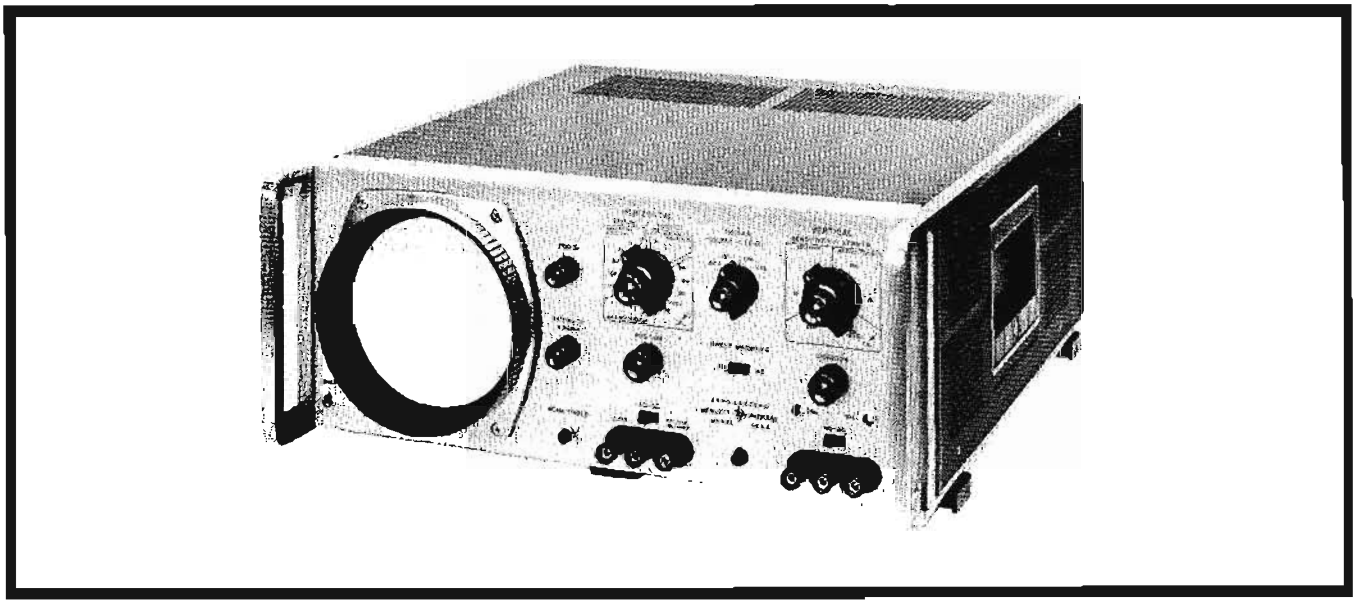
[1]For a direct-reading method of phase shift measurement, the reader is referred to "A Convenient Method for Measuring Phase Shift," hp Application Note No. 29, free on request.

120B 450 KC OSCILLOSCOPE

Easy-to-use, general-purpose 10 mv/cm oscilloscope

The hp 120B Oscilloscope offers high accuracy, convenience, ease of operation, and versatility. The no-parallax, no-glare cathode-ray tube (crt) and the calibrated sensitivity and sweeps permit accurate measurements; the beam finder and automatic triggering simplify operation; the modular cabinet is easily converted for rack mounting. Front-panel controls are logically arranged, making the 120B easy to operate, even by non-technical personnel.

Automatic triggering provides a clear base line even in the absence of an input signal and eliminates complicated trigger adjustment. If desired, the automatic trigger may be switched out and the trigger level selected manually with a front-panel control. A front-panel beam finder pushbutton quickly locates an off-screen trace. Controls are color coded and logically arranged for convenient operation.



Specifications

Sweep

Range: 5 μsec/cm to 200 msec/cm; 15 calibrated sweeps accurate to within ±5%, in a 1, 2, 5 . . . sequence; vernier permits continuous adjustment of sweep time between calibrated steps and extends the 200 msec/cm step to at least 0.5 sec/cm.

Expand: X5 sweep expansion may be used on all ranges and expands fastest sweep to 1 μsec/cm; expanded sweep accuracy is ±10%.

Automatic triggering

Internal: 50 cps to 450 kc for signals causing 0.5 cm or more vertical deflection; also from line voltage.

External: 50 cps to 450 kc for signals at least 1.5 v peak to peak.

Trigger point and slope: zero crossing, pos. or neg. slope of vertical deflection signals; or zero crossing neg. slope of external sync signals.

Amplitude selection triggering: automatic triggering may be disabled and level of triggering set between −7 and +7 volts, this mode can be used to trigger the sweep below the 50 cps minimum of the automatic mode.

Vertical amplifier

Bandwidth: dc coupled: dc to 450 kc; ac coupled, approx. 2 cps to 450 kc: bandwidth is at least 450 kc regardless of sensitivity setting.

Sensitivity: 10 mv/cm to 100 v/cm; 4 calibrated steps with attenuator accuracy of ±3%, 10 mv/cm, 100 v/cm, 1 v/cm and 10 v/cm; vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

Internal calibrator: calibrating signal automatically connected to vertical amplifier for standardizing of gain, accuracy ±2%.

Input Impedance: 1 megohm, approximately 50 pf shunt.

Balanced Input: on 10 mv/cm range; input impedance, 2 megohms shunted by approximately 25 pf.

Common mode rejection: 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 kc when verniers are in Cal.

Horizontal amplifier

Bandwidth: dc coupled: dc to 300 kc; ac coupled: approx. 2 cps to 300 kc; bandwidth is at least 300 kc regardless of sensitivity setting.

Sensitivity: 0.1 volt/cm to 100 volts/cm; 3 calibrated steps, accurate within ±5%, 0.1 v/cm, 1 v/cm and 10 v/cm; vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

Input Impedance: 1 megohm, nominal, shunted by approximately 100 pf.

General

Cathode-ray tube: G203E (P31 phosphor) internal graticule, mono-accelerator normally supplied; 2700-volt accelerating potential; face plate eliminates glare and reduces hazard of implosion; P2, P7 and P11 phosphors are available, see Modifications.

Internal graticule: 10 cm x 10 cm marked in cm squares; major horizontal and vertical axes have 2 mm subdivisions; eliminates parallax error.

Intensity modulation: terminals on front panel; +20 volt pulse will blank trace of normal intensity.

Dimensions: 16¾" wide, 7½" high, 18⅜" deep overall (425 x 190 x 466 mm); hardware furnished for quick conversion to 7" x 19" (178 x 482 mm).

Weight: net 32 lbs (14.4 kg); shipping 45 lbs (20.2 kg).

Power: 115 or 230 volts ±10%, 50 to 1000 cps; approx. 95 w.

Price: hp 120B, $495.

Modifications: crt phosphors (specify by phosphor number): P31 standard; P2, P7, P11 available, no charge.

Options:

05. External graticule crt with P31 phosphor (P1, P2, P7, P11, please specify) in lieu of standard internal graticule, $25 (includes edge-lighting of external graticule).

06. Rear terminals in parallel with front; two 3-pin A/N connectors; one for vertical input, the other for horizontal or trigger and for z-axis inputs, $30 (mating A/N connectors furnished).

10. Provision for single-sweep operation, as well as conventional triggered sweep, $35.

13. Plain 3/16" thick front panel for rack mounting only; suitable for installing special handles to match existing equipment in system or console, $20 (front-panel dimensions 7" x 19").

NOTE: Special x-y version without sweep available; see your hp field engineer for further information.

122A,AR DUAL-TRACE 200 KC OSCILLOSCOPES

Economical versatility

Hewlett-Packard Model 122A Dual-Trace Oscilloscope provides calibrated dual-trace capabilities with highly linear sweeps, is simple to operate even by non-technical personnel. Accurate phase shift measurements also are easily made. Relative phase shift between vertical and horizontal amplifiers is less than 2° at 100 kc. The 122A will accept either single-ended or balanced input signals. Also, since each attenuator operates independently, signals of differing amplitudes may be studied together. Automatic triggering, which provides a clear base-line in the absence of an input signal, eliminates complicated trigger adjustments and speeds operation. The hp-developed internal graticule eliminates parallax for greater measurement accuracy.

Specifications

Sweep

Sweep range: 15 calibrated sweeps, from 5 μsec/cm to 200 msec/cm, accurate to within ±5%, in a 1, 2, 5 . . . sequence; vernier permits continuous adjustment of sweep time between calibrated steps and extends the 200 msec/cm range to at least 0.5 sec/cm.

Sweep expand: X5 sweep expansion may be used on all ranges and expands fastest sweep to 1 μsec/cm; expansion is about the center of the crt, and expanded sweep accuracy is ±10%.

Synchronization: automatic from 50 cps to 250 kc; internally from vertical deflection signals causing 0.5 cm or more vertical deflection, from external signals 2.5 v peak to peak or greater, and from line voltage.

Trigger point: control overrides automatic and permits the trigger point to be set between −10 and −10 v; turning fully counterclockwise into Auto restores automatic operation; pos. or neg. slope.

Vertical amplifiers

Bandwidth: dc coupled: dc to 200 kc; ac coupled: approx. 2 cps to 200 kc. bandwidth is independent of calibrated sensitivity setting.

Sensitivity: 10 mv/cm to 100 v/cm; 4 calibrated steps within ±5%, 10 mv/cm, 100 mv/cm, 1 v/cm and 10 v/cm, vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

Internal calibrator: calibrating signal automatically connected to vertical amplifier for standardizing of gain, accuracy ±2%.

Input impedance: 1 megohm, approx. 50 pf shunt capacitance.

Phase shift: vertical and horizontal amplifiers have same phase characteristics within ±2° to 100 kc when verniers are fully clockwise.

Isolation: >80 db isolation between channel A and B from dc to 200 kc.

Balanced input: on 10 mv/cm range on both amplifiers; input impedance, 2 megohms shunted by approx 25 pf; common mode rejection is at least 40 db; common mode signal must not exceed ±3 v peak.

Difference input: both input signals may be switched to one channel to give differential input on all vertical sensitivity ranges; the sensitivity switches may be set separately to allow mixing signals of different levels; common mode rejection is at least 40 db with both switches on most sensitive range, 30 db on other ranges.

Vertical presentation: switch selects: A Only, B Only, B-A, Alternate or Chopped.

Horizontal amplifier

Bandwidth: dc coupled: dc to 200 kc, ac coupled: approx. 2 cps to 200 kc; bandwidth is independent of calibrated sensitivity setting.

Sensitivity: 0.1 v/cm to 100 v/cm; 3 calibrated steps, accurate within ±5%, 0.1 v/cm, 1 v/cm and 10 v/cm; vernier permits continuous adjustment of sensitivity between steps, extends 10 v/cm step to at least 100 v/cm.

Input impedance: 1 megohm, nominal, shunted by approx. 100 pf.

Phase shift: horizontal and vertical amplifiers have same phase characteristics within ±2° to 100 kc.

General

Cathode-ray tube: 5AQ mono-accelerator; normally furnished with P31 phosphor; other phosphors available, see Options; accelerating potential: 3000 v.

Internal graticule (standard): 10 cm x 10 cm marked in cm squares with axes in 2 mm subdivisions; eliminates parallax error.

CRT bezel: light-proof bezel provides firm mount for oscilliscope camera.

CRT plates: direct connection to deflection plates via terminals on rear; sensitivity approx. 20 v/cm.

Intensity modulation: terminals on rear; +20 v pulse will blank trace of normal intensity.

Power: 115 or 230 v ±10%, 50 to 1000 cps, approx. 150 w.

Dimensions: cabinet: 9¾" wide, 15" high, 21¼" deep (248 x 310 x 540 mm); rack mount: 19" wide, 7" high, 19½" deep behind panel (483 x 178 x 495 mm).

Weight: net 35 lbs (15.8 kg), shipping 51 lbs (23 kg) (cabinet); net 33 lbs (14.9 kg), shipping 48 lbs (21.6 kg) (rack mount).

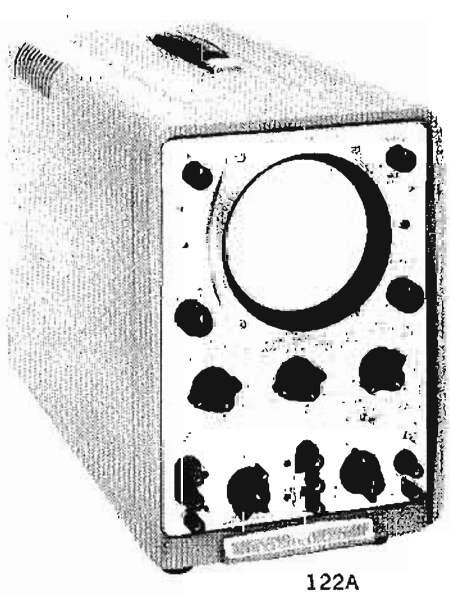
Price: hp 122A, $695 (cabinet); hp 122AR, $695 (rack mount); for single-sweep operation specify H15-122A or H15-122AR, $765.

Modifications: crt phosphors (specify by phosphor number): P31 standard; P2, P7, P11 available, no charge.

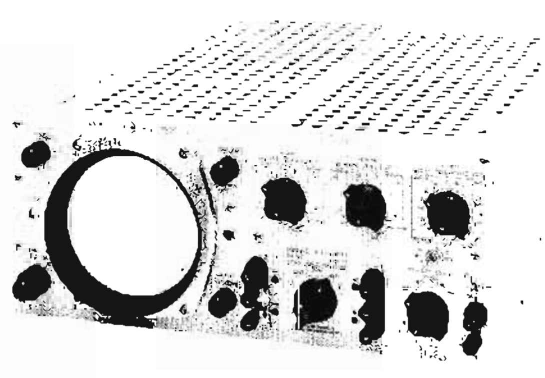
Options:

05. External graticule with edge lighting, with P1 phosphor (P2, P7, P11, P31 please specify), add $25.

06. Rear terminals in parallel with front terminals, two 3-pin A/N connectors for vertical inputs; a BNC connector for the horizontal/external trigger input, $40 (mating A/N connectors included).



122A



122AR

130C 200 μV/CM OSCILLOSCOPE

Features identical amplifiers for x-y plots

The hp 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.

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 push-button beam finder immediately locates an off-screen trace.

Identical amplifiers

Identical horizontal and vertical amplifiers provide a high sensitivity of 200 μv/cm from dc to 500 kc and balanced inputs on all ranges. Balanced output signals from low-level transducers, such as those used in industrial and medical fields, can be measured directly without external amplification. The amplifiers also may be used single-ended with ac or dc coupling. Regulated power supplies, high-stability components and extensive feedback insure excellent gain stability and low noise even on the most sensitive ranges. A front-panel switch (Amplifier AC-DC) provides ac coupling between amplifier stages and virtually eliminates all drift — even on the most sensitive range. Phase shift between amplifiers is held to less than $\pm 1°$ up to 100 kc for accurate phase measurements.

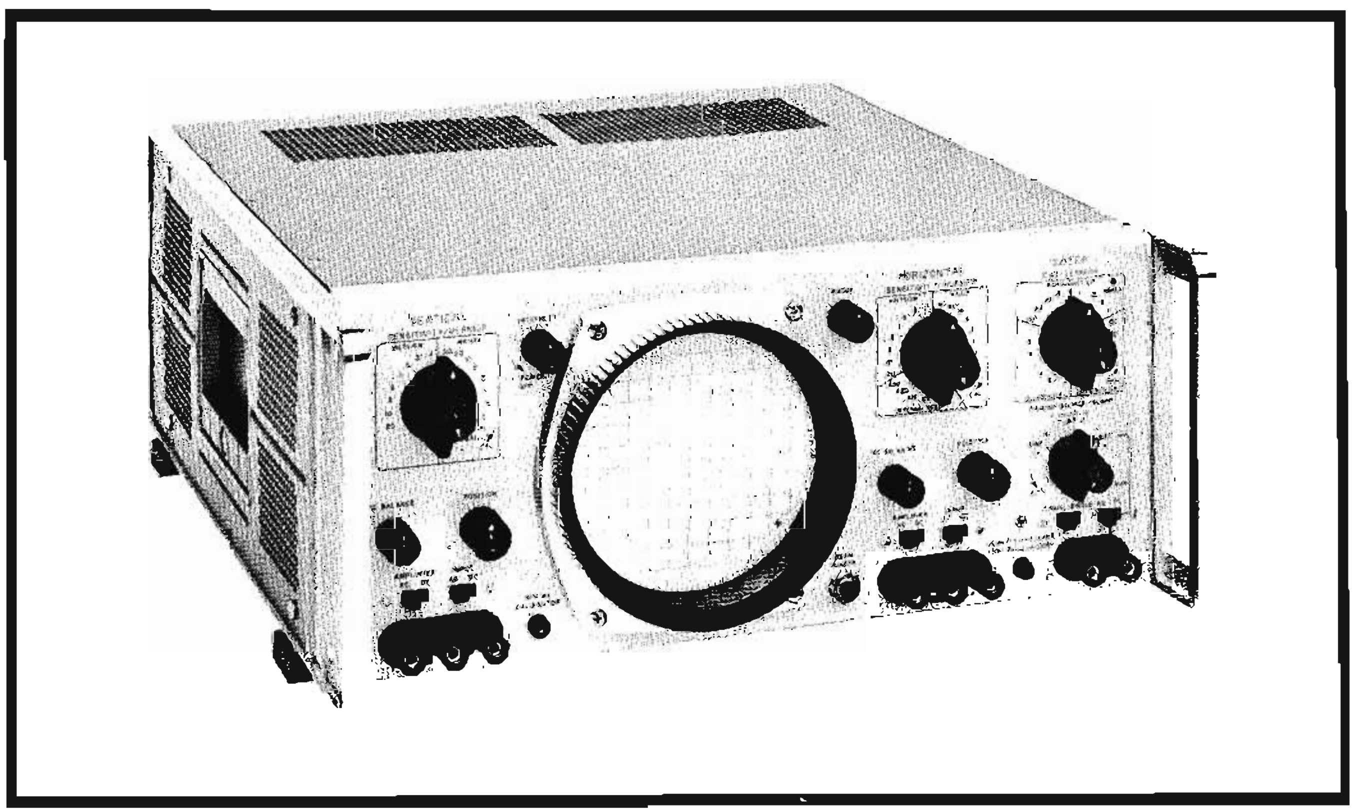
Probes may be used with both the horizontal and vertical amplifiers, and since the input impedance is constant, the probes will not require recompensation between sensitivity ranges.

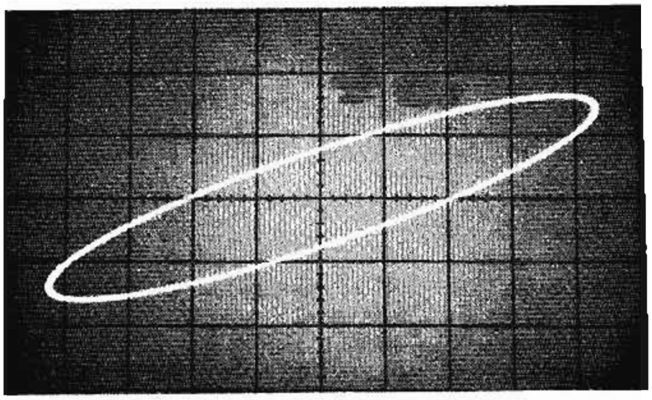
Automatic triggering

Trigger adjustments are minimized with the 130C by the automatic triggering feature, which provides a base line in the absence of an input signal. For fast expanded sweep times where the automatic base line would be too dim for observation, a free run mode establishes a bright base line. A trigger level control is located on the front panel so that automatic triggering may be easily locked out if desired, and a preset trigger level established.

Versatile sweeps

For accurate time measurements, 21 linear direct-reading sweep times from 1 μsec/cm to 5 sec/cm are available, accurate within $\pm 3\%$. A calibrated X2 to X50 magnifier expands the sweep up to 0.2 μsec/cm, accurate within $\pm 5\%$. A vernier control permits continuous adjustment between calibrated ranges and extends the slowest sweep speed to at least 12.5 sec/cm. In addition, a front-panel switch for either normal or single sweep permits observation of single-shot phenomena or random events. Switching to single sweep will disable the sweep circuit after a single sweep so that it can not be retriggered until manually rearmed. A front-panel sweep "armed" light indicates when the sweep is armed and ready to be triggered.





Phase shift measurements are easily made with the Model 130C's identical horizontal and vertical amplifiers.

Specifications

Sweep generator

Internal sweep: 21 ranges, 1 μsec/cm to 5 sec/cm, accuracy within ±3%; vernier provides continuous adjustment between ranges and extends slowest sweep to at least 12.5 sec/cm.

Magnification: X2, X5, X10, X20, X50, overall sweep accuracy within ±5% for sweep rates which do not exceed a maximum rate of 0.2 μsec/cm.

Automatic triggering: base line is displayed in the absence of an input signal.

Internal: 50 cps to 500 kc signal causing 0.5 cm or more vertical deflection and also from line voltage.

External: 50 cps to 500 kc, 0.5 v peak to peak or more.

Trigger slope: positive or negative slope of external sync signals or internal vertical deflection signals.

Amplitude selection triggering

Internal: 10 cps to 500 kc, 0.5 cm or more vertical deflection signal.

External: dc coupled (dc to 500 kc), 0.5 v peak to peak or more; ac coupled (20 cps to 500 kc), 0.5 volt peak to peak or more.

Trigger point and slope: internally from any point of the vertical waveform presented on screen or continuously variable from +10 volts to −10 volts on either positive or negative slope of external signal.

Single sweep: front-panel switch permits single-sweep operation.

Vertical and horizontal amplifiers

Bandwidth: dc coupled, dc to 500 kc; ac coupled (input), 10 cps to 500 kc; ac coupled (amplifier), 2 cps to 500 kc at 0.2 mv/cm sensitivity; lower cut-off frequency (f_{co}) is reduced as sensitivity is reduced; at 20 mv/cm, f_{co} is 0.25 cps; on less sensitive ranges, response extends to dc.

Sensitivity: 0.2 mv/cm to 20 v/cm; 16 ranges in 1, 2, 5 sequence with an attenuator accuracy within ±3%; vernier permits continuous adjustment of sensitivity between ranges and extends minimum sensitivity to at least 50 v/cm.

Internal calibrator: approximately 350 cps square wave; 5 mv ±3%; automatically connected for checking gain when the sensitivity is switched to "Cal."

Input impedance: 1 megohm shunted by 45 pf, constant on all sensitivity ranges.

Maximum input: 600 v peak (dc + ac).

Balanced input: on all sensitivity ranges.

Common mode rejection (dc to 50 kc): at least 40 db from 0.2 mv/cm sensitivity; common mode signal not to exceed 4 volts peak to peak; at least 30 db from 0.5 v/cm to 20 v/cm; common mode signal not to exceed 40 volts peak to peak on the 0.5 v/cm to 2 v/cm ranges or 400 volts peak to peak on the 5 v/cm to 20 v/cm ranges.

Phase shift: within ±1° relative phase shift at frequencies up to 100 kc with verniers in "Cal" position and equal input sensitivities.

General

Calibrator: approximately 350 cps, 500 mv ±2% available at front panel.

Cathode-ray tube: hp G203E (P31) internal graticule, mono-accelerator, 3000 volts accelerating potential; P2, P7, and P11 phosphors are available; equipped with non-glaring safety glass faceplate.

Internal graticule: parallax-free 10 cm x 10 cm, marked in cm squares; 2 mm subdivisions on major horizontal and vertical axis.

Beam finder: depressing beam finder control brings trace on crt screen regardless of setting of balance, position or intensity controls.

Intensity modulation: terminals on rear; +20 volt pulse blanks crt at normal intensity.

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 90 watts.

Dimensions: 16¾" wide, 7½" high, 18⅜" deep overall (425 x 186 x 466 mm); hardware furnished for quick conversion to 7" x 19" (178 x 483 mm) rack mount.

Weight: net 32 lbs (14,4 kg); shipping 45 lbs (22,4 kg).

Price: hp 130C, $695.

Modifications: crt phosphors (specify by phosphor number): P31 standard; P2, P7, P11 available, no charge.

Options (specify by option number):

05. External graticule crt with P31 phosphor (P1, P2, P7, P11 available, please specify) in lieu of internal graticule, add $25; includes edge-lighting of external graticule.
06. Rear terminals in parallel with front-panel terminals; three-pin A/N-type connectors for horizontal and vertical signal inputs; BNC for trigger source, add $40; mating A/N connectors supplied.
13. 6-31/32" x 19" x 3/16" rack mount front panel, suitable for attaching your own handles, add $20.

Special order

Adapter kit for mounting Chassis-Trak slides, CTD-118, to the 130C; order K10-130C, add $20.

Modified 130C for ac-coupled cutoff of 2 cps rather than 10 cps, order H02-130C, price $710.

Terminals installed on rear panel for connection to deflection plates, order C41-130C, price $725.

132A DUAL-BEAM OSCILLOSCOPE

Two completely independent beams

The Hewlett-Packard Model 132A Dual-Beam Oscilloscope is designed to perform many electronic, scientific, bio-medical and mechanical measurements. Its 100 μv/cm sensitivity, 500 kc bandwidth, two completely independent beams, and low microphonics and drift assure ease and accuracy in a wide variety of applications.

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 portion of the slow sweep which corresponds to the magnified trace may be intensified for easy identification, in the same manner as with a sweep delay generator.

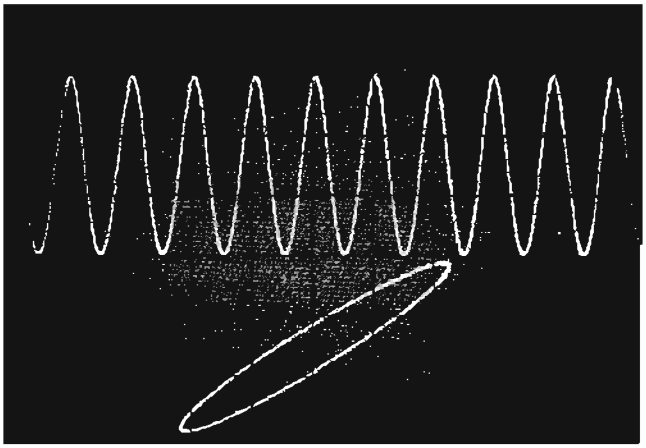


Figure 1. Simultaneous x-y and time plots are possible with Model 132A, since it has two completely independent crt beams.

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 drift stability. Where dc coupling is not needed, drift can be eliminated entirely by using internal ac coupling.

Differential operation is provided on all ranges for the elimination of common mode pickup such as 60-cycle hum. Rejection ratios as high as 40,000 to 1 (92 db) assure completely clean waveforms even in the presence of high common mode interference.

Waveforms look the same from range to range with the 132A, since the full 500 kc bandwidth is retained at all sensitivities from 1 mv/cm through 20 v/cm. At the most sensitive range, 100 μv/cm, bandwidth becomes 200 kc.

Each vertical amplifier has an output at the rear panel of the 132A, allowing the user to monitor displays with an rms voltmeter, or drive a tape recorder. Also, amplifiers may be cascaded to obtain increased sensitivity.

The 3.5 kv aluminized crt provides displays that are twice as bright as those previously available, making the Model 132A an excellent instrument for observing single-shot phenomena. Two signals may be shown with evenly balanced, bright traces and fine resolution for easy viewing and clear, sharp photographs, even at two widely differing sweep speeds as shown in Figure 2. The internal graticule of the crt eliminates parallax error, and the shatter-proof safety face-plate is non-glaring.

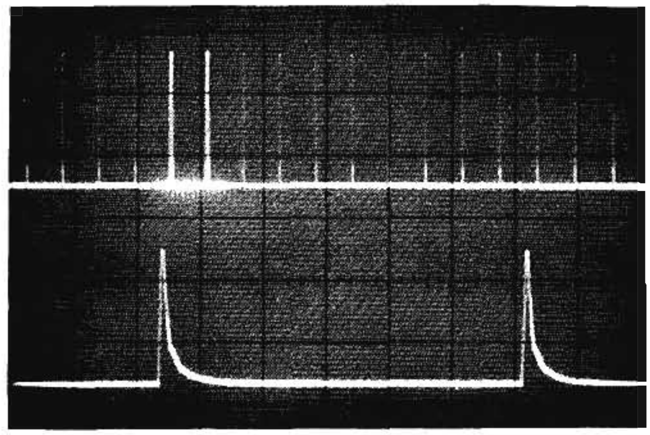
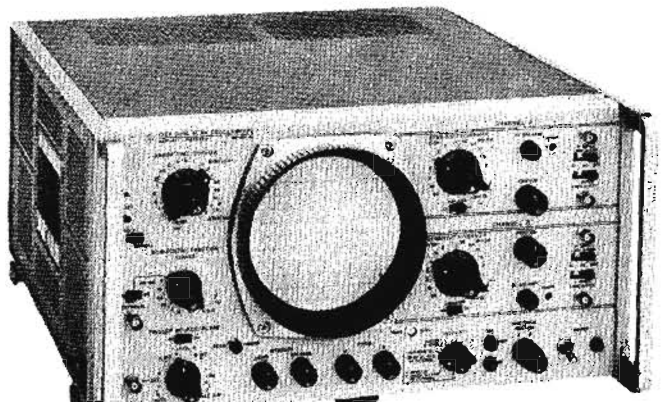


Figure 2. The same signal may be shown at two different sweep speeds, with the slower sweep intensified to show location of fast sweep.

The Model 132A is a small, light instrument with hp modular construction, allowing use either on the bench or mounted in a rack. The front-panel controls are simplified to provide easy operation. A beam finder facilitates locating an off-screen trace by simply depressing a front-panel control.

The Model 132A uses new hp-developed sandwich board modules, which allow entire circuit assemblies to be easily removed for repair or replacement. Should trouble ever develop, an amplifier or a power supply can be replaced in seconds, thus minimizing service time and allowing maximum use of the instrument.

NEW



Specifications

Identical vertical amplifiers

Sensitivity: 100 μv/cm to 20 v/cm; 17 calibrated ranges in 1, 2, 5 sequence with an attenuator accuracy within ±3%; vernier permits continuous adjustment between ranges and extends the minimum sensitivity to at least 50 v/cm.

Bandwidth

Upper limit: greater than 500 kc (10% to 90% rise time less than 0.7 μsec) on all sensitivities from 20 v/cm to 1 mv/cm with vernier in Cal; bandwidth decreases on more sensitive ranges to about 200 kc on 100 μv/cm.

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 cps at 20 mv/cm, increasing with sensitivity to lower than 2.5 cps at 0.1 mv/cm; input set to AC and amplifier set to DC: 2 cps direct or 0.2 cps with a 10X probe.

Differential input: may be selected on all ranges; the following common mode signals will not overdrive the amplifier.

Sensitivity	Input dc	Input ac
0.1 mv/cm to 0.2 v/cm	±2 v	4 v peak to peak
0.5 v/cm to 2 v/cm	±20 v	40 v peak to peak
5 v/cm to 20 v/cm	±200 v	400 v peak to peak

The following rejection ratios are typical when a sine wave, not exceeding the above limits, is simultaneously applied from a low-impedance source to the dc-coupled amplifiers.

Sensitivity range	Input coupling	Sine wave freq.	Approximate rejection ratio
0.1 mv/cm	dc	60 cps	40,000:1 92 db
0.1 mv/cm	dc	1 kc	20,000:1 86 db
0.2 mv/cm	dc	60 cps	20,000:1 86 db
1.0 mv/cm	dc	50 kc	2,000:1 66 db
1.0 mv/cm	ac	60 cps	1,000:1 60 db
0.2 v/cm	dc or ac	60 cps to 50 kc	100:1 40 db
0.5 v/cm to 20 v/cm	dc or ac	60 cps to 50 kc	35:1 30 db

Inputs: two BNC connectors for + and − polarities; ac, dc, off may be individually selected for each input; input impedance is 1 megohm shunted by 47 pf on all sensitivity ranges; maximum input voltage ±600 volts peak (dc + ac).

Amplifier outputs: a single-ended, dc-coupled output is provided for each amplifier on the rear panel; voltage output is approximately 2 v/cm from a 2 K source impedance; bandwidth is about 500 kc with a non-capacitive load.

Sweep generator

Internal sweep: may be selected for both beams or one beam only while the other is driven externally; 21 ranges, 1 μsec/cm to 5 sec/cm in a 1, 2, 5 sequence; vernier provides continuous adjustment between ranges and extends slowest sweep speed to at least 12.5 sec/cm.

Magnification: X2, X5, X10, X20, X50, may be selected for both beams or for one beam only while the other beam is sweeping unmagnified; vernier provides continuous adjustment between steps.

Sweep accuracy: ±3%, typically within ±1%; when magnified ±5%, typically within ±3%; for sweep rates which do not exceed a maximum of 0.5 μsec/cm.

Automatic triggering: base line is displayed in the absence of an input signal.

Internal: 50 cps to 500 kc; signal causing 0.5 cm or more vertical deflection; selected from either the A amplifier signal, the B amplifier signal, or from the line.

External: 50 cps to 500 kc, 0.5 to 10 volt peak to peak required.

Trigger slope: positive or negative slope of external sync signals or internal vertical deflection signals.

Amplitude selection triggering

Internal: dc (dc to 500 kc) or ac (20 cps to 500 kc); signal causing 0.5 cm or more vertical deflection; selected from either the A amplifier, the B amplifier or from the line.

External: dc (dc to 500 kc) or ac (20 cps to 500 kc) coupled, 0.5 to 10 volt peak to peak required.

Trigger point and slope: internally from crt display or from +10 volts to −10 volts on either positive or negative slope of external signal.

External trigger input impedance: ac coupled, 0.01 μf in series with 1 megohm; dc coupled, 1 megohm.

Sweep delay time: a pre-trigger of approximately 1 μsec will allow the leading edge of non-recurrent waveforms to be visible.

Single sweep: front-panel switch and pushbutton permit single-sweep operation.

External horizontal amplifier

Functions: may be used on both beams simultaneously or on one beam only while the other is sweeping unmagnified.

Sensitivity: 5 mv/cm to 2 v/cm; 9 ranges in a 1, 2, 5 sequence with an attenuator accuracy within ±3%; vernier permits continuous adjustment between ranges and extends the minimum sensitivity to at least 5 v/cm.

Bandwidth: dc to >300 kc (with vernier in Cal); ac coupled, the lower limit is 2 cps direct or 0.2 cps with 10X probe.

Input: BNC connector; input impedance is 1 megohm shunted by 47 pf, constant on all sensitivity ranges; maximum input voltage is ±600 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 kc with verniers in Cal and equal input sensitivities.

Dual-beam operation: 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 normally within ±2° for frequencies up to 10 kc with vernier in Cal and equal input sensitivities.

General

Calibrator: approximately 350 cps square wave, 0.5 v and 0.5 mv available at front panel; accuracy ±2%.

Cathode-ray tube: dual-gun crt with two independent sets of vertical and horizontal deflection plates; 3.5 kv mono-accelerator tube with aluminized P2 phosphor (P7, P11, and P31 available at no extra charge); display area for each beam is 8 cm by 10 cm; beams overlap in the center 6 cm vertical area; equipped with non-glare safety glass; internal graticule 10 x 10 cm in cm squares; vertical centerline and horizontal centerline for each beam are marked with 0.2 cm sub-divisions.

Beam finder: depressing beam finder brings traces on crt screen regardless of setting of balance, position or intensity controls.

Intensity modulation: terminals on rear; +20 volt pulse blanks crt at normal intensity; input time constant is about 125 μsec (9400 pf and 13.5 k ohms).

Power: 115 or 230 volts ±10%, 50 to 1000 cps; approximately 130 watts.

Dimensions: 16¾" wide, 9" high, 18⅜" deep overall (425 x 229 x 466 mm); hardware furnished for quick conversion to 8¾" x 19" rack mount, 16⅜" deep behind panel (222 x 483 x 416 mm).

Weight: net 41 lbs (18,5 kg); shipping 55 lbs (24,8 kg).

Price: hp 132A, $1275.

Modifications: crt phosphors (specify by phosphor number) P2 standard, P7, P11, P31 available, no charge.

Options (specify by option number)

05. External graticule with P2 (specify P7, P11, or P31, if required), add $25.
06. Rear terminals, add $45.

PLUG-IN OSCILLOSCOPES

Hewlett-Packard plug-in oscilloscopes enable the user to make a very wide variety of measurements with just one oscilloscope, since instrument characteristics can be altered simply by changing the vertical and horizontal plug-ins. Bandwidth, sensitivity, number of channels, and time base all can be tailored to exact needs; other features such as trace recorders may be added at will. All hp plug-in scopes (Models 140A, 170B, 175A) have wide bandwidth for maximum flexibility.

The Model 140A is capable of bandwidths to 20 mc. The instrument is extremely versatile, since it contains only power supplies and a calibrator. Everything else is plugged in. With appropriate plug-ins, the 140A can become a dual-channel high-frequency scope, a low-frequency scope with 10 µv/cm sensitivity, or even a time domain reflectometer for analyzing broadband systems.

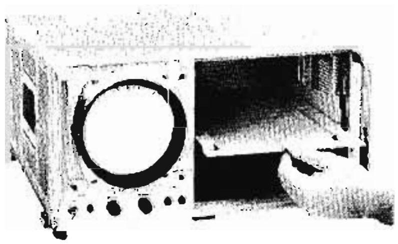


Figure 1. The design of the hp 140A oscilloscope allows a double sized dual-axis plug-in to be used when the center shield is removed from the plug-in compartment.

The 170B is a 30 mc militarized scope, also having flexible dual plug-in construction. It was designed to meet rigid military environmental standards, and is the equivalent of the AN/USM-140B.

The 175A is a 50 mc scope with unusual versatility. It accepts various multi-channel vertical plug-ins, as well as horizontal plug-ins, for recording, sweep delay or time marking displays.

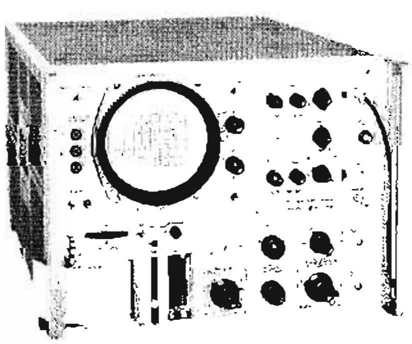


Figure 2. Dual plug-in capability adds unusual versatility to the 50 mc 175A Scope. The 1784A Plug-in produces strip-chart recordings of displays with pushbutton ease.

Cathode-ray tubes

High-frequency oscilloscopes require a cathode-ray tube (crt) which produces bright traces even at fastest sweeps with low duty cycle signals. An additional accelerating potential, known as a post-acceleration voltage, is applied between the gun and phosphor screen regions to obtain the bright traces.

The advanced design crts (see Figure 3) used in the 140A and 175A oscilloscopes permit a full 6 cm of vertical deflection at high frequencies, yet retain high sensitivity. This is obtained by using a curved, high-transmission mesh at the exit side of the deflection region. The mesh develops a spherical equipotential field which increases the sensitivity of the tube, as well as reducing defocusing of the beam and preventing stray illumination of the screen.

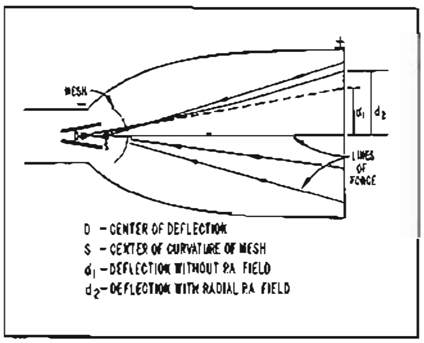


Figure 3. The hp-developed mesh crt makes possible the high performance of the 140A and 175A scopes.

A thin aluminum film on the inner face of the phosphor enhances the brilliance of all hp high-frequency scopes. This film acts as a mirror to reflect inward-directed phosphor light, light which otherwise would be absorbed in the interior of the tube.

Vertical section

While the 140A achieves maximum versatility by depending completely on the vertical plug-in for amplification, the 175A employs a main vertical amplifier to achieve sensitivities as high as 500 µv/cm at 20 mc, or 10 mv/cm at 50 mc. Single-, dual- and four-channel displays are possible simply by changing plug-ins.

Delay lines in the vertical amplifiers of the 175A, 170B and 1402A 20 MC Plug-in for the 140A enable viewing of the leading edge of the waveform which triggers the sweep. Sync takeoff occurs ahead of the delay line, allowing the sweep circuit sufficient time to get under way before the leading edge is actually displayed. Hewlett-Packard scopes use a coaxial cable delay line requiring no frequency compensating adjustments, rather than lumped-element delay lines which have many interacting adjustments.

Horizontal plug-ins

All hp plug-in scopes use horizontal as well as vertical plug-ins, allowing the user to add special capabilities to scope performance as desired. For instance, the basic instrument can be purchased without a delaying sweep, but this unit may be added later if required by unforeseen applications.

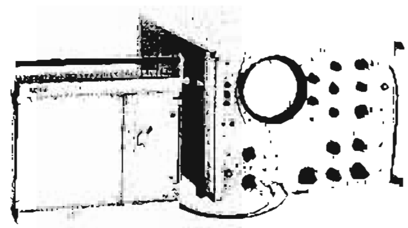


Figure 4. The display scanner plug-in for the 175A can be used to drive an external x-y recorder.

The 175A has a number of unique horizontal plug-ins which greatly expand its versatility. The auxiliary plug-in is a basic, low-cost unit which supplements the normal oscilloscope sweep circuits by providing single-sweep capability. The marker generator plug-in simplifies measurements of time intervals by providing closely spaced time interval markers. The display scanner plug-in enables recording of fast, repetitive waveforms at slow speed on an x-y or strip-chart recorder, as shown in Figure 4. Besides driving a recorder, the "slowed-down" waveform may be fed to tape recorders or wave analyzers for further detailed analysis. The 1784A recorder plug-in is a completely self-contained strip chart recorder, producing accurate records of waveforms with pushbutton ease.

The delay generator, available with all hp plug-in scopes, produces a delay time between the input trigger and the sweep start. This capability is used in a variety of ways for the study of complex waveforms. One of the modes is Mixed sweep, shown in Figure 5.

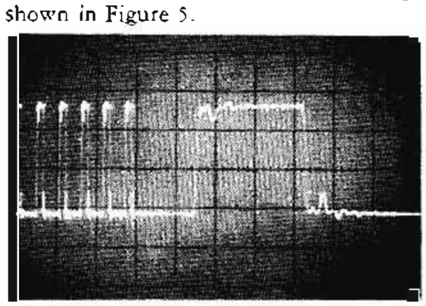


Figure 5. Train of pulses displayed in dual speed Mixed sweep by an hp delay generator plug-in.

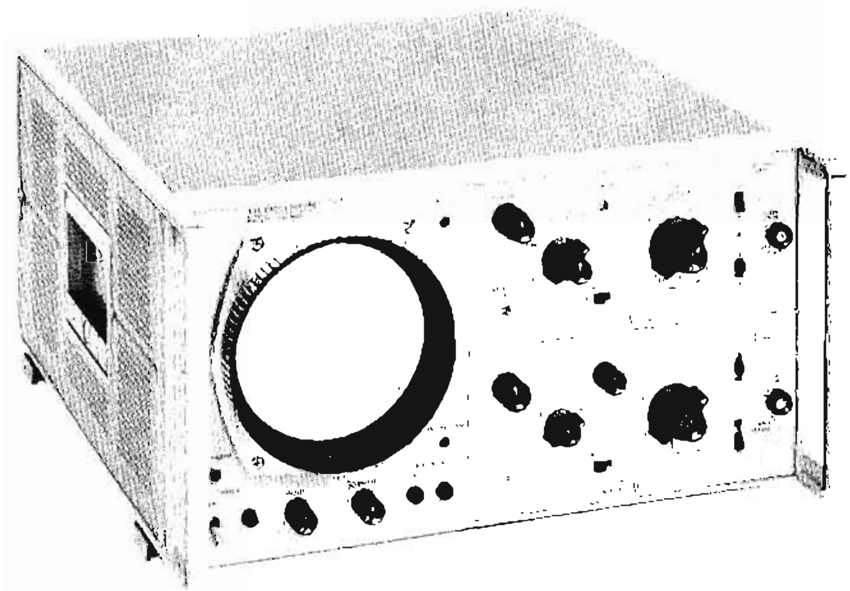
140A OSCILLOSCOPE

A single oscilloscope to do nearly any measurement task

The hp Model 140A Oscilloscope, used with the 1400 Series Plug-ins, provides both high-frequency (to 20 mc) and high-sensitivity (to 10 μv/cm) capabilities for general oscilloscope applications. A total of seven general-purpose plug-in units (five amplifiers and two sweep generators) are presently available and clearly illustrate the versatility of the 140A/1400 series combination. In addition, the design of the 140A has allowed for the use of a single, double-sized plug-in to supply information to both axes of deflection. Double-size plug-ins are available for testing broadband systems by means of pulse reflection (1415A) and for use with swept frequency oscillators (1416A).

The 140A itself consists of the essential functional blocks for both low- and high-frequency oscilloscope applications, as well as those for the sampling technique. It contains a post-accelerator cathode-ray tube, its associated power supplies and control circuitry, and the dc supplies required to power the 1400 series plug-ins. The plug-ins contain all of the deflection circuitry and work directly into the 140's crt. The newly developed 7.5 kv internal graticule crt provides bright, clear parallax-free traces on a large 10 cm x 10 cm display area. High deflection sensitivity in this crt has been achieved through a carefully shaped post accelerator field. This gives the 140A high frequency, as well as high sensitivity capabilities, maintaining a full 6 cm vertical deflection at 20 mc with the 1402A Dual Trace Amplifier and 10 cm with the lower frequency and sampling plug-ins. The deflection sensitivity of the horizontal and vertical crt deflection plates is the same, allowing two amplifiers to be used for accurate x-y measurements.

The 140A also has a convenient beam finder to locate an off-screen trace by simultaneously decreasing the deflection on both axes thus bringing the trace on screen regardless of the setting of the plug-ins' position controls.



Specifications

Plug-ins: accepts 1400 Series Plug-ins; upper compartment for horizontal axis and lower compartment for vertical axis; center shield may be removed to provide double-sized compartment for use with a single dual-axis 1400 Series unit.

Calibrator: 1 v and 10 v peak-to-peak line frequency square waves; accurate to ±1%, +15 to +35°C; to ±3%, 0 to +55°C; rise time is 0.5 μsec or less.

Beam finder: brings trace on screen regardless of setting of plug-ins' position controls.

Intensity modulation: approximately +20 v required to blank trace of normal intensity; ac-coupled input is located on rear panel.

Cathode-ray tube: 7.5 kv post-accelerator tube with aluminized P31 phosphor (P2, P7 and amber filter, and P11 available at no extra charge); equipped with non-glare safety glass faceplate; internal graticule 10 x 10 cm in cm squares; major horizontal and vertical axes have 0.2 cm subdivisions.

Power: 115 or 230 v ±10%; 50 to 60 cps; normally less than 285 w (depends on plug-ins).

Dimensions: 16¾" wide, 9" high, 18⅜" deep overall (425 x 229 x 464 mm); hardware furnished for quick conversion to 8¾" x 19" rack mount, 16⅜" deep behind panel (344 x 483 x 414 mm).

Weight: without plug-ins, net 37 lbs (16,7 kg); shipping 50 lbs (22,5 kg).

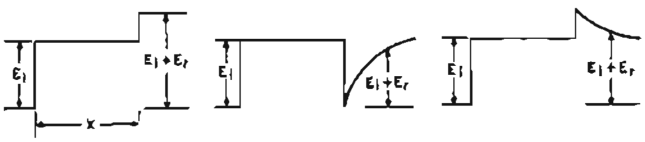
Price: hp 140A, $575.

1415A TIME DOMAIN REFLECTOMETER
1416A SWEPT FREQUENCY INDICATOR

1415A complete system for testing cables, connectors, other broadband devices; 1416A simplifies swept frequency measurements

1415A Plug-in

The 1415A Time Domain Reflectometer/140A Oscilloscope represent a completely integrated broadband system for testing cables, transmission lines, striplines, connectors and many other types of broadband devices. The 1415A itself consists of a fast-rise pulse generator, a single-channel sampler and a time base generator. The method of evaluation is essentially a "closed loop radar"; a voltage step from the pulse generator in the 1415A is fed into the test system and the reflections observed. Reflections occur each time the step encounters an impedance mismatch (i.e., discontinuity) as it travels through the system, and these reflections are added to the incident wave and displayed on the 140A's crt. The time required for the reflection to return to the 1415A's sampler locates the discontinuity; the shape and magnitude of the reflected wave indicate its nature (i.e., resistive, inductive, or capacitive) and the value of the effective R,L or C causing the mismatch.



The three displays above represent resistive, capacitive, and inductive discontinuities, respectively. Each discontinuity is located a distance X from the sampling gate of the 1415A, and that distance can be measured directly on the crt display. From the displays and relationships governing propagation on a transmission line, both qualitative and quantitative information about the system under test is immediately available.

Since discontinuities separated in distance on the line generate reflections separated in time at the monitoring point (input to the 1415A), each individual discontinuity is resolved. (The limit on the resolution of two discontinuities depends on the rise time of the pulse generator-oscilloscope system. With 1415A the system rise time is less than 150 psec, allowing a resolution between discontinuities of less than 1 inch.) The 1415A, therefore, measures cable impedances without interference from the mismatch generated at connectors. It also makes it possible to tune antennas for optimum impedance matching, to adjust broadband attenuators for uniform response, and to perform many other measurements with greater resolution and faster than with traditional microwave methods.

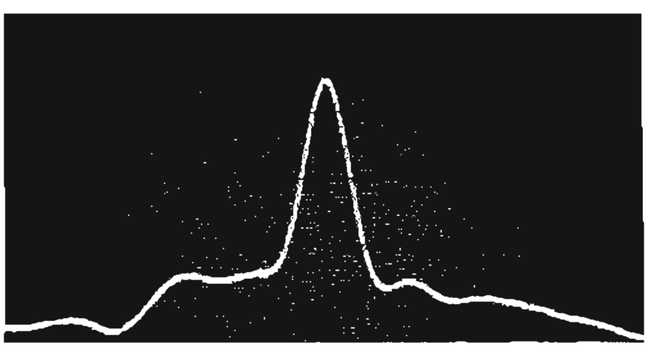


Figure 1. Magnified display of a BNC connector joining two 50-ohm cables. The horizontal axis is set at 2 cm/cm. Multiplying the 3.5 cm deflection by the reflection coefficient sensitivity of 0.01/cm, one can determine the connector has a ρ of 0.035.

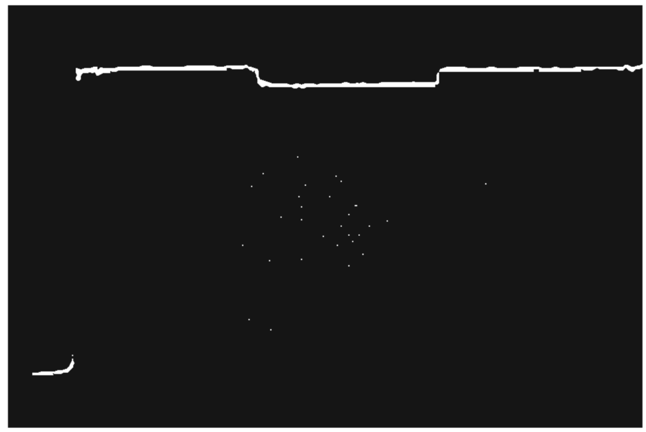


Figure 2. TDR display of a section of unknown cable spliced into a length of 50-ohm cable. Noting the distance setting of 40 cm/cm, and reflection coefficient sensitivity of 0.2/cm, one can determine the unknown cable is 120 cm long and has a Z_0 of 44 ohms. Impedance changes as small as 0.1 ohm are readily resolved when magnified.

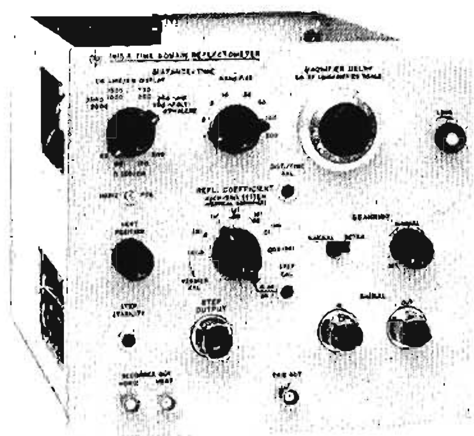
The most conventional method that has been employed to evaluate the quality of a transmission system involves measuring the standing-wave ratio (swr) by feeding a sine wave signal into the line and observing the maximum and minimum amplitudes of the standing waves on the line. A low swr for the overall system is usually desirable. When the system includes several discontinuities, however, the swr measurement does not isolate them; nor does the measurement indicate what must be done to make improvements. It also fails to demonstrate whether or not one discontinuity is generating a reflection of the proper phase and magnitude to cancel the reflection from a second discontinuity, thereby giving a false measure of the actual quality of the system. Pulse reflection testing avoids these inherent disadvantages of the swr technique, since each discontinuity is isolated for analysis. In addition, the measuring system is completely self-contained when using the 140A/1415A, eliminating the cumbersome slotted line-swr meter-signal generator system for broadband transmission.

Features incorporated in the hp 1415A include a "detailed scan" switch which increases the number of samples/cm by a factor of ten. In addition, the 1415A includes a trigger output for synchronizing external equipment and a recorder output with manual scan to preserve the trace on a dc x-y recorder. A more extensive description of the applications and measurement techniques of the hp 1415 is contained in Application Note 62, available on request.

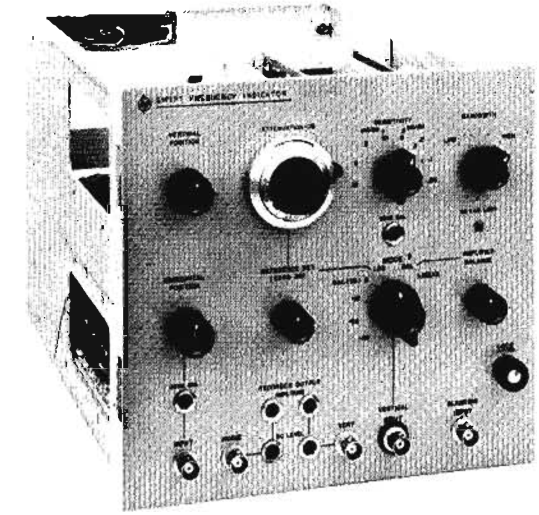
1416A Plug-in

The 1416A Swept Frequency Indicator transforms the 140A into a specialized x-y oscilloscope which speeds and simplifies microwave swept–frequency measurements. Insertion loss vs frequency measurements on ferrite isolators, attenuators and filters and return loss measurements on all types of loads are easily made, with high resolution readouts directly in db. A chopper stabilized input amplifier minimizes drift, and an adjustable bandwidth switch reduces unwanted noise. Other features include an internal db calibrator, x-y recorder outputs and a warning light that indicates when the input signal exceeds the detector square law limit.

AVAILABLE MID-1965



1415A



1416A

Specifications, 1415A*

System (in reflectometer configuration)

Rise time: less than 150 psec.

Overshoot: 5% or less overshoot and ringing (down to 0.5% in 2 nsec).

Internal reflections: <10% (does not limit resolution).

Reflectometer sensitivity: reflection coefficients as small as 0.001 can be observed.

Rep rate: 200 kc.

Signal channel

Rise time: approximately 110 psec.

Reflection coefficient: 0.5/cm to 0.005/cm in 1, 2, 5 sequence.

Input: 50 ohms, feed-thru type.

Noise and internal pickup, peak: 0.1% of step (terminated in 50 ohms).

Dynamic range: ±0.5 volt.

Attenuator accuracy: ±3%.

Step generator

Amplitude: approximately 0.25 v into 50 ohms (0.5 v into open circuit).

Rise time: approximately 50 psec.

Output impedance: 50 ohms ±1 ohm.

Droop: less than 1%.

Distance time scale

Distance scale (cm line/cm display) accuracy: 5%.

Polyethylene line ($\epsilon = 2.25$): 200 cm/cm to 2000 cm/cm.

Air line ($\epsilon = 1$): 300 cm/cm to 3000 cm/cm.

Time scale: 20 to 200 nsec/cm, ±5% accuracy.

Magnification: X1 to X200 in 1,2,5 sequence; accuracy of the basic sweep is maintained at all magnifier settings with the exception of time represented by the first 0.1 cm of the unmagnified sweep.

Delay control: 0 to 10 cm of unmagnified sweep, calibrated.

Jitter: less than 20 psec.

Power: supplied by oscilloscope.

Weight: net 7 lbs (3,2 kg); shipping 11 lbs (5 kg).

Price: hp 1415A, $1050.

* Installed in 140A Oscilloscope.

Tentative specifications, 1416A*

Operating modes: linear or logarithmic

Sensitivity: linear: 50 μv/cm to 10 mv/cm in 8 calibrated ranges in a 1, 2, 5 sequence; accuracy ±3%; log: 1 db/cm to 10 db/cm (referred to rf input into crystal detector) in 4 calibrated ranges; accuracy (after a 1/2 hour warm-up): ±0.05 db/db at 24°C (75°F), ±0.1 db/db from 10° C to +50° C.

Attenuation, db: provides a continuously variable dc offset, 0-30 db range, referred to rf input into crystal detector; accuracy ±0.15 db.

Bandwidth: linear: variable from approximately 1 kc to 30 kc in four steps; log: varies with input level.

Noise: linear: less than 250 μv peak to peak at 30 kc bandwidth, reducing to less than 75 μv peak to peak at 1 kc; log: less than 5 db at 30 db below 0 db (50 mv) reference.

Internal calibrator: four positions: 0, 10, 20 and 30 db below approximately 50 mv; accuracy ±3%.

Sweep and blanking: supplied by 690 Series Sweep Oscillator.

Recorder outputs: vertical: gain adjustable from 0 to approximately 200 mv/cm; dc level adjustable over approximately a 3 v range; horizontal: gain adjustable from 0 to approximately 100 mv/cm; dc level adjustable over approximately a 2 v range.

Inputs

Vertical: input impedance is 75 K ohms; negative signal required; maximum input signal is 200 mv; BNC connector receives output from 423A or 424A Crystal Detectors or 786D or 787D Directional Detectors (all Option 02.).

Horizontal: 0 to +15 v ramp required (supplied by 690 Series Sweep Oscillator).

Blanking: 0 to −5 volt gate (supplied by 690 Series Sweep Oscillator; early models require slight modification).

Square law limit indicator: front-panel light indicates input greater than 50 mv.

Power: supplied by oscilloscope.

Weight: net 7 lbs (3,2 kg); shipping 11 lbs (5 kg).

Price: hp 1416A, $675.

1400A DIFFERENTIAL AMPLIFIER; 1401A, 1402A DUAL-TRACE AMPLIFIERS

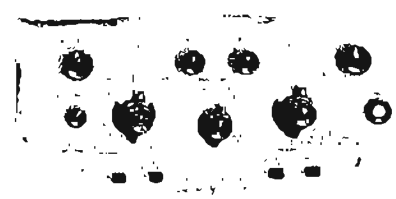
Vertical plug-ins for 140A Oscilloscope

The hp 1400A Differential Amplifier measures outputs from strain gages and transducers without preamplification. Bandwidth is selectable with a front-panel switch for elimination of unwanted noise.

The hp 1401A has two 450 kc channels, each with a sensitivity of 1 mv/cm. In the dual-trace modes, the sweep may be triggered internally from Channel A only, allowing stable traces and accurate time measurements.

The hp 1402A 20 mc Dual-Trace Amplifier has a built-in delay line, following the trigger take-off, allowing the leading edge of fast rise signals to be viewed. Internal syncing from Channel A allows convenient, accurate time measurements.

1400A, 100 µv/cm, 400 kc



1401A, 1 mv/cm, 450 kc.

1402A, 5 mv/cm, 20 mc.

Specifications, 1400A

Sensitivity: 100µv/cm to 20 v/cm; 17 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends minimum sensitivity to at least 50 v/cm; attenuator accuracy is ±3%.

Bandwidth

Upper limit: switch selected at front panel; approx. 400, 40 or 4 kc.

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 cps on 20 mv/cm, increasing with sensitivity to approx. 20 cps at 0.1 mv/cm; input set to "AC" and amplifier set to "DC": 2 cps.

Differential Input: differential input may be selected on all attenuator ranges; common mode rejection is at least 40 db on 0.1 mv/cm to 0.2 v/cm ranges, signal not to exceed 4 v p-p; at least 30 db on 0.5 v/cm to 20 v/cm ranges, signal not to exceed 40 v p-p on 0.5, 1 and 2 v/cm ranges and 400 v p-p on 5, 10, and 20 v/cm ranges; measured with a 1 kc sine wave.

Inputs: two BNC signal jacks; ac or dc coupling of either or both inputs

Input impedance: 1 megohm shunted by 45 pf, constant on all attenuator ranges.

Maximum input: 600 volts (dc + peak ac).

Internal calibrator: 6 cm peak to peak, line frequency square wave displayed when sensitivity switch set to "Cal"; accuracy ±3%.

Weight: net 4 lbs (1,8 kg); shipping 7 lbs (3,2 kg).

Price: hp 1400A, $210.

Specifications, 1401A

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 sweeps switched at approximately 100 kc, with trace blanking during switching, (5) Channel A minus Channel B.

Sensitivity: each channel has sensitivities from 1 mv/cm to 10 v/cm in 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends minimum sensitivity to at least 25 v/cm; attenuator accuracy is ±3%.

Bandwidth: input and amplifier coupling set to "DC": dc to 450 kc; input set to "DC" and amplifier set to "AC": dc to 450 kc for sensitivity from 50 mv/cm to 10 v/cm; from 1 mv/cm to 20 mv/cm, lower cutoff depends on sensitivity; approximately 0.5 cps (to 450 kc) at 20 mv/cm and 10 cps (to 450 kc) at 1 mv/cm; input set to "AC" and amplifier set to "DC": 2 cps to 450 kc.

Differential input: both inputs may be switched to one channel to give differential input.

Common mode rejection: at least 40 db on 1 mv/cm to 0.1 v/cm ranges, signal not to exceed 4 v p-p; at least 30 db on 0.2 v/cm to 10 v/cm ranges, signal not to exceed 40 v p-p on 0.2, 0.5 and 1 v/cm ranges and 400 v p-p on 2, 5 and 10 v/cm ranges; measured with 1 kc sine wave.

Input impedance: 1 megohm shunted by 45 pf.

Maximum input voltage: 600 volts (dc + peak ac).

Internal calibrator: 6 cm peak to peak, line frequency square wave displayed when attenuator switched to "Cal"; accuracy ±3%.

Polarity of presentation: + up or − up selectable for Channel A.

Weight: net 5 lbs (2,3 kg), shipping 7 lbs (3,2 kg).

Price: hp 1401A, $375.

Specifications, 1402A

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 approximately 100 kc, with trace blanking during switching, (5) Channel A and Channel B added algebraically; polarity of Channel A may be inverted to obtain differential operation.

Sensitivity: each channel has sensitivities from 5 mv/cm to 10 v/cm in 11 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends minimum sensitivity to at least 25 v/cm; attenuator accuracy ±3%.

Bandwidth: (6 cm reference signal): dc-coupled, dc to 20 mc; ac-coupled, 2 cps to 20 mc (18 nsec rise time).

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; sine wave common mode signal not to exceed 150 cm (e.g., 150 v on 1 v/cm range) or a frequency of 500 kc

Input impedance: 1 megohm shunted by 43 pf.

Maximum input: 600 volts (dc + peak ac).

Weight: net 6 lbs (2,7 kg); shipping 8 lbs (3,6 kg).

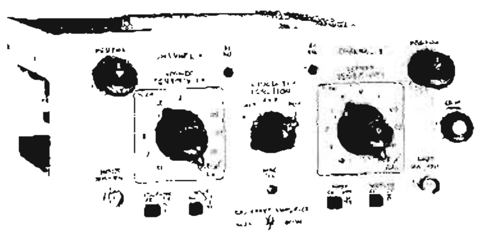
Price: hp 1402A, $550.

1403A GUARDED DIFFERENTIAL AMPLIFIER, 1405A DUAL-TRACE AMPLIFIER

Measure microvolt signals in the presence of large common mode signals; 5 mv/cm at 5 mc

NEW

1403A



1405A

1403A Guarded Differential Amplifier

The hp Model 1403A combines 10 μv/cm sensitivity with a guarded input for 106 db common mode rejection, allowing accurate measurements of low-level differential signals. The guard achieves high common mode rejection by protecting both the differential input amplifier and the two leads to the test point with a floating shield. The shield may be driven either internally by the common mode signal obtained from the amplifier for full 106 db rejection, or externally from the signal source for high common mode rejection even with unbalanced source impedances.

Bandwidth may be reduced if desired from either the high or low end with front-panel switches. This feature minimizes the effective noise, since bandwidth need only be as wide as is necessary for a given measurement.

Tentative specifications, 1403A

Sensitivity: 0.01 mv/cm to 100 mv/cm in 13 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges.

Attenuator accuracy: ±3%.

Bandwidth: 0.1 cps to 400 kc at 50 μv/cm and above (to 200 kc at 10 μv/cm and to 300 kc at 20 μv/cm); upper and lower limits may be independently selected with front-panel controls; lower: 0.1, 1, 10, 100 cps; upper: max. (greater than 400 kc) 100, 10, 1, 0.1 kc.

Sensitivity range (mv/cm)	Common mode rejection (db)	
	Internal guard drive	External guard drive (for source impedance unbalances up to 10 K)
0.01 to 0.2	106	100
0.5, 1, 2	90	90
5, 10, 20	70	70
50, 100	50	50

Differential input: differential input may be selected on all attenuator ranges; common mode rejection may be adjusted to the values given in table for signals from 10 cps to 10 kc and up to 8 volts peak to peak.

Input impedance: 10 megohms shunted by approx. 50 pf.

Input: an input switch provides a selection of input A or input −B single-ended, or A − B differential input; CMR and Cal positions are also provided for calibrating the instrument; A and B inputs, guard, and chassis ground are brought out to a special guarded connector; the guard is normally driven internally by a common mode signal amplifier; if source impedances are unbalanced, the guard may be driven by an external source, preserving high common mode rejection.

Maximum input: 600 volts (dc + peak ac).

Noise: 20 microvolts peak to peak at 100 kc bandwidth; noise is reduced as bandwidth is reduced.

Internal calibrator: 100 mv p-p, line frequency square wave displayed when sensitivity switch 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 four-terminal binding post adapter.

Price: hp 1403A, $475.

1405A Dual-Trace Amplifier

The hp 1405A provides dual-trace 5 mc bandwidth at 10 cm deflection. The two channels may be algebraically added or, by a reversal of the Channel A polarity switch, the differential signal may be viewed. 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 wide dynamic range of the 1405A in the A + B mode permits a 50 cm peak-to-peak signal to be displayed without significant distortion.

Tentative specifications, 1405A

Mode of operation: Channel A alone; Channel B alone; Channel A and Channel B on alternate sweeps; Channel A and Channel B displayed by switching at approximately 70 kc, with trace blanking during switching; Channel A and Channel B added algebraically (polarity of Channel A may be inverted to obtain differential operation).

Sensitivity: each channel has sensitivities from 5 mv/cm to 10 v/cm in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends the minimum sensitivity to at least 25 v/cm; attenuator accuracy is ±3%.

Bandwidth: dc-coupled: dc to 5 mc; ac-coupled: approx. 2 cps to 5 mc (the lower limit can be extended to about 0.2 cps with a X10 probe).

Differential operation: common mode rejection at least 40 db on the 5, 10, 20 mv/cm ranges and at least 30 db on less sensitive ranges, for all frequencies up to 50 kc; common mode signal should not exceed an amplitude equivalent to 50 cm, e.g., 0.5 v on the 10 mv/cm range.

Input: impedance is 1 megohm shunted by approx. 43 pf; maximum input voltage is 600 volts (dc + peak ac).

Weight: net 4 lbs (1,8 kg), shipping 7 lbs (3,2 kg).

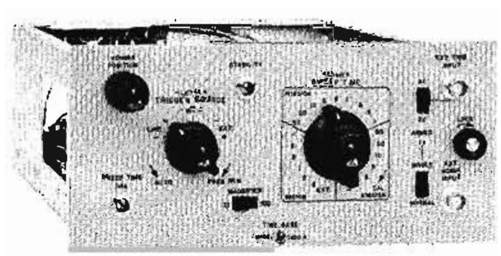
Price: hp 1405A, $325.

1420A TIME BASE, 1421A TIME BASE/DELAY GENERATOR

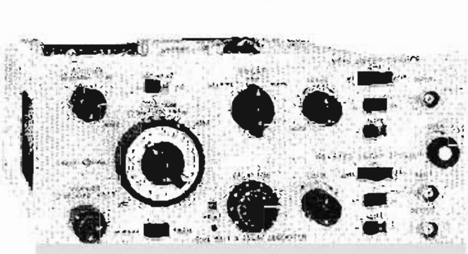
Horizontal plug-ins for 140A Oscilloscope

The hp 1420A Time Base supplies sweep time, trigger and horizontal input functions to the 140A Oscilloscope. The 1420A also features automatic triggering and a single sweep mode for transient photography.

The hp 1421A Time Base and Delay Generator extends the use of the Model 140A to exact time delay measurement between reference signal and the point of interest on a complex signal or train of pulses. Pulse-to-pulse interval measurement on a pulse train, time jitter measurement, and simultaneous slow and fast sweep signal display also are possible.



1420A



1421A

Specifications, 1420A

Internal sweep: 22 ranges, 0.5 μsec/cm to 5 sec/cm, accuracy within ±3%; vernier provides continuous adjustment between ranges and extends slowest sweep to at least 12.5 sec/cm.

Magnification: X10, accuracy ±5%; expands fastest sweep to 50 nsec/cm.

Automatic triggering: base line displayed in the absence of an input signal.

Internal: 40 cps to 500 kc, 0.5 cm vertical deflection required; also from line voltage.

External: 40 cps to 500 kc, 0.5 v peak to peak required.

Trigger slope: positive or negative slope of external trigger source signals or internal vertical deflection signals.

Amplitude selectable triggering

Internal: 10 cps to 20 mc; 0.5 cm vertical deflection required to 10 mc; slightly decreasing sensitivity to 20 mc.

External

DC coupled: dc to 20 mc; 0.5 v peak to peak required to 10 mc; slightly decreasing sensitivity to 20 mc.

AC coupled: 10 cps to 20 mc; 0.5 v peak to peak required to 10 mc, slightly decreasing sensitivity to 20 mc; input capacitor rating is 600 v dc, plus peak ac.

Trigger point and slope: internally from any point of the vertical waveform presented on screen or continuously variable from +7 v to −7 v on external signal; pos. or neg. slope.

Single sweep: front-panel switch permits single sweep operation.

Horizontal input

Sensitivity: approx. 50 mv/cm (magnifier X10) or 0.5 v/cm (magnifier X1); vernier provides continuous adjustment between ranges and extends min. sensitivity to <5 v/cm.

Bandwidth: typically better than 1.5 mc.

Input: dc coupled with a positive signal moving the beam from left to right; impedance is 1 megohm shunted by less than 50 pf.

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: hp 1420A, $325.

Specifications, 1421A

Main sweep: for displaying signals vs time where sweep delay is not required; employs only the main time base.

Range: 21 ranges, 0.2 μsec/cm to 1 sec/cm in a 1, 2, 5 sequence; accuracy is 3%; vernier provides continuous adjustment between ranges and extends slowest sweep to at least 2.5 sec/cm.

Triggering: (1421A used with 1402A Dual-Trace Amplifier).

Amplitude selection

Internal: approximately 10 cps to 15 mc from signals causing 0.5 cm or more vertical deflection, to 20 mc from signals causing 1 cm or more deflection; also from line signal.

External

DC: dc to 20 mc from signals 0.5 v p-p or more.

AC: approx. 5 cps to 20 mc from signals 0.5 v p-p or more.

Trigger point and slope: controls allow selection of level and positive or negative slope; trigger level of external sync signal adjustable from −5 to +5 volts.

Automatic: bright base line displayed in absence of an input signal; triggering internally down to 40 cps on signals having 1 cm or more vertical deflection; also on line signal; triggers externally down to 40 cps on signals 1 v p-p or more; trigger slope selectable, positive or negative.

Intensified mode: used for setting up Delayed or Mixed Sweep mode by increasing in brightness that part of Main Sweep which will be expanded to full screen in Delayed Sweep, or made magnified part of display in Mixed Sweep; rotating Delayed Sweep time switch from Off position activates intensified mode.

Delayed sweep: delayed time base sweeps after a time delay set by the Main Sweep and Delay controls.

Range: 17 ranges, 0.2 μsec/cm to 50 msec/cm in a 1, 2, 5 sequence; accuracy is 3%; vernier provides continuous adjustment between ranges and extends slowest sweep to at least 125 msec/cm.

Delay (before start of delayed sweep):

Time: continuously variable from 0.5 μsec to 10 sec.

Accuracy: ±1%; linearity is ±0.2%; time jitter is 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 <150 nsec rise time, from 1 K 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 signal after end of delay period; signals must be approximately 10 cps to 15 mc causing 0.5 cm or more vertical deflection, to 20 mc from signals causing 1 cm or more deflection.

External: delayed sweep triggered by external signal after end of delay period.

DC: dc to 20 mc from signals 0.5 v p-p or more.

AC: approx. 5 cps to 20 mc from signals 0.5 v p-p or more.

Trigger point and slope (internal and external): controls allow selection of level and positive or negative slope; trigger level of external sync signal adjustable from −5 to +5 volts.

Mixed sweep: dual sweep speed display in which main sweep drives first portion of display and the delayed sweep completes display at sweep speeds up to 100 times faster; changeover point determined approximately by delay setting.

Triggering: same as for delayed sweep.

Single sweep: any display can be operated in single sweep.

Magnifier: expands any display by 10 times; total sweep accuracy is 5%; increases fastest sweep to 20 nsec/cm.

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: hp 1421A, $625.

Option 09.: External horizontal input, add $50.

175A 50 MC OSCILLOSCOPE

High-performance 50 mc scope with versatile horizontal, vertical plug-ins

Advantages:

- Eight vertical plug-ins provide bandwidths to 50 mc, sensitivities to 1 mv/cm
- Five horizontal plug-ins offer sweep delay, pushbutton recordings, 0.5% time measurements
- Bright, sharp trace, 6 x 10 cm display
- No parallax, non-glare crt increases accuracy
- Easy to calibrate and maintain
- Positive syncing over entire bandwidth

The hp Model 175A Oscilloscope is an accurate, general-purpose test instrument that provides at least 50 mc of bandwidth for a wide variety of measurements. It has both horizontal and vertical plug-in capability, allowing the user to choose the exact features he desires.

Using an hp-developed post-accelerator crt with a large 6 x 10 cm display area, the 175A represents a major advance in oscilloscope design. Circuitry has been simplified, making it easier to adjust and maintain. In addition, extra features such as the improved triggering, logically arranged controls and convenient beam finder make the oscilloscope easier to use.

Horizontal and vertical plug-ins

The Model 175A accepts not only a wide line of vertical plug-ins, but also a series of horizontal time axis plug-ins which greatly extend its versatility. Such features as sweep delay, 0.5% time measurements, x-y recorder driving, or pushbutton recordings may be added when needed, allowing one instrument to be used for several widely differing measurements. If no special horizontal capability is needed, the inexpensive basic plug-in may be used. In this way, you need purchase only the features you desire, resulting in maximum economy. Eight vertical and five horizontal plug-ins are available. In different combinations they adapt the Model 175A to almost any test application.

12 kv crt

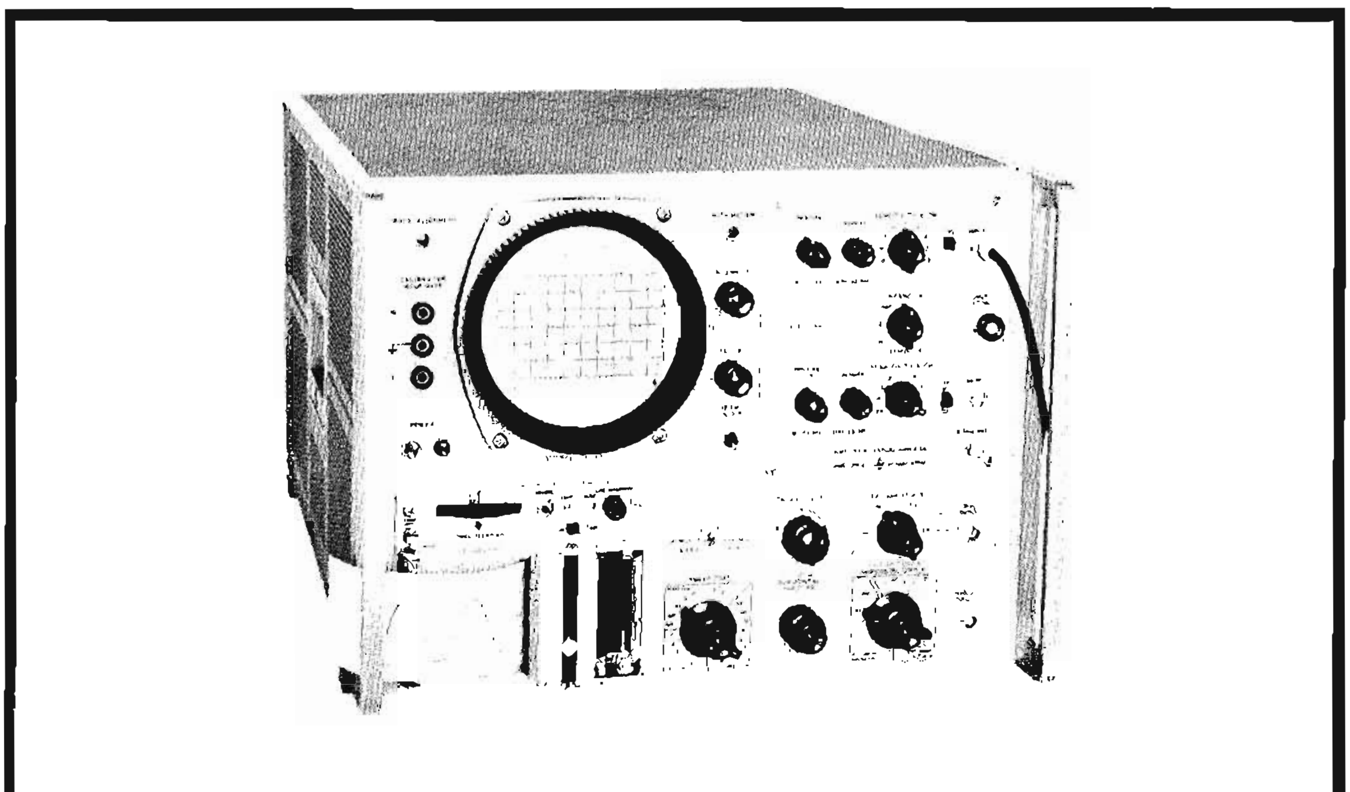
The crt, developed by Hewlett-Packard especially for the Model 175A, gives 6 cm of vertical deflection and yet has a very low level of distortion. Trace deflection defocusing, which causes widening of the trace at extremes of the sweep, is so low that the astigmatism control seldom requires adjustment, and pincushion or barrel distortion is virtually unnoticeable. The tube provides clear, sharp traces over the entire display area.

The crt is operated with a 12 kv accelerating potential which, together with the P31 aluminized phosphor, insures high brightness and writing rate. Thus, the oscilloscope is convenient to use for observing or recording single-shot phenomena, as well as repetitive signals.

In addition, the tube is equipped with an internal graticule, developed by hp, to eliminate parallax error. The optically flat non-glaring glass faceplate minimizes reflections.

Simple, Accessible Circuits

Maximum emphasis has been given to service and maintenance. Component and test-point accessibility is extremely



good, making for ease of adjustment, maintenance and service. Tubes and other components are easy to remove and replace if necessary; etched circuit boards are connected into the circuit with solderless "edge-on" connections, as shown in Figure 1, simplifying their removal and replacement.

The vertical amplifier in the 175A provides over 50 mc of bandwidth and is easy to maintain and adjust. An hp-developed coaxial delay line is used in conjunction with an amplifier containing only ten tubes, all of which are the rugged frame grid type. Such simplified circuitry reduces calibration time and increases reliability. The 175A uses a total of only seven vacuum tube and five transistor types throughout, thus minimizing the number of spares required in the maintenance or service shops.

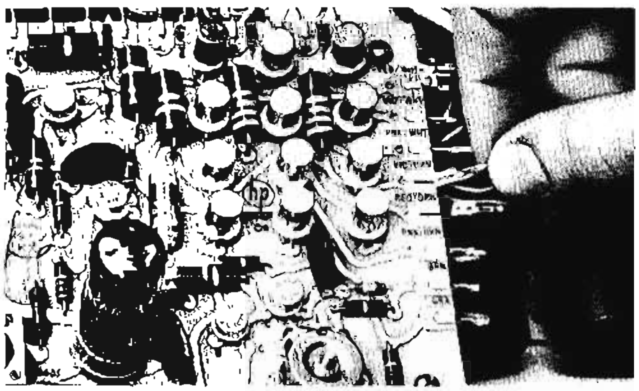


Figure 1. Etched circuitry with solderless "edge-on" connectors simplifies servicing and maintenance.

User conveniences

The Model 175A has been designed with the user in mind. Many features have been included which provide simple, convenient operation. One single preset adjustment establishes optimum triggering for almost all conditions throughout the instrument's entire bandwidth. Employing a tunnel diode circuit to achieve this performance, the preset synchronization feature of the 175A makes possible simpler and faster measurements.

Another feature of the 175A is a pushbutton beam finder which automatically locates the off-screen spot or trace. The beam finder is simple and positive in operation and easily used by inexperienced personnel.

The horizontal amplifier of the 175A provides two sweep magnifications: "times-1" for normal operation and "times-10" for examining any 1 cm section of the normal display. Further, the horizontal amplifier also can be used as an external sweep amplifier and has calibrated sensitivities of 1 volt/cm and 0.1 volt/cm.

Flexible cabinetry

The advanced cabinet design featured in the 175A contributes both to ease of use and ease of maintenance. The oscilloscope is equally suited for bench use or for rack mounting and is easily converted from one to the other whenever desired. The top, bottom and side cabinet covers can be quickly removed, allowing complete accessibility to all components and adjustments. When rack mounted, the dimensions are RETMA standard (12¼" x 19"); when used on the bench, other instruments may be stacked on top.

Specifications

Sweep generator

Range: 0.1 μsec/cm to 5 sec/cm in 1, 2, 5 sequence, 24 steps; vernier provides continuous adjustment between ranges and extends slowest sweep to at least 12.5 sec/cm.

Magnification: X1 and X10.

Accuracy: ±3%, ±5% with X10 magnifier.

Triggering: internal, ac coupled; power line; external, ac or dc coupled.

Triggering sensitivity: internal, approx. 2 mm vertical deflection at 1 mc, 2 cm at 50 mc; external, approx. 0.25 volt peak to peak at 1 mc, approx. 0.5 volt peak to peak at 50 mc.

Triggering point: controls allow selection of level and slope; trigger level of external sync signal adjustable −5 to +5 volts.

Horizontal amplifier

Bandwidth: dc coupled, dc to 500 kc; ac coupled, approx. 2 cps to 500 kc.

Sensitivity: 2 ranges; 0.1 v/cm and 1 v/cm, accuracy ±5%; vernier provides continuous adjustment between the ranges and extends minimum sensitivity to 10 v/cm.

Input impedance: 1 megohm shunted by approximately 30 pf.

Main vertical amplifier

Rise time: less than 7 nsec.

Calibrator

Type: 1 kc square wave, approx. 3 μsec rise time.

Voltage: 2 ranges, 1 v and 10 v peak to peak ±1% at 15° C to 35° C ambient, ±3% 0° C to 55° C ambient.

Cathode-ray tube and controls

Type: post-accelerator, 12 kv accelerating potential, Type G205; P31 aluminized phosphor standard, other phosphors (P2, P7, and P11) are available at no extra charge; equipped with non-glare safety glass faceplate.

Writing rate: a single 6 cm step function displaying 7 nsec main vertical amplifier rise time can be photographed with the 196B, 197A Oscilloscope Camera (pages 302, 303).

Graticule: internal, parallax-free, 6 x 10 cm, marked in cm squares; 2 mm subdivisions on major axis; front-panel recessed Scale control aligns trace with graticule.

Beam finder: depressing beam finder control brings trace on crt screen regardless of setting of horizontal or vertical position controls or intensity control.

Intensity modulation: approximately +20 volt pulse will blank trace of normal intensity (BNC connector on rear panel).

General

Power: 115 or 230 volts ±10%, 50 to 60 cps, 425 watts, maximum (depends on plug-ins used).

Dimensions: 16¾" wide, 12¼" high, 24⅜" deep over all (425 x 311 x 593 mm); hardware furnished for quick conversion to 12¼" x 19" rack mount, 22" deep behind panel (311 x 483 x 559 mm).

Weight: net 70 lbs (31,4 kg); shipping 92 lbs (41,4 kg) (with heaviest plug-ins installed).

Accessories furnished: two 10:1 voltage divider 10003A Probes; detachable power cord; rack mounting hardware.

Price: hp 175A, $1325 (without plug-ins; two plug-ins required).

Modifications: crt phosphors (specify by phosphor number): P31 standard; P2, P7, P11 available, no charge.

Option: (specify by option number):

08. Gate and sawtooth outputs, add $25.

Special order*

Specific modifications, shown below, are available on special order to meet particular situations:

1. 50 to 440 cps frequency; 115 v or 230 v ±10% line power; order H12-175A; price, $1375.
2. Line filter and modifications to meet RFI spec MIL I 16910A for portable test equipment; order H20-175A; price, $1400.
3. Adapters for mounting Chassis-Trak Detented, rotating slides, CTD 124, to the 175A; order K10-175A; price, $20.

*Further information may be obtained by contacting your regional field engineer or Hewlett-Packard directly, c/o Oscilloscope Div.

DUAL- AND SINGLE-CHANNEL PLUG-INS FOR 175A

50 mc at 50 mv/cm

1750B Dual-Trace Vertical Amplifier

Dual 50 mc channels with simplified triggering at low cost — The 1750B Dual-Trace Amplifier permits the user of the 175A Oscilloscope to compare directly two electrical signals with ease and accuracy. Its two independent vertical input amplifiers, each with a bandwidth of more than 50 mc and a maximum sensitivity of 50 mv/cm, can be used either independently or together in five different modes of operation to perform a wide variety of measurements.

For convenience in dual-channel measurements, the Channel B signal can be connected to the Model 175A external trigger input through the use of the trigger amplifier. This feature is useful where dual traces are displayed on alternate sweeps: the time relationship between the two signals is preserved, since the sweep always triggers on the same point on the Channel B signal. Also, using the trigger amplifier when in the chopped dual-trace mode assures syncing on the displayed waveform rather than the chopper. This feature thereby avoids resorting to an external triggering arrangement for either of these dual-trace presentations.

Specifications, 1750B*

Mode of operation

- **One:** Channel A alone.
- **Two:** Channel B alone.
- **Three:** Channels A and B displayed on alternate sweeps.
- **Four:** Channels A and B displayed by switching at 200 kc rate, with blanking during switching.
- **Five:** Channel A plus Channel B (algebraic addition).

Each channel

- **Sensitivity range:** 0.05 v/cm to 20 v/cm; nine calibrated ranges in a 1, 2, 5 sequence; vernier extends minimum sensitivity to approximately 50 v/cm; a sensitivity calibration adjustment for each channel is provided on the front panel.
- **Attenuator accuracy:** ±3%.
- **Bandwidth:** dc to at least 50 mc; ac coupled, approximately 2 cps to 50 mc.
- **Rise time:** less than 7 nsec.
- **Input impedance:** 1 megohm shunted by approximately 23 pf.
- **Input capacitor rating:** 600 v dc (ac-coupled input).
- **Polarity presentation:** + or − Up, selectable.

A + B input

- **Amplifier:** bandwidth and sensitivity remain unchanged; either Channel A or B may be inverted to give A − B operation.
- **Differential input:** common mode rejection at least 30 db at maximum sensitivity or at least 20 db when using attenuators (adjustable to at least 40 db, dc to 50 kc, with vernier controls).

B trigger output

- **Bandwidth:** dc to 2.5 mc.
- **Sensitivity:** will trigger Model 175A sweep externally with approximately 0.5 cm signal on crt.

General

- **Weight:** net 5 lbs (2,3 kg); shipping 7 lbs (3.2 kg).
- **Accessories furnished:** one 10121A Coaxial Cable.
- **Price:** hp 1750B, $325.

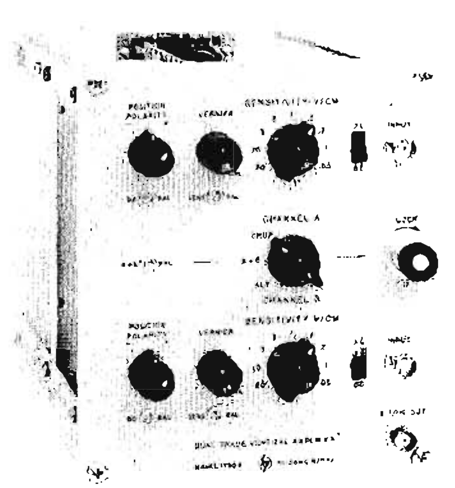
1751A Single-Channel Vertical Amplifier

Low-cost 50 mc plug-in — The hp 1751A Fast Rise Vertical Amplifier makes use of the excellent transient response of the main vertical amplifier in the hp 175A Oscilloscope. The 7 nsec rise time of the 1751A-175A combination permits accurate measurements of fast waveforms. Bandwidth is 50 mc or greater at all input sensitivities from 50 mv/cm to 20 v/cm.

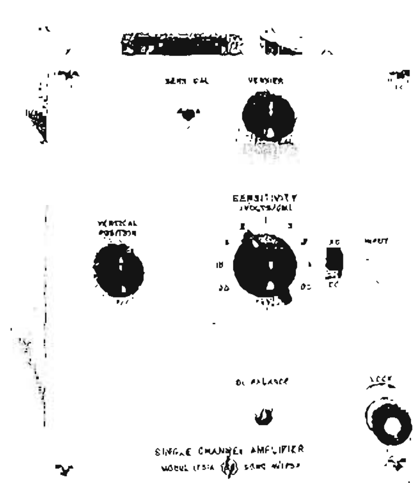
Specifications, 1751A*

- **Bandwidth:** dc coupled, dc to 50 mc; ac coupled, approximately 2 cps to 50 mc.
- **Rise time:** less than 7 nsec.
- **Sensitivity:** nine calibrated ranges in 1, 2, 5 sequence from 0.05 v/cm to 20 v/cm; vernier provides continuous adjustment between ranges and extends maximum sensitivity to at least 50 v/cm.
- **Attenuator accuracy:** ±3%.
- **Input impedance:** 1 megohm (nominal) shunted by approx. 22 pf.
- **Maximum input:** 600 v peak (ac + dc).
- **Weight:** net 5 lbs (2,3 kg); shipping 7 lbs (3, 2 kg).
- **Price:** hp 1751A, $160.

*installed in hp 175A Oscilloscope



1750B



1751A

1752A, 1752B VERTICAL AMPLIFIERS

5 mv/cm at low cost

1752A High-Gain Vertical Amplifier

5 mv/cm sensitivity with differential input. Model 1752A High-Gain Vertical Amplifier enhances the versatility of your 175A Oscilloscope by increasing its sensitivity to 5 mv/cm. The rise time of the 175A/1752A combination is less than 20 nsec; this improves to approximately 16 nsec on the less sensitive ranges.

Differential input with at least 40 db common mode rejection is included for the ranges 5 mv/cm through 50 mv/cm. Isolation between the two input points is at least 80 db. Substantial feedback in the transistor amplifier stage provides unusually high stability characteristics for a high gain amplifier.

Specifications, 1752A*

Sensitivity: 5 mv/cm to 20 v/cm in 12 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjusment between calibrated ranges and extends min. sensitivity to at least 50 v/cm; a sensitivity calibration adjustment is provided on the front panel.

Attenuator accuracy: within ±3%.

Dual Inputs: two signal input jacks (BNC); ac or dc coupling of either input selectable with front-panel switch; isolation between inputs at least 80 db.

Differential input: ac or dc differential input may be selected in the ranges of 5 mv/cm to 50 mv/cm; common mode rejection at least 40 db at 1 kc; common mode signal should not exceed 4 v p-p.

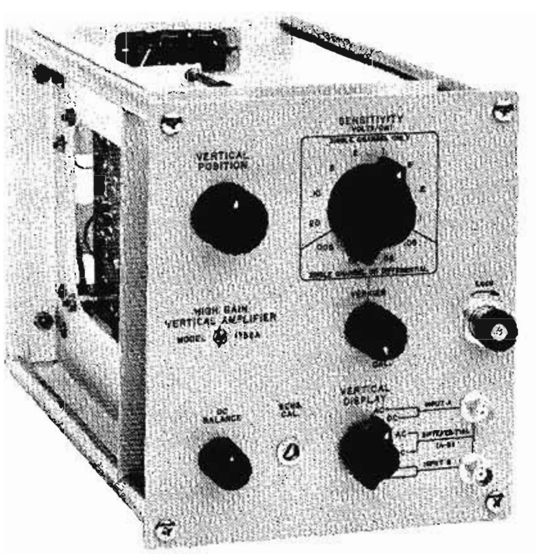
Bandwidth: dc coupled: 50 mv/cm range and above, dc to 22 mc; 20 mv/cm to 5 mv/cm range, dc to 18 mc; ac coupled: identical except down 3 db at approx. 2 cps.

Input impedance: 1 megohm with less than 35 pf shunt capacitance.

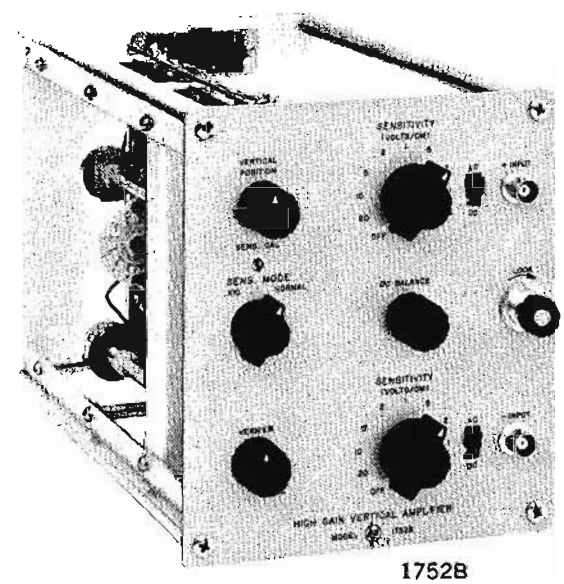
Maximum Input: 600 v peak (ac + dc).

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: hp 1752A, $225.



1752A



1752B

1752B High-Gain Vertical Amplifier

5 mv—dc to 30 mc: 50 mv—dc to 40 mc. The 1752B has a bandwidth of 30 mc at 5 mv/cm and 40 mc at 50 mv and above. Also, separate attenuators on each input allow signals of widely differing amplitudes to be displayed differentially.

Specifications, 1752B*

Sensitivity

- **Normal mode:** 50 mv/cm to 20 v/cm in 9 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends min. sensitivity to at least 50 v/cm.
- **X10 mode:** 5 mv/cm to 2 v/cm in 9 calibrated ranges in a 1, 2, 5 sequence; vernier allows continuous adjustment between calibrated ranges and extends min. sensitivity to at least 5 v/cm.
- **Input attenuator accuracy:** ±3%.

Bandwidth

- **Normal mode:** dc coupled: dc to 40 mc (9 nsec rise time) on all sensitivity ranges; ac coupled: 2 cps to 40 mc.
- **X10 mode:** dc coupled: dc to 30 mc (12 nsec rise time) on all sensitivity ranges; ac coupled: approx. 2 cps to 30 mc.

Input: either single-ended or differential input may be selected on any sensitivity range for both normal and X10 modes; coupling may be ac or dc on either or both inputs, and separate attenuators enable differential operation with signals of widely differing amplitudes.

Input impedance: 1 megohm shunted by no more than 23 pf for each channel; for differential operation, input impedance is 2 megohms shunted by less than 12 pf.

Maximum input voltage: 600 volts (dc + peak ac).

Isolation between inputs: 60 db at 40 mc in Normal mode and at 30 mc in X10 mode.

Common mode rejection: at least 40 db at max. sensitivity, or 30 db on attenuated ranges, for common mode signals up to 3 v p-p.

Dynamic range: amplifier can be overloaded by 18 cm without causing noticeable signal distortion.

Vertical position control: ±9 cm range.

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Price: hp 1752B, $285.

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* Installed in hp 175A Oscilloscope.

1754A, 1755A VERTICAL AMPLIFIERS

40 mc 4-channel, 50 mc high-gain plug-ins

1754A Four-Channel Amplifier

The 1754A provides four 40 mc channels for logic circuit testing. Trace identifiers and selectable triggering from any channel add to convenience of operation.

Specifications, 1754A*

Mode of operation: any channel or combination of channels may be displayed; channels displayed on alternate sweeps or by switching at 1 mc rate with blanking during switching.

Each channel

Sensitivity range: 0.05 to 20 v/cm; 9 calibrated ranges in 1, 2, 5 sequence; vernier extends min. sensitivity to at least 50 v/cm.

Attenuator accuracy: ±3%.

Bandwidth: dc coupled, dc to 40 mc; ac coupled, approx. 2 cps to 40 mc.

Rise time: less than 9 nsec.

Input Impedance: 1 megohm shunted by approximately 22 pf.

Maximum Input: 600 v peak (ac + dc).

Polarity: + up − up, selectable for each channel.

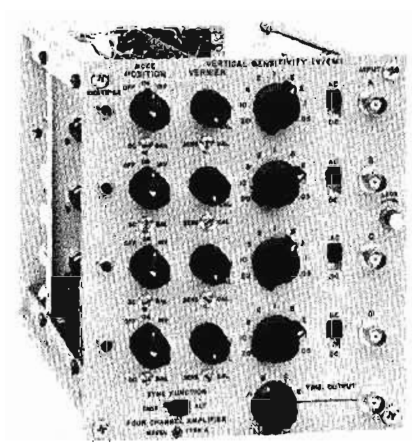
Triggering output: dc coupled output suitable to trigger 175A externally.

Trigger amplifier bandwidth: dc to 8 mc in Alt.

Weight: net 7 lbs (3,2 kg); shipping 9 lbs (4 kg).

Accessory furnished: 1012A Cable, 8 inches long (23 cm), BNC-to-BNC.

Price: hp 1754A, $595.



1754A

1755A

1755A Dual-Trace Amplifier

The 1755A permits dual-trace measurement of low-level, high-frequency signals. Dual-trace sensitivity is 1 mv/cm at 20 mc (500 μv/cm single Channel in A + B) and 10 mv/cm at 50 mc (7 nsec rise time). Triggering from Channel B adds convenience to dual-trace operation.

Specifications, 1755A*

Mode of operation: 1.) Channel A alone; 2.) Channel B alone; 3.) Channel A and B displayed on alternate sweeps; 4.) Channel A and B displayed by switching at 200 kc rate; display blanking during switching; 5.) Algebraic addition of Channel A and B.

Each channel

Sensitivity range

X1 mode: 0.005 v/cm to 5 v/cm in ten calibrated ranges in a 1, 2, 5 sequence; attenuator accuracy ±3%; vernier allows continuous adjustment between ranges and extends minimum sensitivity to 12.5 v/cm; a sensitivity calibration adjustment for each channel is provided on the front panel.

X5 mode: increases maximum sensitivity to 1 mv/cm; accuracy ±5%.

X5AC mode: provides internal ac coupling to eliminate drift with the same sensitivity and accuracy as X5 mode.

Bandwidth and rise time

Sensitivity	Bandwidth
10 mv/cm to 5 v/cm (Sens mode X1)	dc to 50 mc (7 nsec)
5 mv/cm (Sens mode X1)	dc to 40 mc (9 nsec)
1 mv/cm (Sens mode X5)	dc to 20 mc (17 nsec)

Lower bandwidth limit, ac coupled: X1, approx. 2 cps; X5, approx. 2 cps; X5AC, approx. 4 cps.

Input Impedance: 1 meg shunted by approx. 22 pf.

Maximum input: 600 v peak (dc + peak ac).

Algebraic Input: both channels, with their respective attenuators, may be switched to one common channel for algebraic addition; the attenuators may be on different settings to allow combining of signals of different amplitude.

Common mode rejection: 20:1 or more from dc to 50 kc with verniers in Cal position; common mode rejection can be increased to greater than 100:1 by adjusting vernier controls for minimum common mode amplitude; maximum common mode signal allowable on any sensitivity setting is 10 cm.

B trigger output

Sensitivity: 0.5 cm of crt display in the X1 Sens mode (2.5 cm in X5 and X5AC) will provide sufficient signal to externally trigger the 175A; the signal amplification from the channel B Input to B Trig Out is approx. 60 with no input attenuation.

Output Impedance: 200 ohms nominal.

Bandwidth: dc to approximately 5 mc.

Weight: net 5 lbs (2,3 kg); shipping 7 lbs (3,2 kg).

Accessory furnished: one 10121A Coaxial Cable, 8 inches long (23 cm), BNC-to-BNC.

Price: hp 1755A, $575.

* Installed in hp 175A Oscilloscope.

HORIZONTAL PLUG-INS FOR 175A OSCILLOSCOPE

Five plug-ins increase scope versatility

1780A Auxiliary Plug-in

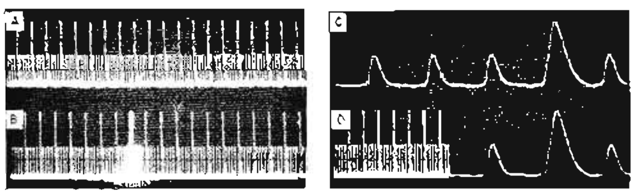
Maximum economy — The hp Model 1780A Auxiliary Unit allows the 175A Oscilloscope to perform all the functions of a standard instrument at minimum cost. Using this plug-in, the full range of the oscilloscope's internal sweeps are available for repetitive sweep operation. In addition, single-sweep operation with either internal arming or arming by an external signal is provided.

Specifications, 1780A*

Sweep occurrence: Normal or Single Sweep.
Sweep arming: internal or by external pulse, 1 to 200 μsec, approximately +15 to +25 volts peak.
Input connector: BNC.
Weight: net 1 lb (0,45 kg); shipping 4 lbs (1,8 kg).
Price: hp 1780A, $25.

1781B Sweep Delay Generator

Measure time intervals and jitter on pulse trains accurately — The 1781B extends the use of the 175A Oscilloscope to exact time delay measurement between reference signal and the point of interest on a complex signal or train of pulses. Pulse-to-pulse interval measurement on a pulse train and time-jitter measurement are also possible.



Four types of sweeps possible with the Model 1781B are shown in the photographs above. They are: (a) Main Sweep; (b) Delaying Sweep (with the section covered by the delayed main sweep intensified); (c) Main Delayed Sweep (with the intensified section expanded to fill the entire horizontal 10 cm); and (d) Mixed Sweep (in which the trace is initially driven by the delaying sweep and then by the fast main sweep).

Sweep and delay functions

Main Sweep: This function "locks out" the 1781B Sweep Delay Generator, allowing the 175A to perform as a normal oscilloscope.

Delaying Sweep: Provides fast setup by intensity modulating those pulses to be displayed in Main Delayed Sweep position.

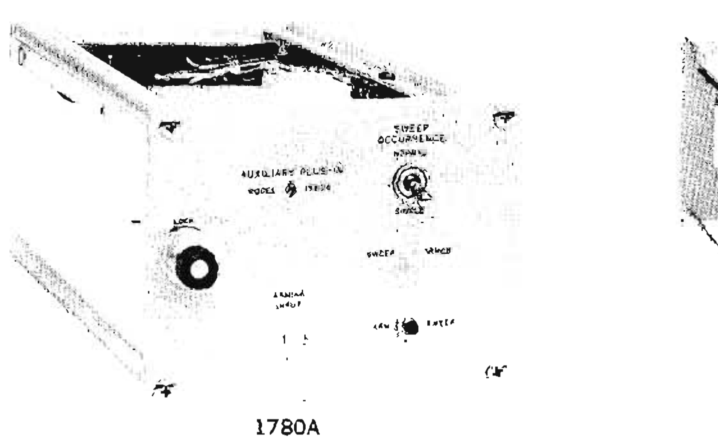
Main Delayed Sweep: The start of the scope trace is delayed from the reference signal by an amount determined by the settings of the front-panel delay controls; thus, time jitter between the reference signal and the observed signal can be conveniently measured, since the observed signal can be magnified using a fast main sweep. If desired, the 175A sweep may be armed to give a trace that is steady and free from jitter even when jitter is present in the signal being observed.

Mixed Sweep: In this function the display is presented using two separate sweep speeds. It is possible to view simultaneously the character of a pulse train and also "peel off" and expand individual pulses for minute inspection at the end of the train.

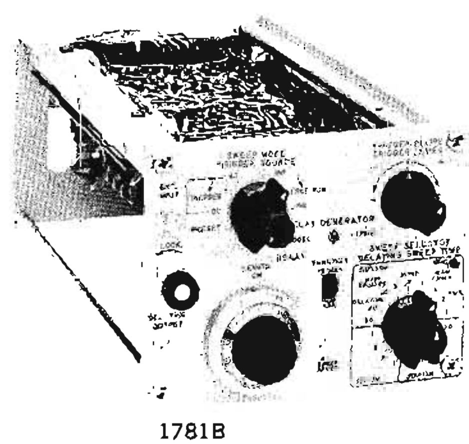
Main Single Sweep: A switch on the hp 1781B allows single-sweep operation of the 175A sweep generator for displaying transient and other single-shot phenomena.

Specifications, 1781B*

Delay time: 0.5 μsec to 10 sec delay time is the product of the Delaying Sweep setting in sec/cm and the Delay Length setting in cm.
Delaying sweep: 2 μsec/cm to 1 sec/cm; 18 calibrated ranges in a 1, 2, 5 sequence.
Delay length: 0 to 10 cm (the physical location, in cm from the beginning of the trace, to the point at which the main sweep is triggered).
Delay accuracy: ±1%, 2 μsec to 0.1 sec/cm ranges; ±3%, 0.2, 0.5, 1 sec ranges; ±0.2% linearity.
Jitter: ±0.002% of max. delay on each range (1 part in 50,000).
Delay function: (a) trigger main sweep; (b) arm main sweep.
Triggering: internal, ac coupled (2 mm or more vertical deflection), power line or external, ac or dc coupled (0.5 volt p-p or more).
Triggering point: controls allow selection of level and slope; trigger level of external sync signal adjustable −5 to +5 volts.
Sweep selector: (a) main sweep; (b) delaying sweep—brightened segment of trace indicates time relationship between delaying sweep display and main sweep display; (c) main delayed sweep; (d) mixed sweep; (e) single sweep of main sweep.
Delayed trigger output: approximately 10 volts positive.
Weight: net 4½ lbs (2,2 kg); shipping 7 lbs (3,2 kg).
Price: hp 1781B, $325.



1780A



1781B

1782A Display Scanner

Record or digitize crt displays — Used with an x-y recorder, the Model 1782A Display Scanner permits permanent recordings of the waveform displayed on the scope crt. These high-resolution recordings are not limited by the width or height of the crt display, but may be as large as the physical size and sensitivity of the recorder will allow.

The 1782A employs sampling techniques to transform high-speed phenomena to the bandwidth of conventional x-y recorders such as the Moseley 7050. An automatic pen stabilizer provides a nearly constant writing rate to the recorder, so that fast pulses may be recorded faithfully in minimum time. For quick correlation of time between the crt trace and recorder, the recorder pen position is identified by an intensity change on the crt trace.

This plug-in also may be used with auxiliary equipment to digitize a crt display. The desired portion of the trace is scanned once or repeatedly and the output reduced in frequency for recording or analysis. To digitize the display you can monitor the output with a digital voltmeter. Or by scanning with an external sawtooth you can use the 1782A to reduce high-speed signals to low-speed signals for recording on audio tape recorders.

Specifications, 1782A*

Vertical output: approximately 200 mv/cm; gain and dc level are independently adjustable.

Horizontal output: output level, adjustable to zero volts; output amplitude, adjustable from 0 to +15 volts.

Bandwidth: at least 30 mc when installed with a 40 mc vertical plug-in amplifier.

Scanning: manual, internal (with pen speed either stabilized or linear) or external, requires 0 to 15 v for full scan; maximum external scan rate, 1 kc.

Scanning time: internal, linear: approximately 1.5 minutes; internal, with pen speed stabilized: approximately 20 seconds when displaying time base only.

Oscilloscope sweep speed: from fastest sweep to 5 msec/cm; signal repetition rate greater than 20 cps.

Remote pen lift: lifts pen when switching from Record to Arm Recorder.

Weight: net 5 lbs (2,3 kg); shipping 8 lbs (3,6 kg).

Price: hp 1782A, $425.

Special order: pulse train amplitudes can be digitized and recorded with 1% accuracy using the H02-1751A Single-Channel Amplifier and Scanner plug-in. Since the H02-1751A is a vertical plug-in containing a scanner, the horizontal plug-in compartment is left free for plug-ins such as the 1781B Delay Generator. Price: hp H02-1751A, $455. See your hp field engineer for further details.

1783A Time Mark Generator

Intensity-modulated time markers, 0.1 to 10 μsec, ±0.5% accuracy — The 1783A Time Mark Generator provides synchronized intensity-modulated time markers on the 175A Oscilloscope trace. The markers simplify rise time and pulse duration measurement and also are useful for scope photographs, for calibrating certain sweeps or for operation between calibrated sweep ranges.

The time mark generator is triggered by the sweep gate of the oscilloscope and thus is synchronized to the crt trace. Markers are selectable at 10, 1 or 0.1 μsec intervals, accuracy ±0.5%. Marker duration is a function of the adjustable intensity but always less than 40% of marker interval. The time markers also may be switched to a front-panel BNC output jack, a feature useful for calibrating oscilloscope sweep speeds or external equipment.

Specifications, 1783A*

Intensity modulation

- **Range:** 10 μsec, 1 μsec or 0.1 μsec intervals.
- **Accuracy:** ±0.5%.
- **Presentation:** trace-intensifying marks with duration a function of intensity, but always less than 40% of marker interval.
- **Synchronization:** triggered by sweep gate; synchronized to crt presentation.

External output markers

- **Range:** 10 μsec, 1 μsec or 0.1 μsec intervals.
- **Accuracy:** ±0.5%.
- **Amplitude:** 0 to 1 v peak (positive) into open circuit, adjustable.
- **Waveform:** positive polarity clipped sine wave with duration a function of amplitude, but always less than 40% of marker interval.
- **Output impedance:** approximately 75 ohms.

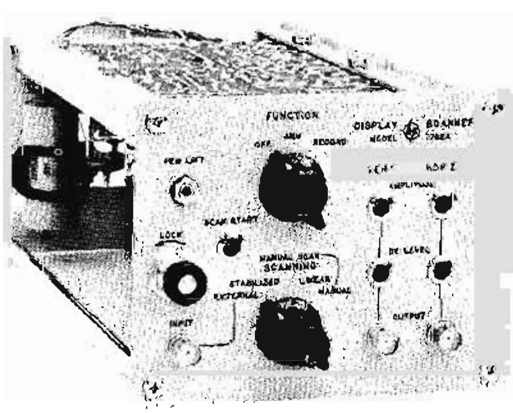
Functions

- **Time marker:** Off, marker de-energized; Output, markers provided at BNC output jack; Display, markers provide synchronized intensity modulation of display (intensity modulation control set to Internal).
- **Intensity modulation:** external, provide input for normal intensity modulation; internal, allows intensity modulation of trace (time markers set to Display).

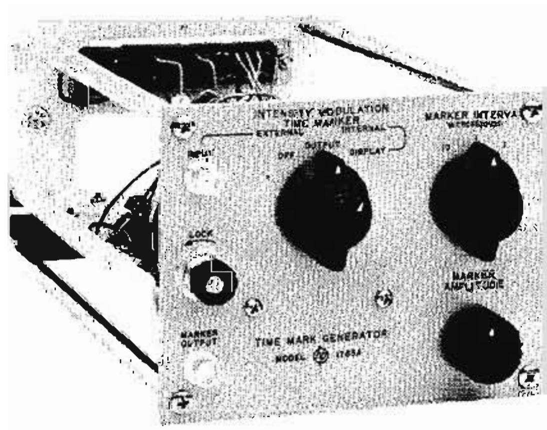
Weight: net 3½ lbs (1,6 kg); shipping 6 lbs (2,7 kg).

Price: hp 1783A, $130.

*installed in hp 175A Oscilloscope



1782A



1783A

1784A RECORDER, 175A SERVICE ACCESSORIES

Recorder offers accurate, permanent records with pushbutton ease

The unique hp 1784A Recorder Plug-in provides an easy, inexpensive way to permanently record displays on the Model 175A Oscilloscope. Simply push a button, and the displayed repetitive waveform is recorded on a strip chart, complete with graticule markings.

The plot is made on special heat-sensitive paper by a heated stylus. Records are permanent, and the paper is easy to write on and attach in notebooks for future reference. The cost of each record is 1/20th the price of a photograph. Lab reports now can be well documented with many waveforms, and a record of actual performance characteristics can be shipped to customers along with an instrument.

The Model 1784A will record signals up to 30 mc when used with a 40 mc or greater vertical plug-in, and faithfully reproduce displays with better than 3% accuracy. With noisy signals, the 1784A eliminates random deviations, actually producing a recording that is much clearer than the crt display.

Multiple traces can easily be recorded by rewinding the paper as many times as desired. By using the thumb wheel, the starting point of the traces can be made to coincide, thereby preserving time correlation.

Tentative Specifications, 1784A*

Repetition rate: signal rep rates of 60 cps or greater and sweep speeds faster than 2 msec/cm are required; (usable below these limits, but with progressively greater distortion in the form of small steps on the plot).

Bandwidth: dc to greater than 30 mc when installed with a plug-in having 40 mc or greater bandwidth.

Writing rate: waveforms with slopes of at least 50:1 can be recorded with a continuous line.

Recording cycle time: approximately 20 seconds.

Accuracy of recording: recording duplicates crt display with better than 3% accuracy.

Line width: approximately 0.25 mm at normal line intensity.

Recording paper: hp recording Permapaper®, imprinted with a strip-chart replica of the 175A crt graticule; the chart marking is approx. 20% smaller than the graticule marking; one 75 ft. roll of paper, (hp Part no. 9281-0083), gives more than 125 recordings; price, $1.50 per roll.

Weight: net 8½ lbs (3,8 kg); shipping 11 lbs (5 kg).

Price: hp 1784A, $775.

175A Service Accessories

10400B, 10402A Plug-in Extenders — The 10400B, 30-inch (762 mm) extension cable for 170B and 175A vertical plug-ins; price: hp 10400B, $25. The 10402A, 24-inch (610 mm) extension cable for 170B and 175A time axis plug-ins; price: hp 10402A, $35.

10403A Alignment Attenuator — The 10403A Alignment Attenuator may be used to check and adjust input capacity. It is adjustable to match the input of any of the 175A or 170B vertical amplifiers. Price: hp 10403A, $35.

10404A Vertical Test Adapter — The 10404A Vertical Test Adapter provides a convenient means of applying a known voltage to the main vertical amplifier of the 175A for setting the gain. Price: hp 10404A, $15.

10405A Vertical Response Tester — The 10405A Vertical Response Tester provides a fast step function for use in establishing and adjusting the "step" response of the main vertical amplifier in the 175A. This plug-in generates a positive or negative 2 v adjustable pulse with a rise time less than 1 nsec, 250 cps. Price: hp 10405A, $125.

* Installed in hp 175A Oscilloscope.

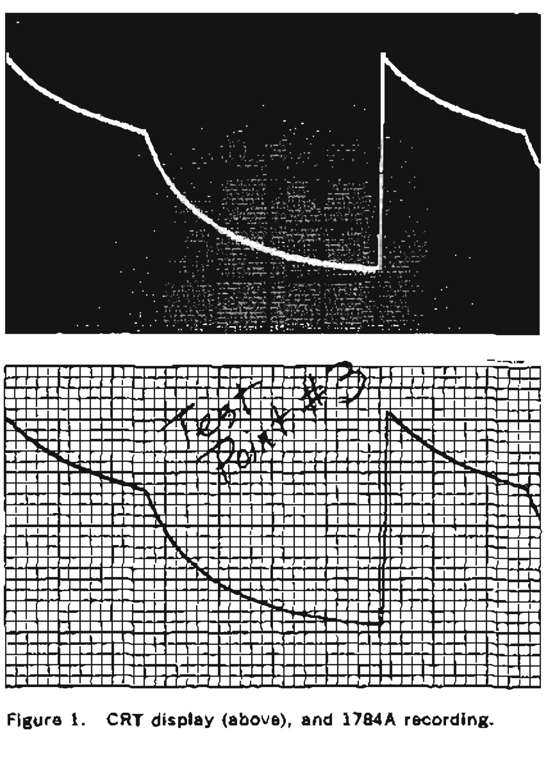
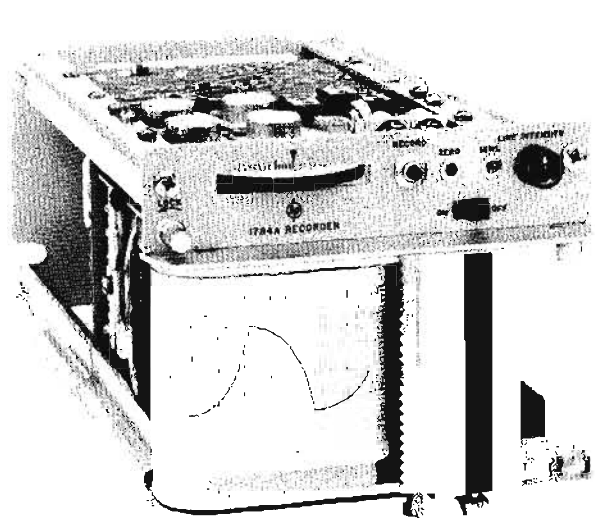


Figure 1. CRT display (above), and 1784A recording.

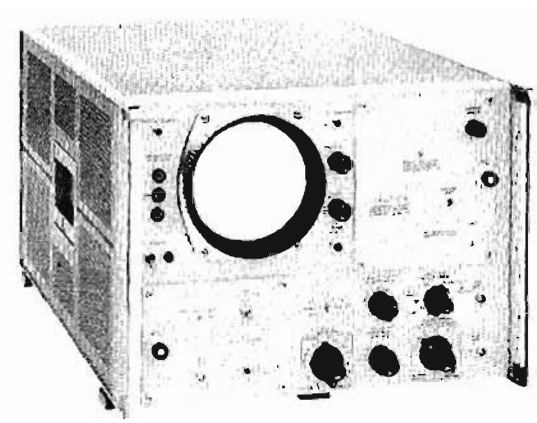
NEW



1784A

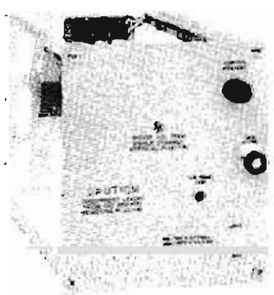
H30-175A HIGH-WRITING-RATE OSCILLOSCOPE; K01-, K02-1759A SINGLE-CHANNEL VERTICAL PLUG-INS

Ideal scope for transient study; plug-ins with 2.5 nsec rise time



H30-175A

NEW



K01-1759A

H30-175A, usable with all 175A plug-ins

The hp Model H30-175A Oscilloscope is a standard 175A equipped with a special high-writing-rate crt. The very small spot size provided by the crt, together with the 12 kv accelerating potential and P11 phosphor, allows high-speed transients to be easily recorded on film.

All 1700 series horizontal and vertical plug-ins may be used with the Model H30-175A, since the standard Model 175A 6 cm by 10 cm internal graticule has been scaled down to match the lower sensitivity of the special crt. Thus, front-panel time and voltage calibrations remain direct reading, and all of the advantages of the standard Model 175A and its plug-ins are retained. Additional dashed-line graticule divisions have been added to take advantage of the increased vertical range obtainable with the K01- and K02-1759A Fast-Rise-Time Vertical Plug-ins (see Figure 1).

The special crt used in the Model H30-175A may be purchased separately and installed in any standard 175A to obtain high-writing capability. No modification is necessary.

Specifications, H30-175A

(Specifications same as standard 175A except as follows)

Cathode-ray tube

Type: post-accelerator, 12 kv accelerating potential; P11 aluminized phosphor standard; equipped with non-glaring safety glass faceplate.

Writing rate: a single 6 cm step displaying 2.5 nsec rise time (obtained with K01- or K02-1759A Vertical Plug-in) can be photographed with the 196B or 197A Oscilloscope Camera.

Graticule: internal, parallax-free, 4 cm x 6 cm internal graticule calibrated vertically in eight divisions and horizontally in ten divisions.

Price: hp H30-175A, $1355; high-writing-rate crt alone (hp Stock No. 5083-0842), $190.

K01-, K02-1759A Plug-ins

On special order, the K01- and K02-1759A Plug-ins are available for increased rise time capability, achieved by connecting the input signal directly to the crt through a modified circuit network.

Expressly suited for studying fast nuclear transients is the combination of either plug-in with the special-high-writing-rate crt for the Model 175A. For the specialty plug-in units, the hp 175A should be externally triggered 200 nsec in advance of the observed signal.

Specifications, K01-, K02-1759A

Direct-coupled plug-in

Rise time: approximately 2.5 nsec.

Sensitivity: approximately 3 v per division.

Input impedance: 50 ohms.

Weight: 2 lbs (0,9 kg); shipping 5 lbs (2,3 kg).

Price: hp K01-1759A, $100.

AC-coupled plug-in

Rise time: approximately 2.5 nsec.

Sensitivity: 1.5 v per division.

Input impedance: approximately 50 ohms.

Sag: approximately 10% in 2 μsec (ac coupled).

Weight: 2 lbs (0,9 kg); shipping 5 lbs (2,3 kg).

Price: hp K02-1759A, $200.

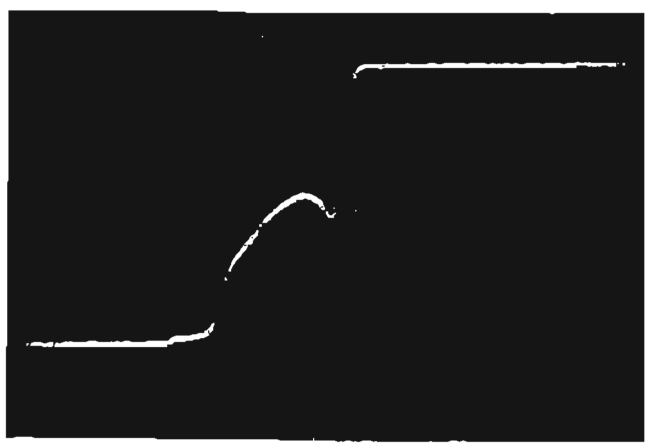


Figure 1. Single-shot transient displayed on Model H30-175A (sweep speed 50 nsec/cm).

170B,BR OSCILLOSCOPES

Militarized high-frequency oscilloscope offers plug-in versatility

Advantages:

- Meets rugged military environmental requirements.
- Maximum versatility through horizontal and vertical plug-ins.
- Simplified operation; convenient beam finder.
- Equivalent to the AN/USM-140B.

The Model 170B Oscilloscope combines militarized design with conventional controls and dual plug-in capability for ruggedness, versatility and utmost convenience—making it ideally suited for shipboard use, mobile calibration vans and system checkout installations.

Besides accepting vertical amplifier plug-ins, the oscilloscope also accepts *time* axis plug-in units for increased versatility, which enables you to add such features as sweep delay when needed and to adapt one instrument for several widely different measurements.

The 170B main vertical amplifier has a bandwidth greater than 30 mc but is easier to maintain and adjust through the use of a fixed delay line and simple amplifier circuitry.

The oscilloscope is easy to operate even by inexperienced personnel. The pushbutton beam finder feature allows quick location of off-screen trace. Simplified triggering and color-coded controls add to the user convenience.

Specifications, 170B,BR

(with 166F installed)

Sweep generator

Internal sweep: 24 ranges, 0.1 µsec/cm to 5 sec/cm; ±3%; vernier extends slowest sweep to 12.5 sec/cm.

Magnification: 7 calibrated ranges, X1, X2, X5, X10, X20, X50 and X100; increases fastest sweep speed to 0.02 µsec/cm; accuracy: X1, X2 and X5, ±3%; X10 and X20, ±5% to 0.02 µsec/cm; X50 and X100, ±10% to 0.02 µsec/cm.

Triggering: internal, power line or vertical input signal (2 mm or more vertical deflection); external, 0.5 v peak to peak or more.

Trigger point: positive- or negative-going voltage: trigger level of external sync signal adjustable from −30 to +30 volts.

Sawtooth output: approximately −40 to +40 volts.

Gate output: approximately +45 volt pulse.

Horizontal amplifier

Bandwidth: dc to 1 mc.

Sensitivity: 7 ranges, 0.1 v/cm to 10 v/cm; vernier extends minimum sensitivity to 25 v/cm.

Input impedance: 1 megohm shunted by 30 pf.

Main vertical amplifier

Bandwidth capability: 35 mc.

Calibrator

Type: 1000-cycle square wave, 1 µsec rise and decay time.

Voltage: 18 calibrated ranges, ±3%; 0.2 millivolt to 100 volts peak to peak.

Current: 5 ma peak to peak, ±3%.

Cathode-ray tube

Type: aluminized 5 BH post-accelerator crt; normally supplied with P2-AL Phosphor; specify P31-AL if required, no extra charge; accelerating potential, 10 kv.

Filter supplied: compatible with phosphor, green with P31 and P2, amber with P7 and blue with P11.

External graticule (standard): 10 cm long x 4 cm high, marked in centimeter squares; 2 mm subdivisions on horizontal and vertical axes; controlled edge lighting.

Internal graticule (optional): graticule in same plane as phosphor; eliminates parallax error; equipped with non-glaring safety faceplate.

Deflection plate connection: pin type terminals.

Deflection sensitivity: approximately 7 v/cm.

General

Power: 115 or 230 volts, ±10%, 50, 60 or 400 cps, approximately 500 watts maximum.

Dimensions: cabinet: 14⅝" high, 19" wide, 22⅛" deep (372 x 483 x 672 mm); rack mount: 12¼" high, 19" wide, 22" deep behind panel (310 x 483 x 559 mm).

Color: grey enamel in accordance with Type III Class 2 of Specifications MIL-E-15090.

Weight: net 85 lbs (38 kg); shipping 108 lbs (49 kg) (includes two plug-ins).

Accessories furnished: one 10001A (red boot), one 10001C (black boot) (both marked MX 2817A/U) Test Probes, 10:1 voltage division; Power Cable Assembly, 170A-16AL-(N) (marked CX 4704/U), 8 ft. (244 cm) minimum.

Price: hp 170B (cabinet) or hp 170BR (rack mount), $2350.

Options

03. Internal-graticule crt in lieu of standard crt, add $30.

Tilting detented slides for 170BR rack mount are available on special order. Price installed, add $105.

Special order

E03-170B to include the 170B with 162C, 166F and 10165B Front Cover with accessories; price, $2905 (same as AN/USM-140B without source inspection and tubes, transistors, transformers and blower motor)

E03-170BR to include the 170BR with 162C and 166F; price, $2875 (same as AN/USM-141A without source inspection of tubes, transistors, transformers and blower motor; includes accessories but not front cover).

AN/USM-140B and AN/USM-141A (rack mount) are also available to those who have prime government contract numbers; contact your local hp field engineer for details.

Plug-ins for the 170B

Three militarized plug-ins for the hp 170B Oscilloscope increase measuring flexibility by adding dual-trace, high-gain and sweep delay capabilities. These vertical and time-axis plug-ins provide expandable measurement capability as it is needed.

162C Dual-Trace Amplifier

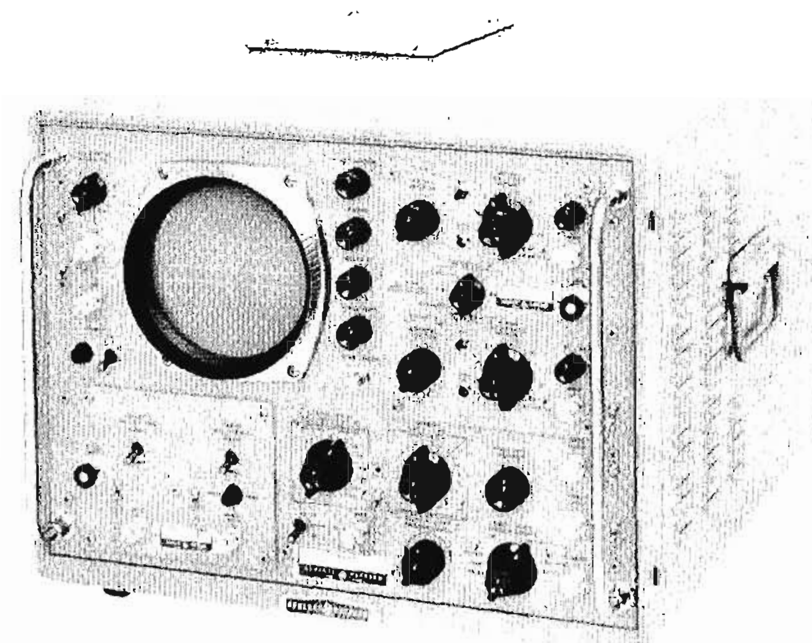
Model 162C Dual-Trace Amplifier permits you to view two electrical phenomena simultaneously with 20 mv/cm sensitivity. A and B channel amplifiers may be electronically switched by chopping or by alternate sweeps. Differential operation allows undesirable common mode signals, such as hum, to be eliminated.

Specifications, 162C*

Each channel

Sensitivity range: 0.02 v/cm to 20 v/cm; ten calibrated ranges in 1, 2, 5 ... sequence; vernier extends minimum sensi-

* installed in 170B Oscilloscope



170B

tivity to at least 50 v/cm, and provides continuous adjustment between ranges; a sensitivity calibration adjustment for each channel is provided on the front panel.

Attenuator accuracy: ±3%.

Bandwidth: dc coupled, dc to 22 mc, less than 0.016 μsec rise time; ac coupled, 2 cps to 22 mc.

Input impedance: 1 megohm (nominal) shunted by <30 pf.

Polarity of presentation: + up or − up, selectable.

Maximum input: 600 volts (dc + peak ac).

Differential input: both input attenuators may be switched to one channel to give differential input; the input attenuators may be set separately to allow mixing signals of different levels.

Amplifier: Channel A; amplifier input A − input B.

Common mode rejection: at least 40 db at maximum sensitivity, at least 30 db when using attenuators.

Weight: net 6 lbs (2,7 kg); shipping 13 lbs (5,9 kg).

Price: hp 162C, $420.

166E Sweep Delay Generator

The 166E extends the use of the 170B Oscilloscope to exact time delay measurement between reference signal and the point of interest on a complex signal or train of pulses; pulse-to-pulse interval measurement on a pulse train; time-jitter measurement; and with Mixed Sweep, simultaneous slow and fast-sweep signal display.

Specifications, 166E*

Delay time: 1 μsec to 10 sec.

Delaying sweep: 18 calibrated ranges for 2 μsec/cm to 1 sec/cm in 1, 2, 5... sequence.

Delay length: 0.5 to 10 cm; when delaying sweep functions in place of main sweep, setting in cm controls occurrence of main sweep; when delayed main sweep is used, setting acts as multiplier on Delaying Sweep setting to determine total delay time.

Delay accuracy: ±1%, 2 μsec to 0.1 sec ranges; ±3%, 0.2, 0.5, 1 sec ranges; ±0.2% linearity, all but 2, 5 and 10 μsec ranges; ±5% linearity, 2, 5 and 10 μsec ranges.

Jitter: less than 0.01 μsec or ±0.005% of total delay.

Delay functions: (a) trigger main sweep; (b) arm main sweep.

Triggering: internal, power line or vertical input signal (0.5 cm or more vertical deflection); external, 0.5 v peak to peak or more.

Triggering point: positive- or negative-going voltage; trigger level of external sync signal adjustable −30 to +30 volts.

Sweep selector: (a) Main Sweep; (b) Delaying Sweep; brightened segment of trace indicates time relationship between delaying sweep display and main sweep display; (c) Main Sweep delayed; (d) Mixed Sweep.

Delayed trigger output: approximately 20 volts positive.

Weight: net 4½ lbs (2,9 kg); shipping 8½ lbs (3,8 kg).

Price: hp 166E, $435.

166F Auxiliary Plug-in

The hp Model 166F Auxiliary Plug-in fits into the receptacle for 170B Oscilloscope time axis plug-in units and provides the connections for normal oscilloscope operation. The 166F permits full flexibility of the oscilloscope's internal sweeps with all available vertical amplifier plug-ins.

Specifications, 166F*

Intensity modulation: internal or external; +20 v pulse will blank crt trace of normal intensity.

Sweep occurrence: normal or single sweep.

Sweep arming: internal or external.

External arming pulse required: 1 to 200 μsec, approximately +15 to +25 volts.

Weight: net 1 lb (0,45 kg); shipping 5 lbs (2,25 kg).

Price: hp 166F, $35.

* installed in 170B Oscilloscope

SAMPLING OSCILLOSCOPES

Sampling oscilloscopes use a stroboscopic approach to reconstruct the input waveform from samples taken during many recurrences of the waveform, thereby circumventing the bandwidth limitations of conventional cathode-ray tubes and amplifiers. This technique is illustrated by the waveforms of Figure 1. In reconstructing a waveform, the sampling pulse "turns on" the sampling circuit for an extremely short interval (approximately 50 psec in the 188A) and the waveform voltage at that instant, shown by the dots on the waveform, is measured. The crt spot is positioned vertically to the corresponding voltage amplitude.

ramp reaches the voltage level being held by the horizontal deflection circuits, a comparator circuit generates a pulse which initiates the sampling pulse. The horizontal waveform then steps to a higher level.

The "real time" ramp controls the time base of the reconstructed display. The sweep speed control is labeled in nsec or μsec per cm and is operated in conventional fashion. Sampling density is determined by the voltage change between steps of the horizontal deflection waveform. Sampling density, therefore, remains constant despite any changes in the sweep speed or sweep magnifier controls, even on the fastest sweeps.

Sampling circuit

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

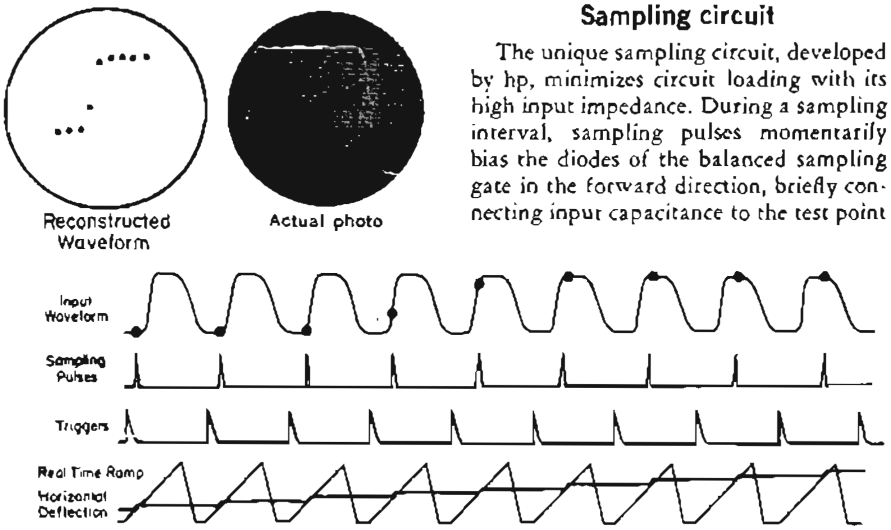


Figure 1. Waveforms pertinent to operation of sampling oscilloscope. Actual photo has 1000 samples which blend into continuous line.

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. Also, small fluctuations on large signals may be examined in detail because of the exceptional dynamic range of the sampling scope. For instance, any part of a 2 v signal may be viewed with 0.4 mv/cm sensitivity by adjusting vertical position.

The progressive delay in the sampling pulses is derived from the other waveforms shown in Figure 1. Trigger pulses initiate the "real time" ramp, which functions during the portion of the input waveform being examined. When the

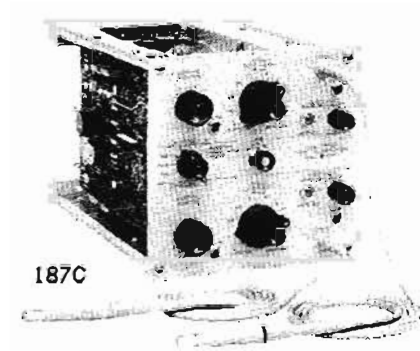
(the balanced bridge minimizes coupling of the sampling pulses back into the test circuit). The capacitance is charged slightly toward the new voltage level. This charge is then amplified to the original value present in the test circuit and fed back to the input. In effect, the circuit detects the "error" signal between the previous and the new samples and nulls out the difference. High sensitivity and gain stability are thus achieved.

Dual-trace operation

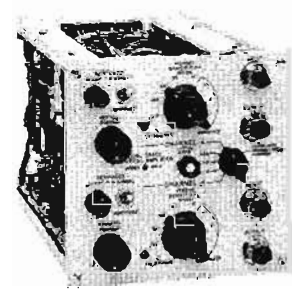
Separate sampling circuitry and inputs are provided for each channel of the 187C and 188A dual-trace plug-ins. Sampling operations are carried out in both channels simultaneously. This allows simultaneous display of two input waveforms with no displacement in their phase relationship.

Circuit measurement considerations

The high-impedance probes supplied as integral parts of 187C Dual-Trace



Amplifier enable circuit probing in the usual sense with minimum circuit disturbance. When working with fast pulse or high-frequency circuits, however, the inductance of any conductor can have an appreciable effect (about 0.025 μh per inch), and stray capacitance can resonate with this inductance. The 187C probes have short, low-inductance probe pins to minimize this effect. Compatible accessories, such as dc blocking capacitors and voltage dividers, are available for extending the usefulness of the probes.



188A

The Model 188A, with its feed-thru samplers, was designed especially for use with 50-ohm coaxial systems at frequencies up to 4 gc (to 10 gc at reduced amplitude). The signal is fed into the input and reappears at the output connector, where it may be fed back into the system under test. This method allows transmission lines and other circuits to be monitored without termination. The feed-thru system is also excellent for time domain reflectometry (see pages 278, 279), since it does away with reflection-producing tees and attenuators.

Another vertical channel option is the hp 186A Switching Time Tester Plug-in, a self-contained test system for evaluating transistor, diode and tunnel diode switching times, and for other pulse response measurements.

185B SAMPLING OSCILLOSCOPE

Convenient, versatile scope for picosecond measurements

Advantages:

- Plug-ins for fast-rise, high Z probing and switching time measurements
- Bright 10 x 10 cm display of picosecond signals
- High-impedance samplers to minimize circuit loading
- Sweep speeds to 40 psec/cm for extreme time resolution
- Positive synchronization to 1000 mc
- Non-parallax, no-glare, internal-graticule crt
- Easy to operate; conventional scope controls with beam finder, x-y recorder output and time and amplitude calibrators

The hp Model 185B Oscilloscope brings low-frequency scope convenience to high-frequency measurements. Employing a sampling technique using special Hewlett-Packard high-speed diodes, the hp 185B offers extremely wide bandwidth while maintaining large, bright, easy-to-read displays. Three plug-ins are available for the Model 185B, giving it added versatility for fast measurements. In addition to the Model 187C 1000 MC Dual-Trace Amplifier for use where fast rise and minimum loading are important, a Model 186A Switching Time Tester is offered for semiconductor and general-purpose measurements, and a Model 188A Amplifier for very fast rise measurements.

Direct-reading conventional controls

With the 185B, direct observation of fast pulse phenomena on a 5-inch crt is possible without optical magnification or use of photography because of the full 10 cm x 10 cm display area, fast sweep speeds and high brightness independent of duty cycle. Bright traces are obtained for pulse rates as low as 50 cps, and the hp internal graticule completely eliminates parallax error and minimizes glare.

A calibrated 10-position sweep time selector and 7-position sweep magnifier provide direct reading of time. Because sample density and trace duty cycle are independent of magnifier setting, there is no decrease in brightness and accuracy with magnification. For convenience, a beam finder control quickly locates an off-screen trace and facilitates its positioning to center screen, no matter how far the position or intensity controls may have been misadjusted.

Versatile triggering and scanning

The 185B Oscilloscope will synchronize on signals with repetition rates from 50 cps to 1000 mc. The triggering range can be extended to 10 gc with the 1103A Trigger Countdown. At most sweep speeds the maximum sampling rate is 100 kc, and on these sweeps the oscilloscope synchronizes independently on each input signal from 50 cps

185B with 188A

to 100 kc, presenting a steady display even when signals are randomly spaced. Above 100 kc, hold-off and countdown circuitry is used to provide synchronization on a subharmonic of the input signal, thereby allowing synchronization beyond 1000 mc and beyond 10 gc when using the Model 1103A Trigger Countdown.

Additionally, 15 mv trigger sensitivity is available for triggering on small signals. The sync circuitry is designed so that virtually no signal is fed back to upset the operation of the system under test.

The Model 1100A Delay Line is available for viewing the leading edge of the signal used to trigger the 185B. Versatility can be further increased with a combination of the delay line and a resistive divider probe that increases input resistance.

Sync pulse output and recorder output

The fast-rise, 1.5 volt sync pulse conveniently allows external circuit triggering or testing; triggering the test circuit with the sync pulse automatically synchronizes the oscilloscope and enables the signal's leading edge to be viewed without a delay line. To test high-speed circuits, the sync pulse may be free-run at about 100 kc or externally controlled by such instruments as the hp 211A (page 334).

Inherent in the sampling technique is the ability to reduce the advance rate for x-axis scan, so that even slow-speed x-y recorders can track. Both x and y recorder outputs are provided, as are three types of scanning: Record (automatic 60-second x-axis scan), Manual (front-panel control), External (programmed scanning, rear terminals provided).

Specifications

Horizontal

Sweep speeds: 10 ranges, 10 nsec/cm to 10 μsec/cm, accuracy within ±5%; vernier gives continuous adjustment between ranges and increases fastest unmagnified sweep speed to 4 nsec/cm; accuracy of the basic sweep is maintained at all magnifier settings with the exception of time represented by first 0.25 cm of the unmagnified sweep.

Magnification: 7 calibrated ranges: X1, X2, X5, X10, X20, X50 and X100; increases maximum calibrated sweep speed to 100 psec/cm; with vernier, maximum sweep speed is further extended to 40 psec/cm; intensity and sample density are not affected by magnification.

Delay control: three-turn variable delay control is available when using magnified sweep; permits any portion of unmagnified trace to be viewed.

Minimum delay (input trigger to start of trace): less than 120 nsec at 100 nsec/cm sweep and faster; on slower sweep speeds, minimum delay increases to a maximum of approximately 5 μsec on the 10 μsec/cm range.

Sample density: continuously adjustable from approximately 70 samples per trace to 1000 samples per trace.

Scanning functions

Internal: x-axis driven by internal staircase for normal viewing.
Record: x-axis driven by internal slow ramp; approximately 60 seconds for one trace.
Manual: x-axis driven by manual scan control knob.
External: x-axis driven by external voltage; approx. 12 v for 10 cm deflection, input impedance >25 K.

Trigger functions

Normal-external trigger

Amplifier: ±150 mv to ±2 v peak; up to 5 v rms or 100 v peak will not damage input circuit.
Width: 5 nsec at minimum amplitude.
Rate: 50 cps to 1 mc on the 10 μsec/cm sweep speed setting; maximum rate increases to 100 mc on the 200 nsec/cm and faster ranges.
Jitter: less than 30 psec or 0.02% of time represented by the unmagnified sweep, whichever is greater (fast rise signals); reduced approx. 5:1 in the "smoothed" response position.
Input impedance: 50 ohms nominal, dc coupled; reflection from a step of 0.5 nsec rise time is less than 8%.

Sensitive-external trigger

Amplitude: ±15 mv to ±200 mv peak; up to 5 v rms or 10 v peak will not damage input circuit.
Width: 5 nsec at minimum amplitude.
Rate: same as Normal.
Jitter: same as Normal.
Input impedance: 50 ohms nominal, dc coupled.

High frequency

Input frequency: 50 mc to 100 mc for sweep speeds of 200 nsec/cm and faster.
Sensitivity: 200 mv peak to peak; operates from smaller signals at some increase in jitter; up to 5 v rms or 15 v peak will not damage the input circuit.
Jitter: 5% of cycle from 50 to 400 mc; 8% of cycle from 400 to 1000 mc.
Internal signal appearing at input connector: less than 15 mv peak to peak, approximately 10 mc.
Input impedance: 50 ohms nominal, ac coupled; reflection from a step of 0.5 nsec rise time is less than 8%.

Sync probe: the 10200B (use with any trigger function) increases input impedance to more than 750 ohms, ac coupled; it reduces sensitivity by approx. 4:1 at 10 mc and higher, and by approx. 20:1 at low frequencies.

Sync pulse output

Amplitude: positive; at least 1.5 volts into 50 ohms.
Rise time: less than 2 nsec.
Width: approximately 5 μsec.
Recurrence: one pulse per sample.

Calibrator

Voltage: 20 mv, 100 mv, 200 mv and 1000 mv; ±3%.
Time: approximately 5 μsec burst of 50 mc sine wave; frequency accuracy ±2%.

X-Y recorder output: x- and y-axis signals are available at rear terminals in all positions of the scanning control; in the Manual and Record positions the voltage can be used to make pen recordings with a conventional x-y recorder.
Horizontal output: approx. 0 v at start of sweep to +13 v at end of sweep (1.2 v/cm); source impedance approx. 20,000 ohms.
Vertical output: approx. +1 v at top of graticule, −1 v at bottom (0.2 v/cm); source impedance approx. 10,000 ohms.

General

Cathode-ray tube: 3 kv mono-accelerator crt with P2 phosphor.
Internal graticule (standard): graticule in same plane as phosphor eliminates parallax; 10 cm x 10 cm display area; 1st and 9th cm lines (10% and 90%) along with major axes, have 2 mm subdivisions.
Power: 115 or 230 v ±10%, 50 to 60 cps, approx. 300 w.
Dimensions: cabinet: 14⅝" high, 19" wide, 22⅛" deep (372 x 483 x 562 mm); rack mount: 12¼" high, 19" wide, 21" deep behind panel (313 x 483 x 234 mm).
Weight: net 75 lbs (34 kg); shipping 99 lbs (44.5 kg), includes plug-in.
Accessories furnished: 10200B Sync Probe.
Price: hp 185B (cabinet) or 185BR (rack mount), $2000 (vertical plug-in required).
Modifications: crt phosphors (specify by phosphor number): P2 standard; P7, P11, P31 available, no charge.
Option 05.: E. G. with P2 (specify P7, P11, P31 if required), add $25.
Special: Channel A versus channel B; x-y display available by ordering H04-185B; price $2185.

187C DUAL-TRACE AMPLIFIER

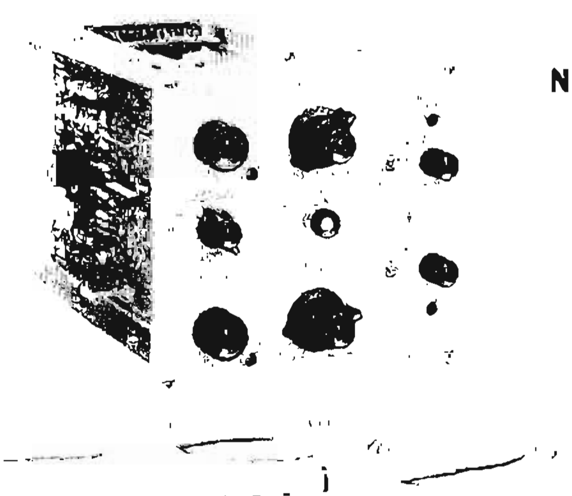
Versatile 1 gc probes

The hp Model 187C Dual-Trace Amplifier has a 350 psec rise time (1000 mc), while permitting easy, accurate circuit probing with small high-impedance probes. With the new "slenderized" probes, measurements may be made in crowded circuits. Convenience is further enhanced with the attachment of the hp 10216A Isolator or the hp 10214A 10:1 Divider to provide an extra long small-diameter probe. An input impedance of 100 K shunted by 2 picofarads insures maximum versatility for circuit probing or bridging transmission lines.

A maximum calibrated sensitivity of 1 mv/cm with automatic smoothing allows measurement of very small signals at a low noise level. A wide dynamic range permits viewing sub-millivolt disturbances on 2 volt pulses. Where less sensitivity is desired, the hp 10214A 10:1 Divider extends the maximum signal level to 2 v/cm and increases input impedance to 1 megohm.

The wide variety of accessories furnished with the hp 187C increases versatility, accuracy and convenience. The 10216A Isolator prevents dc shift of the trace with test circuit impedance changes; blocking capacitors eliminate unwanted dc; dividers attenuate large input signals; BNC and GR adapters make direct connection to cables possible; and the Microdot adapter permits easy connection to a female 50-ohm Microdot miniature coaxial connector. In addition, the hp 10221A 50-ohm Tee allows bridging of a 50-ohm transmission line with minimum disturbance to the signal being fed through. If termination is desired, the 50-ohm termination may be used.

Simultaneous sampling of the two channels permits accurate time comparisons between events viewed on Channel A and events viewed on Channel B. The delay difference between channels is less than 100 psec. The trace is time-shared in such a way that there is no reduction in the rate of information presented and a minimum loss of brightness when shifting from single- to dual-channel operation. The scope also can be used to view differential signals, facilitating analysis of signals containing common mode elements.



NEW

Specifications*

Modes of operation

1. Channel A alone.
2. Channel B alone.
3. Channel A and Channel B.
4. Channel A and inverted Channel B.
5. Channel A minus Channel B (differential).

Each channel

Rise time: <350 psec using a 10221A 50-ohm Tee Connector in a 50-ohm system (bandwidth, dc to >1 gc); overshoot or undershoot: <5%.

Sensitivity: calibrated ranges from 1 mv/cm to 200 mv/cm in 1, 2, 5 sequence; automatic smoothing in the 1 and 2 mv/cm positions to provide noise suppression; vernier control provides continuous adjustment between ranges and increases maximum sensitivity to 0.4 mv/cm.

Isolation between channels: greater than 40 db.

Attenuator accuracy: ±3%.

Input impedance: 100 K shunted by 2 pf, nominal.

Noise: (3X rms, or observed signal excluding 10% of random dots) <1 mv, 5 mv/cm to 200 mv/cm; on the automatically smoothed ranges, <1 mv at 2 mv/cm and 0.8 mv at 1 mv/cm; smoothed position of smoothing switch reduces noise or jitter approx. 2:1; vernier control provides continuous adjustment between the normal and smoothed modes of operation.

Drift: typically less than 3 mv/hr after warm-up.

Dynamic range: ±2 volts.

Maximum input voltage: ±5 volts.

Accessories furnished

Quantity	hp Model	Description
2	10214A	10:1 divider
2	10216A	isolator
2	10217A	0.001 μf blocking capacitor
2	10218A	BNC adapter
1	10219A	GR adapter
2	10220A	Microdot adapter
1	10221A	50-ohm tee
1	GR 874-W50	50-ohm load (hp part #0950-0090)
6	10213-62102	ground clips
6	5020-0457	probe tips
1		accessory box

Weight: net 7 lbs (3 kg); shipping 14 lbs (6,5 kg).

Price: hp 187C, $1250.

*Installed in 185B

188A DUAL-TRACE AMPLIFIER

Observe 90 picosecond rise times without terminating test circuit

The hp Model 188A Dual-Trace Vertical Amplifier, a plug-in for the 185B Oscilloscope, provides 90 psec rise time, 1 mv/cm calibrated sensitivity and a unique "bridging" sampler that allows analysis of extremely high-frequency, low-level signals without termination. A unique, advanced design, two-diode sampler permits "state-of-the-art" measurements. At 100% sampling efficiency (amplitude reaches final value in one sample), the rise time is specified at less than 90 psec. By adjusting the front-panel response control for lower sampling efficiencies, rise times as fast as 60 psec are possible, extending the bandwidth to 5.8 gc. Signals up to 10 gc may be observed by using the Model 1103A Trigger Countdown.

Signals such as circuit-driving pulses may be accurately measured with the 188A without disturbing the circuit under test. A high-impedance sampler bridges a 50-ohm line connecting the input and output connectors of each channel, thus allowing the signals to pass through the 188A completely unattenuated. When a 50-ohm terminated input is needed, a 50-ohm load is simply connected to the output connector. Thus, the 188A is ideal for measuring the input and output of switching circuits or monitoring several waveforms in a 50-ohm system.

The 188A has sensitivities to 1 mv/cm for analysis of low-level signals. The sensitivity may be further extended to 0.4 mv/cm with a vernier that also provides continuous control between attenuation ranges. In the lower three ranges, 5 mv/cm to 1 mv/cm, the display is automatically "smoothed" to reduce the noise level. On the "smoothed" ranges, random changes in signal amplitude are attenuated, reducing the noise level without bandwidth degradation.

Time delay measurements

Accurate time delay measurements may be made at the plug-in's highest frequency limit, since the time difference between channels is less than 20 psec. Furthermore, with good time coincidence between channels, the use of the plug-in's differential mode is greatly enhanced for the analysis of signals containing high frequency, common mode elements.

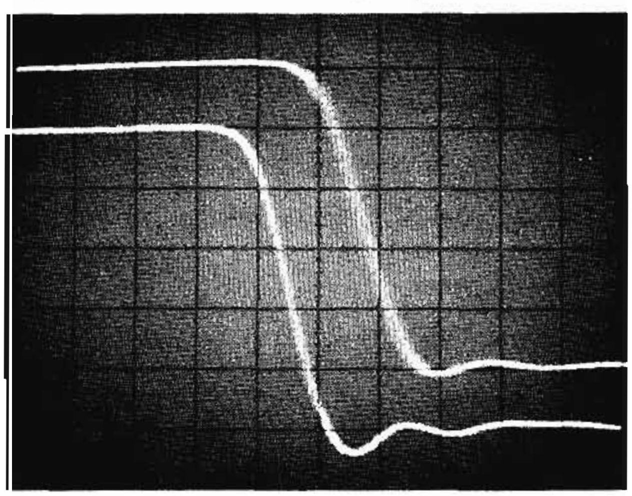
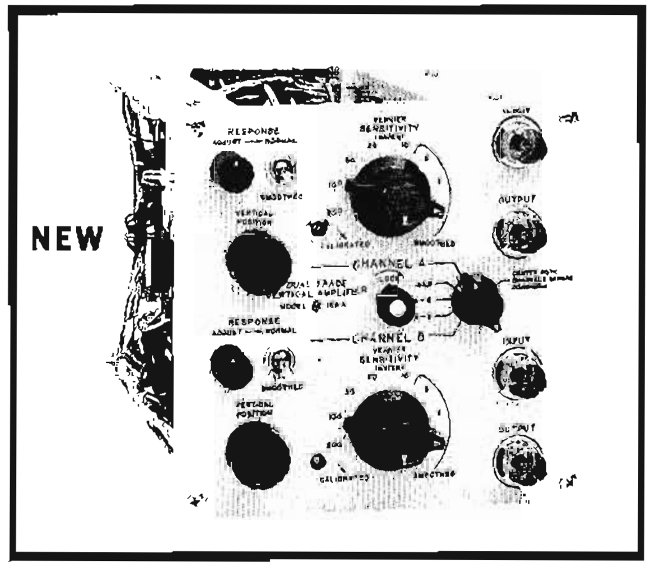


Figure 1. Upper trace shows step response with 100% sampling efficiency; lower with 20%. Rise times are 70 psec and 60 psec, respectively; sweep speed, 50 psec/cm.



For convenient circuit probing and as a means of increasing the 50-ohm input impedance of the Model 188A, resistive divider probes with signal divisions of 5 and 10 are available. Both the hp 10201A (5:1) and the hp 10201B (10:1) have a low shunt capacitance of only 0.4 pf to reduce loading at high frequency. Price, $40 each.

Specifications

(Installed in the 185B)

Mode of operation: (1) Channel A alone, (2) Channel B alone, (3) Channel A and Channel B, (4) Channel A and (−) Channel B, (5) Channel A minus Channel B (differential).

Each channel

- **Characteristic impedance of input:** 50 ohms; a 50-ohm load may be connected to the output connector to terminate the line.
- **Rise time:** less than 90 psec.
- **Overshoot:** less than 5%.
- **Sensitivity:** 8 calibrated ranges, 1 mv/cm to 200 mv/cm in a 1, 2, 5 sequence; vernier gives continuous attenuation between ranges and increases the sensitivity to 0.4 mv/cm.
- **Attenuator accuracy:** ±3%.
- **Dynamic range:** ±1 volt.
- **Noise:** (3X rms, or observed signal excluding 10% of random dots) less than 3 mv, 10 mv/cm to 200 mv/cm; on the automatically smoothed ranges: less than 2 mv at 5 mv/cm, 1 mv at 2 mv/cm, and 0.8 mv at 1 mv/cm; smoothed position of response control reduces noise by a factor of approximately two.

General

- **Accessories provided:** two 50-ohm terminations.
- **Weight:** net 7 lbs (3 kg); shipping 14 lbs (6,5 kg).
- **Price:** hp 188A, $1500.

186A SWITCHING TIME TESTER

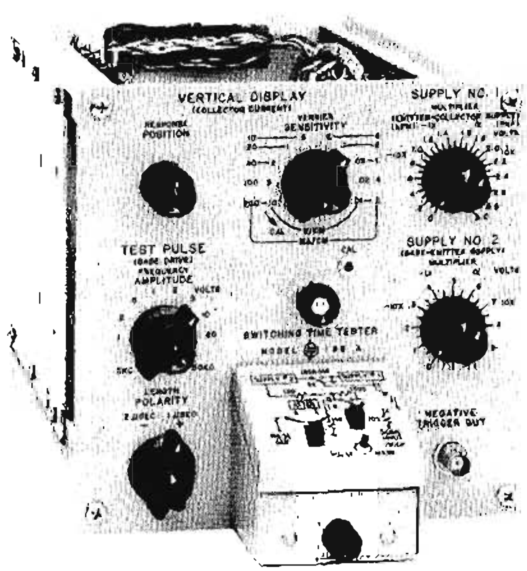
Complete solid-state device tester

The hp Model 186A Switching Time Tester provides easy, accurate measurements of transistor, diode and tunnel diode switching characteristics, as well as the pulse response of circuit networks.

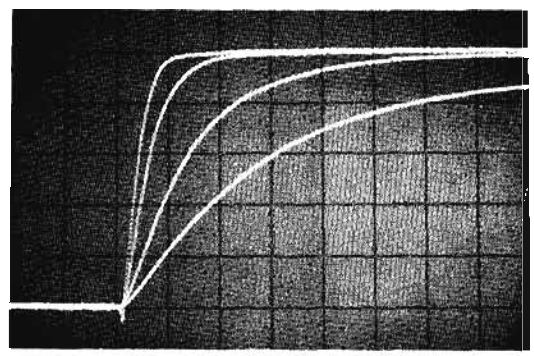
For maximum flexibility, the plug-in contains: a fast-rise pulse generator, a wideband vertical amplifier for the 185B Oscilloscope, and two bias supplies for biasing the component or circuit under test. Hence, with one plug-in, measurements can be made under various bias and driving pulse conditions. No additional instrumentation is necessary.

Transistor rise and fall times, tunnel diode switching times, and forward switching and reverse recovery times of diodes are but a few of the parameters that can be closely examined on the large 10 x 10 cm crt display.

Test set-ups may be changed in seconds by attaching various test boards to the test board adapter. Furthermore, the circuit components also can be easily changed for special applications.



186A with transistor test board



Four rise time curves of a PNP 2N1495 transistor driven into saturation with driving pulse amplitudes of 1, 2, 5 and 10 v. Collector emitter voltage, 7 v. Driving pulse width, 0.2 μsec. Scope sensitivity, 10 ma/cm; sweep speed, 20 nsec/cm.

Specifications (Installed in the 185A,B)

Pulse generator

- **Rise time:** less than 1 nsec.
- **Fall time:** less than 3 nsec for 0.2 μsec pulse; less than 4 nsec for 1 μsec pulse.
- **Overshoot and ringing:** less than 10% peak to peak.
- **Width:** 0.2 μsec or 1 μsec, switch selected (set at factory; each is adjustable from approximately 0.2 μsec to 1 μsec internally).
- **Amplitude:** 0.1 volt to 20 volts peak into 50 ohms, in a 1, 2, 5 sequence, either polarity.
- **Source output impedance:** 50 ohms, except on 20 v range.
- **Repetition rate:** approximately 5 kc to 50 kc, continuously variable.
- **Trigger out:** triggers the 185A,B approximately 120 nsec in advance of the pulse output.

Vertical amplifier channel

- **Sensitivity:** 10 mv/cm to 10 v/cm, in a 1, 2, 5 sequence; vernier provides continuous adjustment between steps and increases maximum sensitivity to 4 mv/cm.
- **Rise time:** less than 0.5 nsec.
- **Overshoot:** less than 5%.
- **Noise:** less than 3 mv.
- **Input impedance:** 50 ohms.

Bias supplies

- **Supply No. 1 (collector):** 0 to ±30 v; 50 ma max. average current (1 amp peak with 5% duty cycle).
- **Supply No. 2 (base):** 0 to ±10 volts, referable either to ground or to the emitter-collector supply voltage; 10 ma maximum average current (0.2 amp peak with 5% duty cycle).

Accessories furnished: 186-76A Test Board Adapter; 186-65D Transistor Test Board; 186-65E Diode Test Board; 186-65F Tunnel Diode Test Board; 186A-65G-1 Pulse Test Board (for observing the 186A output pulse); 10225A Universal Adapter for circuit tests; 10226A Blank Board for building special test circuits; 10121A Sync Cable, 8 inch (20 cm) male BNC-to-male-BNC, 50 ohm; accessory case.

Accessory available: 10227A Extender Cable for remote operation of adapter and test board, $50.

Weight: net 7 lbs (3 kg); shipping 13 lbs (6 kg).

Price: hp 186A, $1700.

SAMPLING OSCILLOSCOPE ACCESSORIES

1100A Delay Line

The hp Model 1100A Delay Line enables signals to be viewed whenever suitable triggers are not separately available by providing a delay between the trigger input and the vertical amplifier input. The 185B Oscilloscope may be set on top of the 1100A. Price: hp 1100A, $300.

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 187C where the Model 1100A 50-ohm Delay Line is needed for internal triggering. The kit also is ideal for 188A and 186A where a high input impedance is needed to prevent loading of the test circuit.

Quantity	Model	Description
1	10201A	5:1 resistive divider
1	10201B	10:1 resistive divider
1	10201C	50:1 resistive divider
1	10201D	100:1 resistive divider
1	10208A	0.001 μf blocking capacitor
1	10209A	0.1 μf blocking capacitor
1	10122A	cable, coaxial, Type N-to-BNC female
1	GR Type 874	Type N female-to-GR adapter
2	5060-0415	ground clip
1		accessory box

Price: hp 1102B, $300.

1103A Trigger Countdown

The hp Model 1103A Trigger Countdown permits stable triggering to 10 gc by dividing down the frequency of triggering signals to approximately 30 mc. This permits the triggering circuits of timing systems to lock in solidly with high-frequency signals in the gigacycle range. Price: hp 1103A, $265.

Specifications, 1100A

Rise time: approximately 0.25 nsec.
Delay: 120 nsec.
Overshoot: <2% overshoot contributed to 0.5 nsec rise time signal.
Input impedance: 50 ohms.
Connectors: Type N female input, Type N male output.
Accessories furnished: 10205A Sync Take-off, Type N female input, Type N male output, BNC female for sync output; 10121A Sync Cable, connects 10205A to the 185; 10212A or 10222A Delay Line Load, Type N female input, mating connector for 187B or 187C probe.
Dimensions: cabinet: 19⅛" wide, 4" high, 22¾" deep (486 x 102 x 578 mm); rack mount: 19" wide, 3½" high, 20¾" deep behind panel (483 x 89 x 528 mm).

Specifications, 1103A

Input

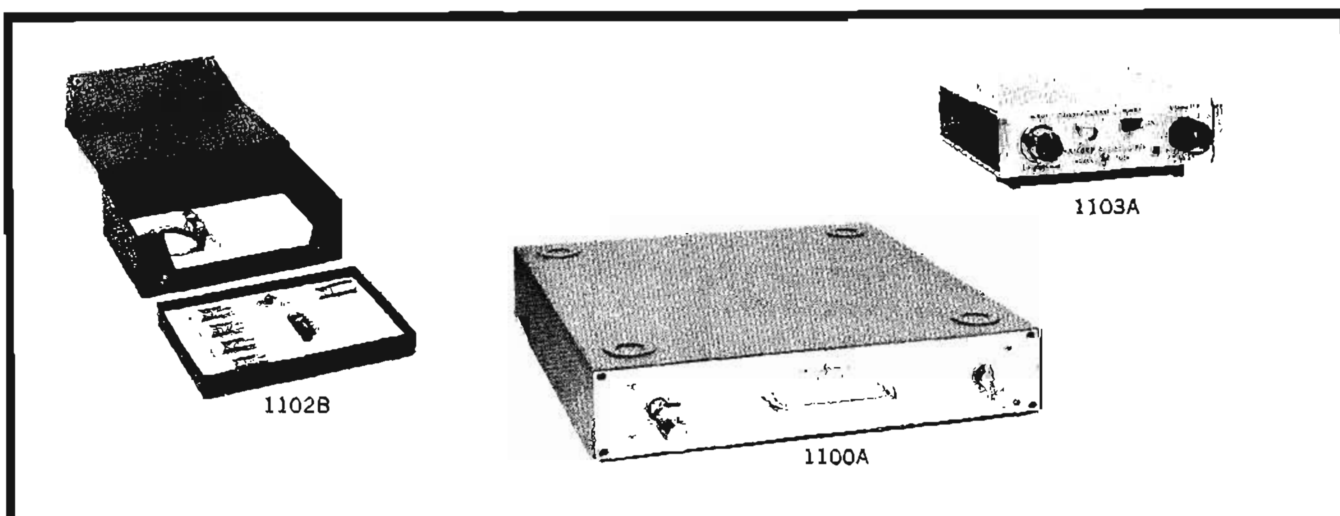
Frequency range: 500 mc to 10 gc.
Sensitivity: (minimum input required for specified jitter) 15 mv from 500 mc to 5 gc, increasing above 5 gc to 250 mv at 10 gc.
Time Jitter: (at specified sensitivity) time jitter of 1103A/185B combination is 30 psec or less for inputs above 1 gc, 60 psec or less for inputs below 1 gc.
Maximum input voltage: 2 volts peak (4 volts p-p).
Input Impedance: 50 ohms; reflection from 100 psec step less than 7.5%.
Signal appearing at input connector: alternate positive and negative pulses of <100 mv amplitude and <1 nsec duration (input terminated in 50 ohms).

Output

Center frequency: typically 25 to 35 mc.
Variation: typically ±2 mc (depends upon setting of stability control).
Amplitude: typically 90 mv.

General

Power: 115 or 230 v ±10%, 50 to 1000 cps, 2.5 w.
Dimensions: 5⅛" wide, 1½" high, 6¾" deep (130 x 38 x 172 mm).
Weight: net 2 lbs (0,9 kg); shipping 3 lbs (1,4 kg).
Price: hp 1103A, $265.



1103A

1102B

1100A

OSCILLOSCOPE PHOTOGRAPHY

Oscilloscope cameras produce permanent records of oscilloscope displays for use in engineering reports or in other situations where pictures of waveforms facilitate discussion and analysis. Furthermore, oscilloscope cameras can photograph single transients and other phenomena which are too short-lived for the eye to see.

Polaroid® Land Film is widely used in scope photography, primarily because the finished print may be examined shortly after the exposure is made. This "quick check" makes it easy to find the optimum camera and oscilloscope control settings, thus assuring satisfactory photos in short order.

Oscilloscope cameras

Oscilloscope cameras are similar to conventional cameras but have additional refinements for facilitating scope photography. The camera is within a light-tight enclosure which clamps or bolts over the face of the cathode-ray tube, preventing external light from "washing out" the crt trace. Also, the optical system is in line with the axis of the crt (no mirrors means no inversions). A viewing port wide enough for "two-eye" viewing permits observation of the displayed waveform. The port has a face-fitting flexible hood for preventing light leakage around the eyes.

Special lens

The lenses used in Hewlett-Packard cameras are designed especially for oscilloscope use. They eliminate the barrelling and pin-cushioning effects so often encountered in similar close-up situations, insuring accurate reproduction of oscilloscope traces. Accurate scale measurements of photos made with these cameras are possible, especially when the cameras are used in conjunction with Hewlett-Packard's internal graticule cathode-ray tubes. (The internal graticule tube eliminates any inaccuracies commonly caused by parallax between the trace and an external graticule.)

Hewlett-Packard cameras can be moved vertically through 11 detented positions, allowing several traces to be photographed on one film without disturbing the position of the crt trace.

Graticule illumination

A new technique which enhances the quality of scope photos is available with Hewlett-Packard cameras. A low-power ultraviolet (UV) light is used for exposing the black graticule in Hewlett-Packard internal graticule crt's. The UV light causes the crt phosphor to glow uniformly over its entire surface, this glow appearing as an intermediate gray in the finished picture. The gray background sharply contrasts the white trace with the black graticule lines, making oscillograms taken with this camera easier to interpret. Figure 1 shows the improvement in photographic quality obtained with the ultraviolet light.

The ultraviolet light also obtains a two-fold increase in film speed by generating an effect equivalent to "pre-fogging" of the film at the same time that the picture is taken. Ordinarily, a single, faint trace may not expose the film sufficiently to bring the density level above the brightness threshold level (the "toe" of the density/exposure curve as shown in Figure 2.) The gray background provided by the UV light, however, moves the trace's "zero" exposure level into the gray region, where a slight increase in exposure, caused by the trace, becomes visible.

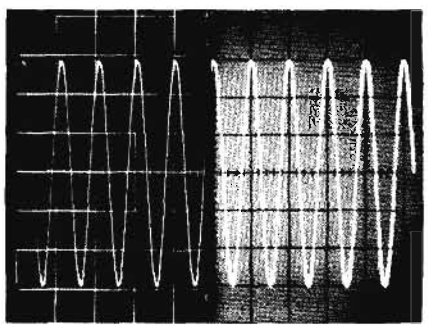


Figure 1. "Half-and-half" photo made with special cathode-ray tube compares photographic qualities of conventional external graticule (left) and UV-lighted internal graticule.

Making oscilloscope photos

Many variables must be accounted for in making oscilloscope photos. Initial attempts involve cut-and-try procedures, first-time procedures usually going as follows:

The crt trace intensity is adjusted so that fast transients in the waveform almost disappear (trace contrast actually photographs brighter than it appears to the eye); crt focus is adjusted for the finest trace. The UV light is adjusted for a visible phosphor glow.

For steady waveforms, a relatively long exposure and a small iris opening are recommended, e.g., 1/2 second at $f/11$. As in other types of photography, a small iris opening (large f-number) is preferred for best overall photographic quality.

If the waveform is unstable or noisy, exposure time is reduced to capture fewer trace repetitions, and the f-number is decreased accordingly.

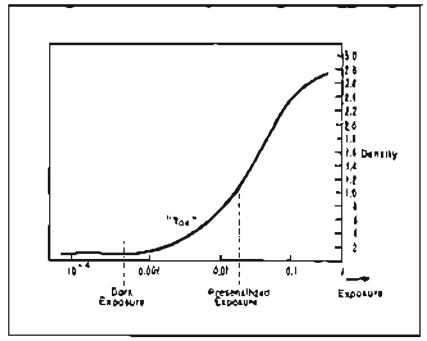


Figure 2. Typical density/exposure curve of photographic film shows how "pre-fogging" (presensitizing) moves exposure level into region of maximum sensitivity.

Single-trace photography

Single-trace photography of fast transients is possible with the sensitive film now available. Single events which are too fast and faint for the eye to notice can be captured on Polaroid Type 107 Film (ASA 3000).

In single-trace photography, the oscilloscope initially should be set by using a pulse generator operating at a low repetition rate (30 cps or less) as a test signal. The low repetition rate avoids the increase in trace brightness caused by phosphor persistence when traces overlap and permits optimum crt focus adjustment. During this initial adjustment, the sweep speed should be set on the same speed to be used in the final picture. To make the photograph of the desired transient, the camera shutter is held open manually on Bulb or Time while the oscilloscope sweep is triggered once by the signal being photographed.

To include graticule information in a single-sweep photo, the graticule, whether edge-lighted or UV-lighted, should be captured during a separate time exposure with no trace. The trace then is photographed during a second exposure with the graticule light turned off.

One further precaution regarding external graticules concerns parallax between the trace and graticule; allowance for parallax should be made when adjusting trace height and position. Parallax is not present, though, if an internal graticule crt is being used.

"Polaroid"® by Polaroid Corporation

196A,B AND 197A OSCILLOSCOPE CAMERAS

Permanent records of scope traces

Advantages, 197A:

- New hp electronic shutter: accurate speeds from 1/60 sec to 4 sec, remote operation, sync contacts to trigger external equipment, all solid-state circuitry
- New $f/1.9$ high light transmission lens
- Color-coded controls, outside camera for easy adjustment
- Interchangeable, rotatable back
- Continuous, easy adjustment of focus and reduction ratio

197A Camera

The 197A Oscilloscope Camera provides an accurate, convenient way of recording oscilloscope displays. It is a precision instrument, meant for long, hard use.

The 197A employs a new electronic shutter which provides accurate exposure times from 1/60 to 4 sec. The shutter may be tripped electrically from a remote source, and an X sync output provides a contact closure when the shutter is opened, allowing synchronizing of other equipment with the camera. Circuitry is all solid state.

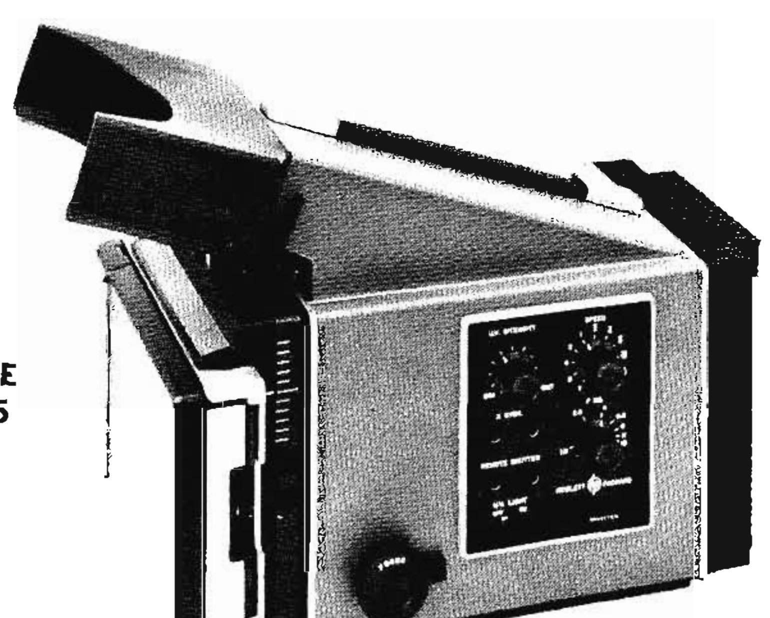
The new $f/1.9$ lens, designed for Hewlett-Packard by Wollensak, is mounted in a direct line with the film and transmits a maximum amount of light for photography of dim traces.

An ultra-violet light is included in the 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 glow gently, clearly illuminating 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 clearer, sharper photographs of both repetitive and single sweep phenomena.

All 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 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 easier lining up 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 stacked on oscilloscopes with heights as low as 7 inches.

The 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, or it can be removed and replaced with another camera back such as the 4 x 5" Graflok® back. The entire film area of a new 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.

AVAILABLE MID-1965



Specifications, 197A

Object-to-image ratio: continuously adjustable from 1:1 to 1:0.7.

Lens: 75 mm, $f/1.9$ high-transmission lens, manufactured exclusively for hp by Wollensak; $f/1.4$ lens available.

Shutter: electronically operated and timed shutter, with all solid-state circuitry; shutter speeds are 1/60, 1/30, 1/15, 1/8, 1/4, 1/2, 1, 2, 4 sec, Time, Bulb; shutter has X sync contact closure output and input jack for remote operation.

Camera back: Polaroid Land Camera for the new pack film standard; Graflok 4 x 5" back available; backs may be interchanged without refocusing and 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" high scopes.

Multiple exposure: back moves vertically through 11 detented positions at ½ cm per detent at 1:0.9.

Focus: adjustable focusing with lock; split image focusing plate provided for Polaroid Land Camera Back.

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 $\pm10\%$, 60 cps, 6 w.

Accessories furnished: split image focusing plate.

Accessories available (prices on request): 10352A Graflok® 4 x 5 inch back; 10353A Polaroid Land Pack Film Back; 10354A Viewing Hood Replacement Plate; 10355A Tektronix or Dumont 5" bezel adapter; 10356A Tektronix 560 series adapter; 10357A Tektronix 647 series adapter; 10358A Carrying Case; 10359A Viewing Lens.

Price: on request.

"Graflock"® by Graflex, Inc.

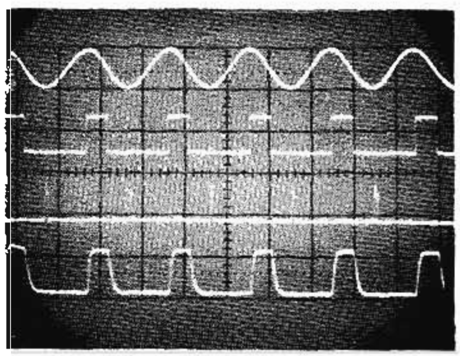
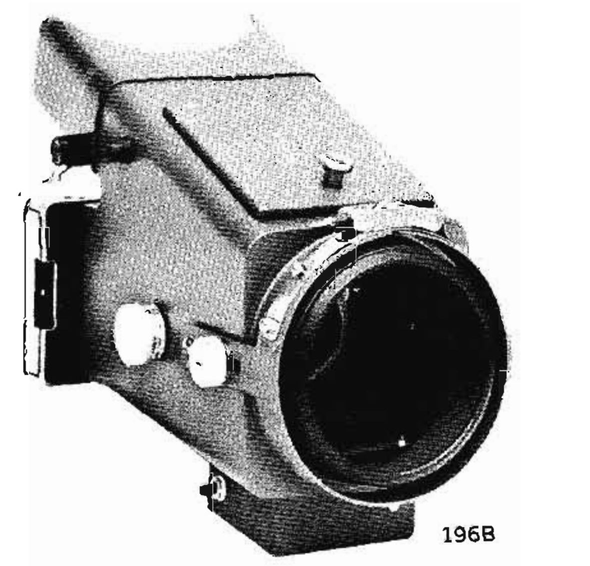


Figure 1. Multiple-exposure photographs are easily made with the 196A,B and 197A Cameras.



196A,B Cameras

Advantages of the 196A,B include sharp definition and high resolution $f/1.9$ lens; easy-to-use Polaroid Land Film-Pack Back; prefocused for convenient operation; no image inversion; quick-release clamp for easy mounting; distortion is imperceptible; internal UV light with 196B.

Specifications, 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 1/100, 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: (196B) 115 v $\pm10\%$, 60 cps, 10 w.

Accessories available: 10351A Carrying Case, $40; 10350A Tektronix Adapter, $4.50.

Price: hp 196B, $445; hp 196A (identical with 196B, but without black light source), $395.

On special order: 1:1 object to image ratio, add $25; and order C01-196A for 196A, C06-196B for 196B; solenoid-operated shutter for remote operation (actuated by external contact closure), 115 v ac external power required, add $125 and order H05-196A for 196A, H05-196B for 196B; solenoid operation same as above, except 28 v dc external power required, add $65 and order H01-196A for 196A, H06-196B for 196B.

Conversion kits: 196A-95C, converts "A" to "B", price: $50; 196A-95D, same as above but with Option 12, price: $65.

Option 12.: 196B for 115 or 230 v $\pm10\%$, 50 to 60 cps operation, add $15.

1110A AC CURRENT PROBE, 1111A AMPLIFIER; 1116A, 1117B TESTMOBILES

Accessories for increasing oscilloscope versatility

With the hp 1110A and 1111A Current Probe and Amplifier you can observe fast-rise, ac current waveforms on any wideband oscilloscope. The 1110A Probe may be used by itself, giving a sensitivity of 1 mv/ma. The 1111A Amplifier increases the 1110A Probe's sensitivity and extends low frequency response. When used with a 50 mv/cm sensitivity oscilloscope, the 1111A's attenuator indicates directly in milliamperes per centimeter on the crt, thus eliminating cumbersome conversion factors.

The 1116A Testmobile offers the advantage of convenient oscilloscope viewing. It readily adjusts to operator height, makes it easy to move heavy instruments and features toe-operated wheel locks. The 1117B offers the capability of mobilizing a complete set of test equipment. It features standard rack mounting, front and rear, and accepts convenient accessory drawers.

Specifications, 1110A

Sensitivity: 1 mv/ma.

Accuracy: ±3%.

Bandwidth: lower limit: 1700 cps (850 cps with 10100B 100-ohm termination); upper limit: inversely proportional to capacitance of load: 4 pf load, 45 mc, 7 nsec rise time (e.g., 185B/187C Sampling Oscilloscope); 30 pf load: 35 mc, 9 nsec rise time (e.g., 175A/1750B Oscilloscope).

Maximum dc current: 0.5 ampere.

Maximum ac current: 15 amperes p-p above 4 kc; decreasing below 4 kc at the rate of 3.8 amps/kc (30 amps p-p max. with 10100B 100-ohm termination).

Insertion impedance: approximately 0.01 ohm, shunted by 1 μh; capacity to ground is less than 3 pf.

Accessory available: 10100B 100-ohm feed-through termination; decreases sensitivity to 0.5 mv/ma, lower cutoff to 850 cps; increases maximum ac current to 30 amps p-p above 4 kc; price $17.50.

1110A with 1111A

Sensitivity: 1 ma/cm to 50 ma/cm in X1, and 100 ma/cm to 5 amps/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 1110A and 1111A are calibrated together).

Bandwidth: 50 cps to 20 mc (18 nsec rise time).

Noise: less than 100 μa p-p, referred to input.

Maximum ac current: 50 amps p-p above 700 cps, decreasing below 700 cps at the rate of 1.4 amps/20 cps.

Output impedance: 50 ohms.

General

Dimensions: amplifier: 1½" high, 5⅛" wide, 6" deep (3,8 x 13 x 15 cm); probe: aperture, 5/32" (0.4 cm) diameter; 5 ft. cable (152 cm).

Weight: approximately 2 lbs (0,9 kg).

Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 1.5 watts.

Price: hp 1110A, $100; hp 1111A, $160.

Specifications, 1116A

(Use with hp Models: 160B, 170A, 185A,B, 524C,D)

Dimensions: approximately 40" high, 24" deep, 20" wide (102 x 61 x 51 cm); bottom basket 16¾" wide, 23¼" deep (425 x 591 mm).

Weight: net 39 lbs (17,5 kg); shipping 45 lbs (25 kg).

Price: hp 1116A, $85.

Specifications, 1117B

Dimensions: 39" high, 20-7/32" wide, 24⅛" deep (991 x 514 x 613 cm).

Weight: net 82 lbs (37 kg); shipping 120 lbs (54 kg).

Instrument mounting hardware provided: 8 Screws (10-24 x ¾), hp stock No. 2680-0029; 8 Tinnerman Nuts, hp stock No. 0510-0737.

Price: (without drawers) hp 1117A, $155.

10475A 3-inch Drawer

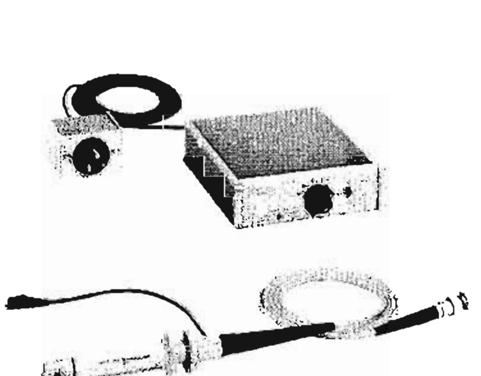
Weight: net 10 lbs (4,5 kg); shipping 13 lbs (5,9 kg).

Price: hp 10475A, $30.

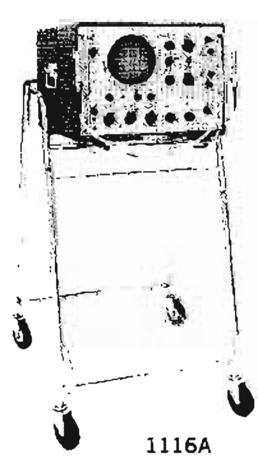
10476A 8-inch Drawer

Weight: net 14 lbs (6,3 kg); shipping 17 lbs (7,7 kg).

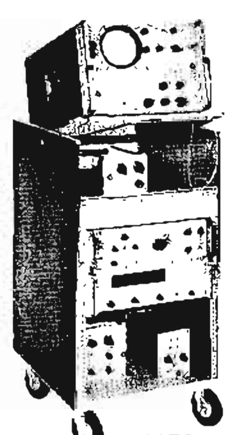
Price: hp 10476A, $35.



1110A with 1111A



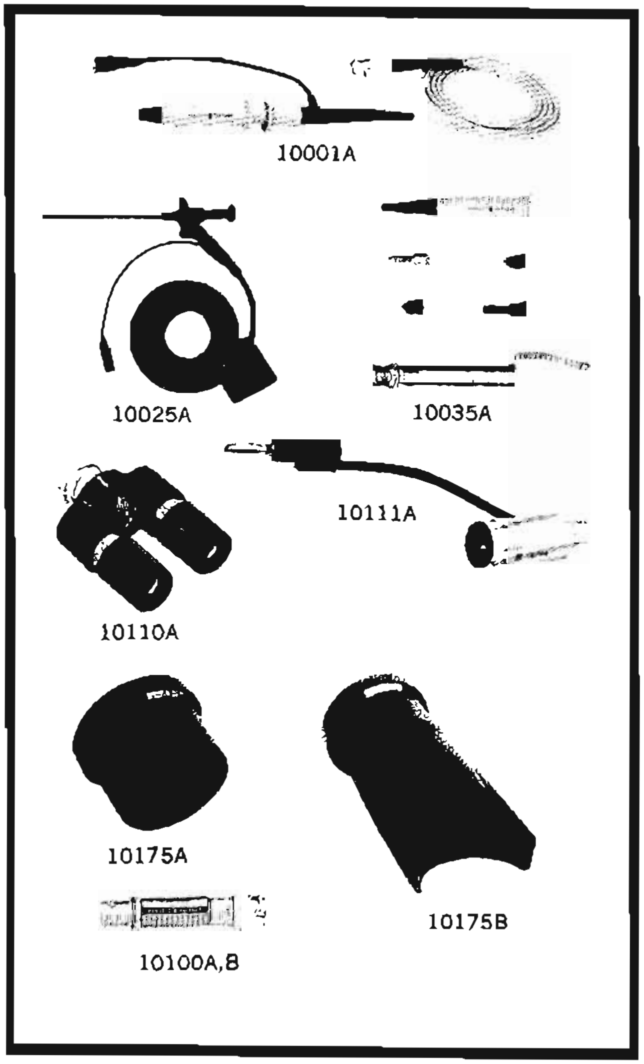
1116A



1117B

OSCILLOSCOPE ACCESSORIES

For increased measurement versatility, accuracy



Probe specifications

hp Probe	Atten.	Bandwidth (0.5 db)	Resistance (megohms)	Capacitance	Div. accuracy	Peak input volts	Approx. overall length ft. (cm)	Approx. rise time
10000A or C*	10:1	dc to 30 mc	10	10 pf	2%	600	5 (152)	5 nsec
10001B or D*	10:1	dc to 30 mc	10	20 pf	2%	600	10 (305)	5 nsec
10002A or C*	50:1	dc to 30 mc	9	2.5 pf	3%	1000	5 (152)	5 nsec
10002B or D*	50:1	dc to 30 mc	9	5 pf	3%	1000	10 (305)	5 nsec
10003A or B*	10:1	dc to 40 mc	10	10 pf	2%	600	4 (122)	3 nsec

*These probes have black identification boots; the others have red boots.

Cable specifications

hp Model	Length	Description	Price
10120A	3′ (91 cm)	male BNC-to-male BNC	$10
10121A	8″ (203 mm)	male BNC-to-male BNC	$10
10122A	3′ (91 mm)	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
10126A	18′ (549 cm)	male BNC-to-male BNC	$13
10127A	1′ (305 mm)	GR-to-male BNC	$13
10128A	1′ (305 mm)	GR-to-female BNC	$13

Voltage divider probes

The high impedance input of these probes reduces loading of oscilloscopes on the circuit under test, and the probes provide attenuation for large signals. The probes may be quickly and accurately compensated for optimum step response; price, $30 each.

Voltage divider probe tips

Provide maximum versatility when used with the voltage divider probe. The kit contains a pincer jaw, banana tip, pin tip, hook tip and spring tip. Price: hp 10035A Probe Tip Kit, $5; 10010C BNC Tip, $10.

Straight-through voltage probe

The hp 10025A is a thin, flexible probe with small, pushbutton pincer jaws which provides a straight-through connection to voltmeters, ohmmeters and oscilloscopes. Maximum input voltage is 600 volts peak, and the shunt capacity is approximately 150 picofarads. The cable is terminated in a shielded dual banana plug. Price: hp 10025A, $9.

Adapters

The Model 10110A Adapter (BNC male-to-dual-banana post) quickly converts standard BNC input terminals on oscilloscopes to dual banana posts. Price: hp 10110A, $5.

The hp Model 10111A Adapter (shielded banana-post-to-female-BNC) converts banana post inputs on oscilloscopes to shielded BNC inputs for low-level signal work. This adapter may be used in pairs for balanced input characteristics. Price: hp 10111A, $7.

Viewing hoods

The hp 10175A polarized hood increases contrast and reduces glare for viewing dim traces under all ambient light conditions; price, $10.

The hp 10175B hood with removable vinyl face mask is ideal for viewing fast transients; price, $15.

Terminations

The hp Model 10100A is a 50-ohm (±1 ohm) feed-through termination which can be used to terminate 50-ohm systems at scope inputs. Price: hp 10100A, $15.

The hp Model 10100B is a 100-ohm (±2 ohms) feed-through termination which can be used to increase the maximum ac current capability of the 1110A current probe. Price: hp 10100B, $17.50.

High-quality cables

Specifically designed for high-frequency pulse application, the hp 10120 Series of 50-ohm coaxial cables insures faithful transmission of fast rise signals. Mismatch loss is reduced to a minimum by using close tolerance (1%) 50-ohm cable and high quality connectors. Long life and good flexibility are assured by enclosing the low-density polyethylene dielectric in a single-braided shield with a tough vinyl jacket.

8000A PULSER

Ideal for work with fast circuits

Advantages:

- Step output with less than 1 nsec rise time
- Excellent pulse shape—overshoot and top variations less than 2%
- 0.1 to 10 volts, positive or negative
- 100 kc repetition rate for bright display
- Advance trigger output—no delay line required

Uses:

- Measure response of fast circuits and instruments
- Determine transition times of semiconductors

The hp Model 8000A Pulser provides 1 nanosecond rise time pulses at a repetition rate of 100 kc. This rapid rise time and the high quality of the pulse shape make this instrument particularly suitable for accurate determination of the pulse response of high-speed components, circuits and instruments. A flat top is maintained for at least 100 nsec; overshoot and pulse top variations are less than 2%. Amplitude is adjustable in a 1, 2, 5 sequence from 0.1 volts to 10 volts, either polarity. A trigger output of 0.5 volts into 50 ohms is available 200 nsec in advance of the pulse, so that the pulser may be used with the hp Model 185B or similar sampling oscilloscope without a delay line.

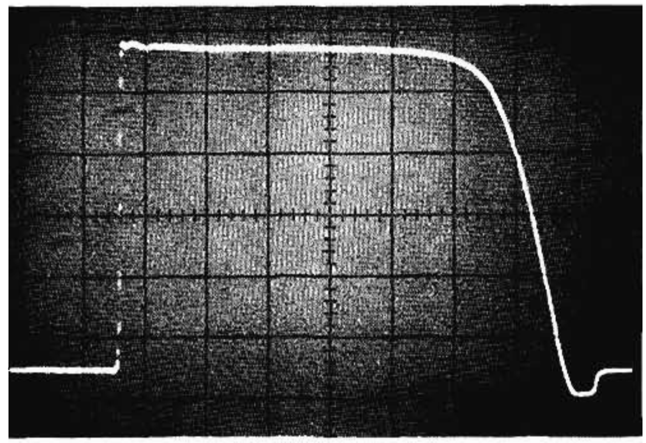
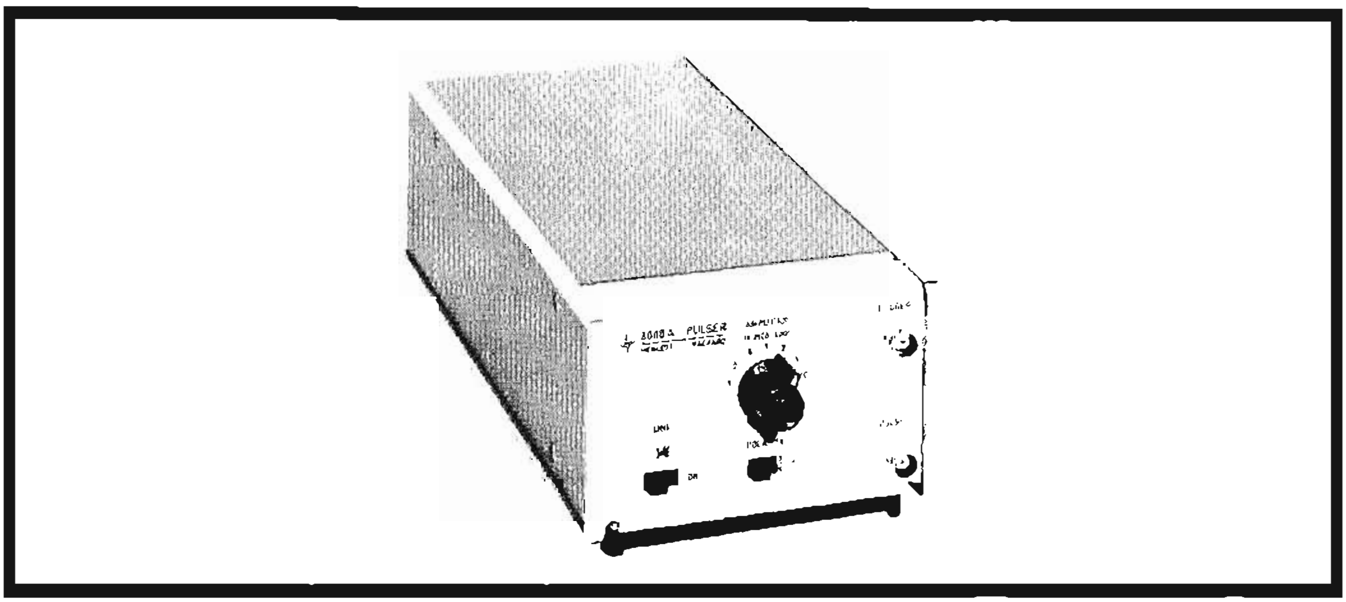


Figure 1. 8000A pulse; 1 volt output; sweep 20 nsec/cm; sensitivity, 200 mv/cm.



Specifications

Output pulse

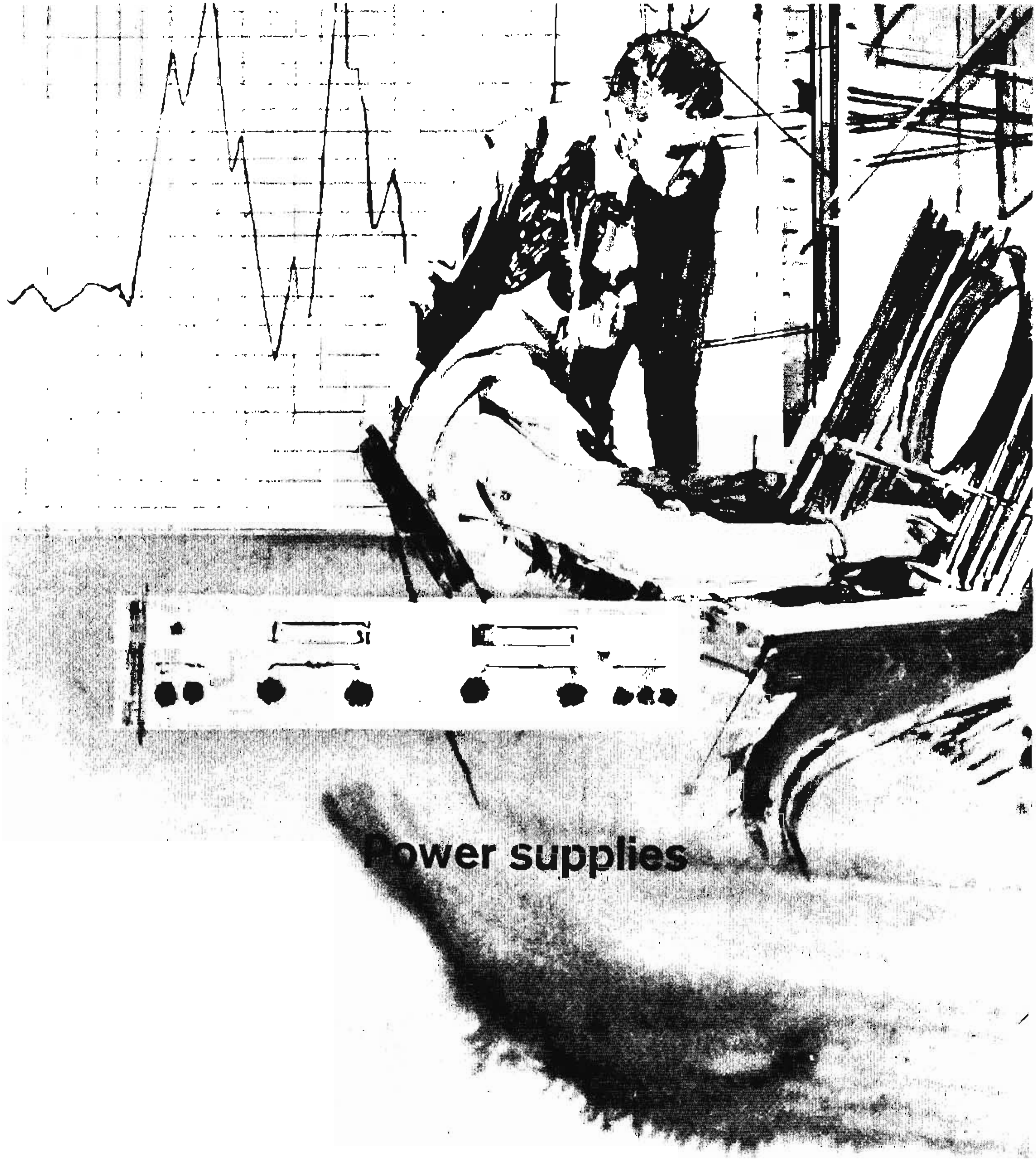
- **Rise time:** less than 1 nanosecond.
- **Amplitude:** 0.1 v to 10 v into 50 ohms, adjustable in 1, 2, 5 sequence.
- **Polarity:** positive or negative.
- **Shape:** overshoot and pulse top variations less than ±2%.
- **Width:** flat top maintained for at least 100 nanoseconds.
- **Fall time:** less than 20 nanoseconds.
- **Repetition rate:** 100 kc ±20%.
- **Source impedance:** 50 ohms nominal.

Trigger pulse

- **Timing:** 200 nanoseconds advance ±20%.
- **Jitter:** less than 100 picoseconds, trigger to output.
- **Rise time:** less than 6 nanoseconds.
- **Amplitude:** 0.5 v into 50 ohms.
- **Polarity:** negative.
- **Width:** 20 nanoseconds ±20% (between 10% points).

General

- **Output connector:** BNC.
- **Input power:** 115 or 230 v ±10%, 50 to 400 cps.
- **Dimensions:** 5⅛" wide, 3-7/16" high, 11⅝" deep (130 x 87 x 295 mm).
- **Weight:** net 4.4 lbs (2 kg); shipping 6 lbs (2,7 kg).
- **Price:** hp 8000A, $375.



Power supplies

POWER SUPPLIES

Electronic power supplies can be defined as circuits which transform electrical input power, either ac or dc, into output power, either ac or dc. The ac in-dc out power supply is by far the most common and is generally the one referred to when speaking of a "power supply." This catalog section deals entirely with ac input-dc output regulated power supplies.

The basic elements of a voltage-regulated dc power supply are shown in Figure 1. The rectifier and filter convert the

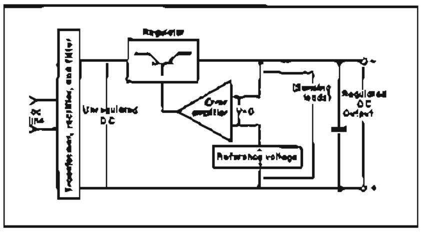


Figure 1. Regulated dc power supply.

ac line power into raw, unregulated dc power. The regulator functions as a variable impedance connected in series with the output line. It introduces the right amount of voltage drop in the line to hold the output at a preset, constant level despite changes in the raw dc.

Regulator control originates in the error amplifier, which compares the output voltage to the reference voltage and controls the regulator action to maintain this voltage difference constant.

Because many elements are common to the constant voltage power supply and the constant current power supply, the two circuit principles can be combined in one supply. Fortunately, most of the expensive, heavy power elements are common to both configurations, and only low-voltage circuitry and a current monitoring resistor need be added to the constant voltage supply so that it can be used as a constant current source. Most Harrison supplies employ this CV/CC circuit technique.

Two comparison amplifiers are included in a CV/CC supply, one for controlling output voltage and the other for controlling output current. The two comparison amplifiers cannot operate simultaneously. For a given value of load resistance, the power supply acts either as a constant voltage source or as a constant current source. Transfer between the two modes is accomplished automatically at the value of load resistance equal to R_C as defined in Figure 3.

In the constant voltage mode, the voltage drop across resistor R_R equals the reference voltage. This means that the

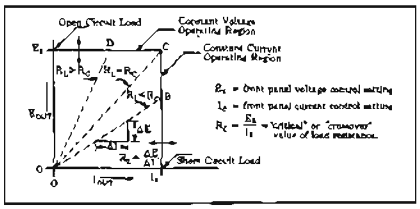


Figure 3. Operating locus of CV/CC power supply.

current through R_R (and thus R_P) is constant, and the voltage drop across R_P is a linear function of the voltage control. By feedback action, the regulator matches the output voltage to the voltage drop across R_P.

Constant current control is achieved with the other feedback loop shown in Figure 2. In this case, the voltage drop across series resistor R_S is made equal to the voltage across the current programming resistor R_Q.

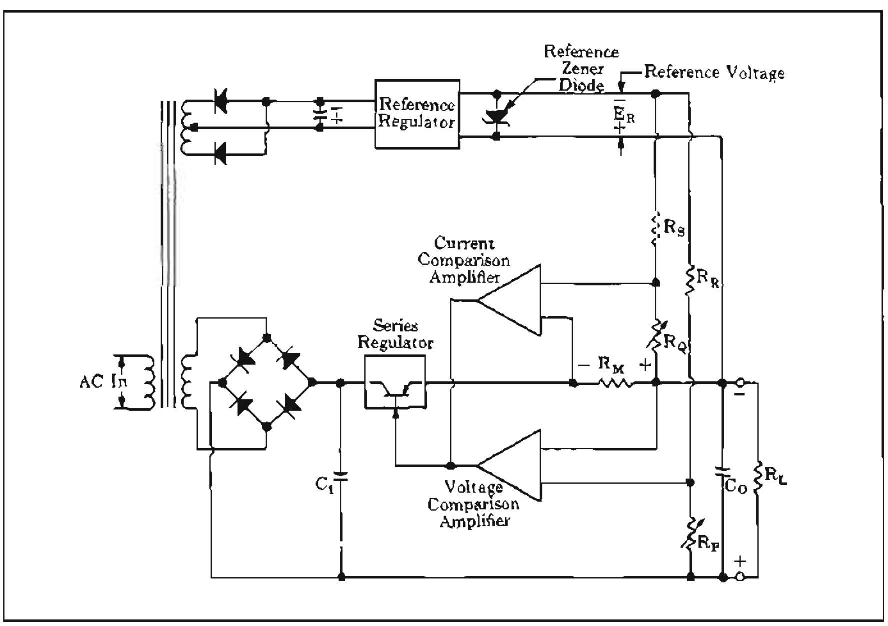


Figure 2. Constant voltage/constant current (CV/CC) power supply.

Heavy-duty SCR supplies

The block diagram of Figure 4 shows a regulating circuit suitable for supplying large amounts of current with high efficiency. This type of supply uses silicon controlled rectifiers (SCR's) with the Harrison "Ramp-Lock" phase control circuit to perform simultaneously the rectifying and series-regulating functions. Each SCR in the rectifier bridge passes no current until triggered by a signal, and then maintains conduction until the voltage across the SCR is reversed. The firing angle during each ac cycle is controlled by an error amplifier, thus maintaining the output voltage at the desired level.

This same technique also is used (1) for three-phase input power supplies and (2) as a preregulator in higher-power supplies employing a tandem series regulator. In the latter application, the SCR's serve to minimize the power dissipated in the series regulator transistors.

Basic specifications

Regulation is a measure of the change of the static output voltage or current resulting from changes in output load demand and/or input line variations.

Ripple is the residual ac component which is superimposed on the dc output.

Stability refers to the variation in power supply output which occurs in the presence of constant load, line, and ambient temperature.

Temperature coefficient relates the change in output to a temperature change causing it. It is specified in per cent per degree Centigrade.

Transient response (or transient recovery time) is, loosely speaking, the time required for the output voltage to come back to within a level approximating the normal dc output following a sudden change in load current.

Power supply features

Remote Sensing: Certain operational refinements contribute to the usefulness

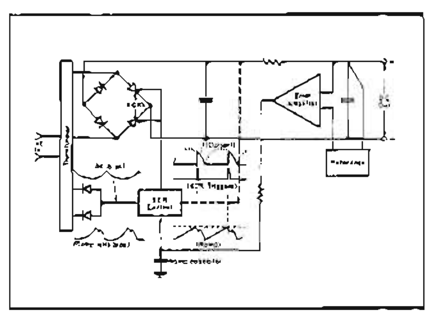


Figure 4. SCR regulated power supply.

of dc power supplies. Remote sensing, for instance, prevents degradation of regulation at the load when there is a significant IR drop in the connecting leads. Remote sensing is effected simply by disconnecting the control leads, shown attached to the output buses in Figure 1, and extending them for reattachment directly at the load.

Remote programming: Remote programming, or remote control of the output, is desirable in a number of situations, particularly in automatic check-out equipment where sequences of voltages or currents are required for test purposes. Remote programming can be accomplished using a control resistance (R_P placed externally), control voltage, or current.

Series operation: Automatic series operation (Auto-Series) of regulated supplies, with total output control coming from one supply, enables several power supplies to be "cascaded" for higher voltage output.

Parallel operation: Parallel operation (Auto-Parallel) permits several power supplies to be used in parallel for higher current output, again with one-knob control.

Power supply selection

(1.) Determine dc output voltage rating. A dc voltage requirement often is 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).

(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 up to 105% or 110% of the nominal current rating of the power supply.

(3.) Consult condensed listing (pages 311-314). 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 also are 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, don't forget to consider series and parallel combinations of power supplies.

(4.) Constant voltage and/or constant current output. Most applications require constant voltage power supplies. However, some load devices, such as electromagnet coils and certain semiconductor loads, require a constant current source of dc power. Still other applications call for supplies which have automatic crossover between constant voltage and current limiting 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—further evaluation of these constant current supplies must be based on the detailed specifications in this catalog. Remember that all remote programming constant voltage supplies also can be converted to constant current use with one external resistor.

(5.) Specifications for load regulation, line regulation, ripple and transient response. Generally speaking, a power supply employs one of two basic circuit techniques—(A) a transistor regulator, or (B) 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 (A), since this results in both lower cost and better performance. Either circuit technique (A) or (B) may be utilized in a supply of moderate output power capability—the former yielding a well regulated output, the latter achieving moderate regulation with greater efficiency and lower cost. Power supplies of very high output power employ circuit technique (B). These two circuit techniques result in distinctly different performance characteristics—particularly with regard to regulation, ripple and transient response.

Specification	(A) Transistor regulated	(B) SCR regulated
Load regulation	0.01% to 0.05%	0.1% to 1%
Line regulation	0.01% to 0.05%	0.1% to 1%
Ripple and noise	100 μv to 1 mv	0.1% to 1%
Transient response	less than 50 μsec	less than 50 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 power supplies with a check under "Remote programming".

(7.) Physical configuration. Power supplies are available in three basic packages—rack mounting (standard 19", 483 mm, RETMA), bench and modular. For high output ratings, rack mounting is the only practical configuration. All supplies not normally rack mounting are easily adapted to rack applications. Reference to appropriate catalog pages will indicate the nature and cost of this rack mounting adapting hardware.

(8.) Miscellaneous requirements. Depending on the particular application one should 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.

(9.) Klystron power supplies. Two klystron power supplies (page 331) include the hp 716B, which offers outstanding regulation, noise, ripple and hum characteristics, giving the broad capability of powering more than 250 klystrons. The hp 715A is an economy model with high performance standards for low-power klystrons.

Series designations of Harrison power supplies

In order to clarify the relationships which exist among various power supplies, certain families have been assigned three-letter designations. These series designations have been applied only to the most up-to-date lines. These designations underscore family groupings of power supplies related in circuit technique and operating characteristics. Note that each three-letter series designation suggests the general type of power supply in a given category and, 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 "R" as the final letter means that the supplies have not been designated primarily for either bench or rack use.

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
HVR	High Voltage Rack, highly regulated, output greater than 750 v
LAB	Laboratory Bench, latest generation, adapted to rack mounting
LVR	Low Voltage Rack, highly regulated, output less than 75 v
MOD	Modular Plug-in, well regulated, adapted to rack installation
MVR	Medium Voltage Rack, highly regulated, outputs up to 320 v
SCR-1	Silicon-Controlled Rectifier Rack, single phase input, medium regulation
SCR-1P	Silicon-Controlled Rectifier Rack, single phase input, medium regulation, reduced size and weight
SCR-3	Silicon-Controlled Rectifier Rack, three-phase input, medium regulation

Bench supplies*									**Page**
General-purpose laboratory supplies	output	0-7.5 v, 0-3 a	0-18 v, 0-0.6 a 0-36 v, 0-0.3 a	0-20 v, 0-1.5 a 0-40 v, 0-0.75 a	0-20 v, 0-1.5 a	0-40 v, 0-0.75 a	0-32 v, 0-1 a 0-64 v, 0-0.5 a	0-160 v, 0-0.2 a	315 to
LAB Series	model	6203A	6204A	6200A	6201A	6202A	6206A	6207A	317
Heavy duty bench supplies	output	twin 0-36 v, 0-1.5 a	0-36 v, 0-2.5 a	0-100 v, 0-1 a					318
	model	800A-2	800B-2	880					
Compact laboratory supplies	output	0-18 v, 0-3 a	0-30 v, 0-0.15 a	0-36 v, 0-1.5 a	0-40 v, 0-0.5 a				319
	model	6224A	721A	6226A	723A				
Medium voltage multiple output	output	0-500 v, 0-0.1 a 12.6/6.3 v ac	0-500 v, 0-0.2 a,—300 v, 0.05 a,0 to —150 v, 0.005 a,and 6.3 v ac,C.T.						330
	model	711A,AR	712B,BR						
High-speed laboratory supplies	output	0-18 v, 0-1.5 a	0-40 v, 0-0.5 a						
	model	855C	865C						332

* These supplies can also be rack mounted. Refer to pages indicated for details.

Rack supplies										**Page**
Strain gage power supply	output	0-25 v, 0-0.2 a								
	model	801C								318
Twin power supply	output	twin 0-36 v, 0-1.5 a								
	model	802B								
Highly regulated versatile rack supplies	output			0-18 v, 0-10 a	0-18 v, 0-20 a	0-36 v, 0-3 a	0-36 v, 0-5 a	0-36 v, 0-10 a	0-60 v, 0-3 a	320,
LVR Series	model			6263A 6363A	6264A 6364A	6265A 6365A	6266A 6366A	6267A 6367A	6271A 6371A	321
General-purpose rack supplies	output	0-32 v, 0-2 a 0-64 v, 0-1 a	0-36 v, 0-3 a	0-36 v, 0-5 a	0-36 v, 0-10 a	0-36 v, 0-25 a	0-60 v, 0-2 a	0-60 v, 0-7.5 a	0-100 v, 0-1 a	322,
	model	6242A	6244A	808A	809A	814A	726AR	810B	881A	323
SCR regulated medium power	output	0-36 v, 0-10 a	0-36 v, 0-25 a	0-72 v, 0-5 a						324
SCR-1 Series	model	510A	520A	505A						
SCR regulated medium power	output	0-18 v, 0-15 a	0-18 v, 0-45 a	0-32 v, 0-10 a	0-60 v, 0-5 a	0-60 v, 0-15 a	0-120 v, 0-2.5 a			325
SCR-1P Series	model	6427A	6428A	6433A	6438A	6439A	6443A			
SCR regulated high power	output	0-8 v, 0-300 a	0-15 v, 0-200 a	0-32 v, 0-100 a	0-36 v, 0-75 a	0-64 v, 0-50 a				326
SCR-3 Series	model	6450A	6453A	6456A	6455A	6459A				
Medium voltage supplies	output	75-160 v, 0-2.5 a	0-320 v, 0-0.6 a	0-320 v, 0-1.5 a						327
MVR Series	model	896A	890A	895A						
High voltage supplies	output	0-1 kv, 0-200 ma	0-2 kv, 0-100 ma	0-4 kv, 0-50 ma						327
HVR Series	model	6521A	6522A	6525A						

Special products										**Page**
Modular plug-in* power supplies	output	0-18 v, 0-0.3 a	0-18 v, 0-1 a	0-18 v, 0-2.5 a	0-36 v, 0-0.15 a	0-36 v, 0-0.5 a	0-36 v, 0-1.5 a	0-160 v, 0-0.4 a	0-320 v, 0-0.2 a	328,
MOD Series	model	6343A	6344A	6345A	6346A	6347A	6348A	6354A	6357A	329
"Crowbar" protectors	models 6910A and 6916A overvoltage protectors									330
Klystron power supplies	models 715A and 716B									331
DC standards, differential voltmeters	models 740A and 741A									154- 156

* These supplies can also be rack mounted. Refer to pages indicated for details.

HARRISON POWER SUPPLIES

Condensed listing

Output volts	Output amps	Harrison model	Series	Catalog page number	Load regulation	Line regulation	RMS ripple and noise (mv)	Recovery time* (μsec)	Input line voltage	Input line frequency (cps)	Meter(s) provided	Remote programming	Remote sensing	Bench model	Rack model***	Net weight lbs, kg	Shipping weight lbs, kg	Dimensions inches mm wide	Dimensions inches mm high	Dimensions inches mm deep	Constant Voltage/Constant Current operation**	Auto-Series/Auto-Parallel/Auto-Tracking	Special features	Price
0 to 7.5	0 to 3	6203A	LAB	315	5 mv	3 mv	0.2	50	105-125 or 210-250	50 to 400	v/a	√	√	√	R	18 8 1	20 9	8¼ 210	3½ 89	13 330	√	√	front and rear output terminals, ½ rack width package, variable voltage and current limit	$179
0 to 8	0 to 300	6450A	SCR-3	326	25 mv combined		80	50 (msec)	3φ 208/230 460±10%	57 to 63	v&a	√	√		√	238 107,1	275 123,8	19 483	14 356	18¼ 464	√	√	high efficiency; variable voltage and current limit	$1550
0 to 15	0 to 200	6453A	SCR-3	326	0.2% + 10 mv combined		150	50 (msec)	3φ 208/230/ 460±10%	57 to 63	v&a	√	√		√	238 107,1	275 123,8	19 483	14 356	18¼ 464	√	√	high efficiency; variable voltage and current limit	$1550
0 to 18	0 to 0.3	6343A	MOD	328	3 mv or 0.03%	3 mv or 0.03%	1	50	105-125 or 210-250	48 to 440	no	√	√		R	3 1,4	5 2,3	3 76	2½ 64	8 203		√	plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$120
0 to 18	0 to 0.6	6204A 6204AM	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	no v&a	√	√	√	R	12 5,4	16 7,2	8½ 216	3½ 89	10 254		√	front and rear output terminals, ½ rack width package, dual range output selected by front-panel pushbuttons; other range: 0-36 v, 0-0.3 a; variable current limit	$124 $144
0 to 18	0 to 1	6344A	MOD	328	3 mv or 0.03%	3 mv or 0.03%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	7 3,2	10 4,5	5 127	3 76	9 229		√	plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$165
0 to 18	0 to 1.5	855C	—	332	250 μa + 0.02%	250 μa + 0.02%	0.2	50	105-125 or 210-250	50 to 440	v/a	√	√	√	R	14 6,3	16 7,2	7-13/16 199	5-1/16 128	8½ 216	√	√	high-speed programming; useful as a low-frequency amplifier	$179
0 to 18	0 to 2,5	6345A	MOD	328	3 mv or 0.03%	3 mv or 0.03%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	13 5,9	19 8,6	6¼ 159	9 229	5 127		√	plug-in module; all input, output and control connection via 11-pin plug; variable current limit	$225
0 to 18	0 to 3	6224A	—	319	2 mv or 0.03%	2 mv or 0.02%	0.5	50	105-125 or 210-250	50 to 70	v/a	√	√	√	R	15 6,8	20 9	5⅕ 130	6¾ 171	11 279	√	√	front and rear output terminals, ⅓ rack width package; variable voltage and current limit	$340
0 to 18	0 to 10	6263A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	36 16,2	47 21,2	19 483	3½ 89	17½ 445	√	√	variable voltage and current limit	$435
0 to 18	0 to 10	6363A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	34 15,3	45 20,3	19 483	3½ 89	17½ 445		√	well-regulated "stripped-down" version of 6263A	$359
0 to 18	0 to 15	6427A	SCR-1P	325	15 mv or 0.15% combined		36	300 (msec)	105-125	57 to 63	v&a	√	√		√	35 15,8	46 20,7	19 483	3½ 89	17½ 445	√	√	high efficiency, variable voltage and current limit	$380
0 to 18	0 to 20	6264A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	54 24,3	66 29,7	19 483	5¼ 133	17½ 445	√	√	variable voltage and current limit	$525
0 to 18	0 to 20	6364A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	52 23,4	64 28,8	19 483	5¼ 133	17½ 445		√	well-regulated "stripped-down" version of 6264A	$450
0 to 18	0 to 45	6428A	SCR-1P	325	54 mv combined		36	300 (msec)	105-125	57 to 63	v&a	√	√		√	65 29,3	78 35,1	19 483	5¼ 133	16¾ 425	√	√	high efficiency; variable voltage and current limit	$550
0 to 20	0 to 1.5	6200A	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	v&a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330	√	√	dual range output selected by front-panel pushbuttons; other range: 0-40 v, 0-0.75 a; variable voltage and current limit	$210
0 to 20	0 to 1.5	6201A	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210 250	50 to 400	v/a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330	√	√	front and rear output terminals, ½ rack width package; variable voltage and current limit	$179
0 to 25	0 to 0.2	801C	—	318	2 mv	2 mv	0.1	50	105-125	55 to 65	no		√		√	4 1.8	8 3,6	1⅝ 41	5 127	14⅞ 378			strain gage supply, 9 fit on 5¼" high panel; high R and low C to case and input ac	$149
0 to 30	0 to 0.15	721A	—	319	30 mv or 0.3%	±15 mv or 0.3%	0.15	—	115/230 ±10%	50 to 60	v/a			√		4 1,8	7 3,2	7 178	4⅜ 111	5¼ 133			4-position current limit switch	$145

additional listings on next page

HARRISON POWER SUPPLIES

Condensed listing

Output volts	Output amps	Harrison model	Series	Catalog page number	Load regulation	Line regulation	RMS ripple and noise (mv)	Recovery time* (μsec)	Input line voltage	Input line frequency (cps)	Meter(s) provided	Remote programming	Remote sensing	Bench model	Rack model***	Net weight lbs, kg	Shipping weight lbs, kg	Dimensions inches mm: wide	high	deep	Constant Voltage/Constant Current operation**	Auto-Series/Auto-Parallel/Auto-Tracking	Special features	Price
0 to 32	0 to 1	6206A 6206AM	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	no v&a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330		√	front and rear output terminals, ½ rack width package, dual-range output selected by front-panel pushbuttons; other range: 0-64 v, 0-0.5 a; variable current limit	$164 $184
0 to 32	0 to 2	6242A†	—	322	3 mv or 0.02%	5 mv or 0.03%	0.2	50	105-125 to 210-250	50 to 400	v&a	√	√	√	√	25 11,3	30 13,5	19 483	3½ 89	16¾ 425	√	√	plug-in printed circuit selects dual-output range, other range: 0-64 v, 0-1 a; variable voltage and current limit	$435
0 to 32	0 to 10	6433A	SCR-1P	325	24 mv or 0.15% combined		32	300 msec	105-125	57 to 63	v&a	√	√		√	33 14,9	44 19,8	19 483	3½ 89	17½ 445	√	√	high efficiency; variable voltage and current limit	$370
0 to 32	0 to 100	6456A	SCR-3	326	0.2% + 10 mv combined		160	50 (msec)	3φ 208/230/460±10%	57 to 63	v&a	√	√		√	238 107,1	275 123,8	19 483	14 356	18¼ 464	√	√	high efficiency; variable voltage and current limit	$1450
0 to 36	0 to 0.15	6346A	MOD	328	3 mv or 0.02%	3 mv or 0.02%	1	50	105-125 or 210-250	48 to 440	no	√	√		R	3 1,4	5 2,3	3 76	2½ 64	8 203		√	plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$120
0 to 36	0 to 0.3	6204A 6204AM	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	no v&a	√	√	√	R	12 5,4	16 7,2	8¼ 210	3½ 89	10 254		√	front and rear output terminals, ½ rack width package, dual-range output selected by front-panel pushbuttons; other range: 0-18 v, 0-0.6 a; variable current limit	$124 $144
0 to 36	0 to 0.5	6347A	MOD	328	3 mv or 0.02%	3 mv or 0.02%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	7 3,2	10 4,5	5 127	3 76	9 229		√	plug-in module: all input, output and control connections via 11-pin plug; variable current limit	$165
0 dual to 36	0 to 1.5	800A-2	—	318	5	5	0.2	100	105-125	55 to 65	v&a			√	R	29 13	32 14,4	7 178	9 229	10½ 267			2 sides can be series'ed for 0-72 v at 0-1.5 a; rack mounting panels available; fixed current limit	$580
0 dual to 36	0 to 1.5	802B	—	318	3.6 mv or 0.01%	3.6 mv or 0.01%	0.2	100	105-125	50 to 400	v&a		√		√	28 12,6	34 15,3	19 483	3½ 89	15 381			2 sides can be series'ed for 0-72 v at 0-1.5 a; fixed current limit	$580
0 to 36	0 to 1.5	6226A	—	319	2 mv or 0.02%	2 mv or 0.02%	0.5	50	105-125 or 210-250	50 to 70	v/a	√	√	√	R	15 6,8	20 9	5⅛ 130	6¾ 171	11 279	√	√	front and rear output terminals, ⅓ rack width package; variable voltage and current limit	$325
0 to 36	0 to 1.5	6348A	MOD	328	3 mv or 0.02%	3 mv or 0.02%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	13 5,9	19 8,6	6¼ 159	5 127	9 229		√	plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$225
0 to 36	0 to 2.5	800B-2	—	318	10 mv	5 mv	0.25	50	105-125	50 to 440	v&a			√	R	25 1,3	30 13,5	7 178	9 229	10½ 267			rack mounting panel available; fixed current limit	$339
0 to 36	0 to 3	6244A†	—	322	5 mv or 0.02%	2 mv or 0.01%	0.5	50	105-125 or 210-250	50 to 70	v&a	√	√	√	√	25 11,3	41 18,5	19 483	3½ 89	16¾ 425	√	√	variable voltage and current limit	$460
0 to 36	0 to 3	6265A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	36 16,2	47 21,2	19 483	3½ 89	17½ 445	√	√	variable voltage and current limit	$350
0 to 36	0 to 3	6365A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	34 15,3	45 20,3	19 483	3½ 89	17½ 445		√	well-regulated, "stripped-down" version of 6265A	$279
0 to 36	0 to 5	808A†	—	322	3.6 mv or 0.01%	3.6 mv or 0.01%	0.5	50	105-125	57 to 63	v&a	√	√		√	35 15,8	46 20,7	19 483	3½ 89	16¾ 425	X	√	variable current limit	$475
0 to 36	0 to 5	6266A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	36 16,2	47 21,2	19 483	3½ 89	17½ 445	√	√	variable voltage and current limit	$435
0 to 36	0 to 5	6366A	LVR	320	200 μv + 0.01%	200μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	34 15,3	45 20,3	19 483	3½ 89	17½ 445		√	well-regulated, "stripped-down" version of 6266A	$359

additional listings on next page

HARRISON POWER SUPPLIES

Condensed listing

Output volts	Output amps	Harrison model	Series	Catalog page number	Load regulation	Line regulation	RMS ripple and noise (mv)	Recovery time* (μsec)	Input line voltage	Input line frequency (cps)	Meter(s) provided	Remote programming	Remote sensing	Bench model	Rack model***	Net weight lbs, kg	Shipping weight lbs, kg	Dimensions inches mm wide	high	deep	Constant Voltage/Constant Current operation**	Auto-Series/Auto-Parallel/Auto-Tracking	Special features	Price
0 to 36	0 to 10	510A	SCR-1	324	180 mv combined		360	50 (msec)	105-125	57 to 63	v&a	√	√		√	48 21,6	58 26,1	19 483	5¼ 133	12 305		√	high efficiency; variable current limit	$450
0 to 36	0 to 10	809A†	—	322	7.2 mv or 0.02%	7.2 mv or 0.02%	0.5	50	105-125	57 to 63	v&a	√	√		√	55 24,8	63 28,4	19 483	5¼ 133	16¾ 425	×	√	variable current limit	$575
0 to 36	0 to 10	6267A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	54 24,3	66 29,7	19 483	5¼ 133	17½ 445	√	√	variable voltage and current limit	$525
0 to 36	0 to 10	6367A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	52 23,4	64 28,8	19 483	5¼ 133	17½ 445		√	well regulated, "stripped-down" version of 6257A	$450
0 to 36	0 to 25	520A	SCR-1	324	180 mv combined		360	50 (msec)	105-125	57 to 63	v&a	√	√		√	85 38,3	101 45,5	19 483	7 178	16½ 419		√	high efficiency; variable current limit	$575
0 to 36	0 to 25	814A†	—	322	10 mv or 0.03%	10 mv or 0.03%	1	100	105-125	57 to 63	v&a	√	√		√	90 40,5	100 45	19 483	7 178	18⅜ 467	√	√	variable voltage and current limit	$775
0 to 36	0 to 75	6455A	SCR-3	326	180 mv combined		180	50 (msec)	3φ 208/230 ±10%	57 to 63	v&a	√	√		√	220 99	255 114,8	19 483	14 356	17 432		√	high efficiency, variable current limit	$1450
0 to 40	0 to 0.5	723A	—	322	20 mv	10 mv	0.15	—	115/230 ±10%	50 to 1000	v/a	√		√	R	11 5	21 9,5	5⅛ 130	6¾ 171	12 305		√	variable current limit	$240
0 to 40	0 to 0.5	865C	—	332	25 μa + 0.02%	25 μa + 0.02%	0.2	50	105-125 or 210-250	50 to 440	v/a	√	√	√	R	14 6,3	16 7,2	7-13/16 198	5-1/16 129	8½ 216	√	√	high-speed programming; useful as a low-frequency amplifier	$179
0 to 40	0 to 0.75	6200A	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	v&a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330	√	√	dual-range output selected by front-panel pushbuttons; other range: 0-20 v, 0-1.5 a; variable voltage and current limit	$210
0 to 40	0 to 0.75	6202A	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	v/a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330	√	√	front and rear output terminals; ½ rack width package; variable voltage and current limit	$179
0 to 60	0 to 2	726AR	—	322	5 mv	2.5 mv	0.25	200	115/230 ±10%	50 to 60	v&a	√	√		√	25 11,3	38 17,1	19 483	5¼ 133	12 305			front and rear output terminals; variable current limit	$595
0 to 60	0 to 3	6271A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	v&a	√	√		√	36 16,2	47 21,2	19 483	3½ 89	17½ 445	√	√	variable voltage and current limit	$435
0 to 60	0 to 3	6371A	LVR	320	200 μv + 0.01%	200 μv + 0.01%	0.5	50	105-125 or 210-250	48 to 63	no	√	√		√	34 15,3	45 20,3	19 483	3½ 89	17½ 445		√	well regulated, "stripped-down" version of 6271A	$359
0 to 60	0 to 5	6438A	SCR-1P	325	45 mv or 0.15% combined		120	300 (msec)	105-125	57 to 63	v&a	√	√		√	32 14,4	43 19,4	19 483	3½ 89	17½ 445	√	√	high efficiency; variable voltage and current limit	$360
0 to 60	0 to 7.5	810B†	—	322	10 mv or 0.02%	5 mv or 0.01%	1	100	105-125	57 to 63	v&a	√	√		√	60 27	67 30,2	19 483	5¼ 133	16¾ 425	√	√	variable voltage and current limit	$695
0 to 60	0 to 15	6439A	SCR-1P	325	180 mv combined		60	300 (msec)	105-125	57 to 63	v&a	√	√		√	60 27	73 32,9	19 483	5¼ 133	16¾ 425	√	√	high efficiency; variable voltage and current limit	$550
0 to 64	0 to 0.5	6206A 6206AM	LAB	315	4 mv + 0.01%	4 mv + 0.01%	0.2	50	105-125 or 210-250	50 to 400	no v&a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330		√	front and rear output terminals, ½ rack width package, dual-range output selected by front-panel pushbuttons; other range: 0-32 v, 0-1 a; variable current limit	$164 $184
0 to 64	0 to 1	6242A†	—	322	3 mv or 0.02%	5 mv or 0.02%	0.2	50	105-125 or 210-250	50 to 400	v&a	√	√	√	√	25 11,3	30 13,5	19 483	3¼ 83	16¾ 425	√	√	plug-in printed circuit card selects dual-output range; other range: 0-32 v, 0-2 a; variable voltage and current limit	$435
0 to 64	0 to 50	6459A	SCR-3	326	0.2% + 10 mv combined		160	50 (msec)	3φ 208/230/460±10%	57 to 63	v&a	√	√		√	238 107,1	275 123,8	19 483	14 356	18¾ 454	√	√	high efficiency; variable voltage and current limit	$1450
0 to 72	0 to 5	505A	SCR-1	324	360 mv combined		720	50 (msec)	105-125	57 to 63	v&a	√	√		√	50 22,5	60 27	19 483	5¼ 133	12 305		√	high efficiency; variable current limit	$475

additional listings on next page

HARRISON POWER SUPPLIES

Condensed listing

Output volts	Output amps	Harrison model	Series	Catalog page number	Load regulation	Line regulation	RMS ripple and noise (mv)	Recovery time* (μsec)	Input line voltage	Input line frequency (cps)	Meter(s) provided	Remote programming	Remote sensing	Bench model	Rack model***	Net weight lbs, kg	Shipping weight lbs, kg	Dimensions inches mm wide	high	deep	Constant Voltage/Constant Current operation**	Auto-Series/Auto-Parallel/Auto-Tracking	Special features	Price
0-100	0-1	880	——	318	5 mv or 0.02%	5 mv or 0.02%	0.5	50	105-125	50 to 440	v&a			√	R	25 11,3	30 13,5	7 178	9 229	10½ 267			rack mounting panels available; fixed current limit	$375
0-100	0-1	881A†	——	322	5 mv or 0.02%	5 mv or 0.05%	0.2	50	105-125	57 to 63	v&a	√	√		√	35 15,8	42 18.9	19 483	3½ 89	16¾ 425	×	√	variable current limit	$475
0-120	0-2.5	6443A	SCR-1P	325	90 mv or 0.15% combined		240	300 (msec)	105-125	57 to 63	v&a	√	√		√	32 14,4	43 19.4	19 483	3½ 89	17½ 445	√	√	high efficiency; variable voltage and current limit	$360
0-160	0-0.2	6207A	LAB	315	2 mv + 0.02%	2 mv + 0.02%	0.5	50	105-125 or 210-250	57 to 63	v/a	√	√	√	R	18 8,1	20 9	8¼ 210	3½ 89	13 330	√	√	front and rear output terminals, ½ rack width package; variable voltage and current limit	$194
0-160	0-0.4	6354A	MOD	328	2 mv + 0.005%	1 mv + 0.005%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	13 5,9	19 8,6	6¼ 159	5 127	9 229	√	√	plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$259
75-160	0-2.5	896A†	MVR	327	10 mv or 0.007%	10 mv or 0.007%	1	100	105-125	57 to 63	v&a	√	√		√	50 22,5	66 29,7	19 483	5¼ 133	16¾ 425			fixed current limit; fuse blows for severe overloads	$675
0-320	0-0.2	6357A	MOD	328	2 mv + 0.005%	1 mv + 0.005%	1	50	105-125 or 210-250	48 to 63	no	√	√		R	13 5,9	19 8,6	6¼ 159	5 127	9 229			plug-in module; all input, output and control connections via 11-pin plug; variable current limit	$259
0-320	0-0.6	890A†	MVR	327	10 mv or 0.007%	10 mv or 0.007%	1	100	105-125	57 to 63	v&a	√	√		√	35 15,8	43 19,4	19 483	3½ 89	16¾ 425			fixed current limit; fuse blows for severe overload	$445
0-320	0-1.5	895A†	MVR	327	10 mv or 0.007%	10 mv or 0.007%	1	100	105-125	57 to 63	v&a	√	√		√	50 22,5	66 29,7	19 483	5¼ 133	16¼ 425			fixed current limit; fuse blows for severe overload	$625
−250 to −400 0 to −900	0.03-0.05 0-10μa	715A‡	——	331	1% 1%	1% 1%	7 10	——	115/230 ±10%	50 to 60	a			√		19 8.6	24 10,8	7⅜ 187	11½ 292	13¾ 349			klystron supply; 6.3 v ac, 1.5 a output; direct reading calibrated voltage controls; choice of modulated signal; protection circuit	$365
0-500	0-0.1	711A‡ 711AR‡	——	330	1000 or 0.5%	1000 or 0.5%	1	——	115-230 ±10%	50 to 1000	v&a			√	√	20 9 24 10,8	26 11,7 35 15,8	7⅛ 178 19 483	11½ 292 7 178	14½ 368 12¾ 324			2 ranges on voltmeter and ammeter; 12.6 v ac ct aux. 3 a output; overload protection includes ac line fuse and dc protection relay	$275 $280
0 to +500 −300 0 to −150	0-0.2 0-0.05 0-0.005	712B‡ 712BR‡	——	330	50 50 ——	±100 ±100 ±100	0.5 0.5 0.5	100 —— ——	115 ±10%	50 to 60	v&a			√	√	70 31,5 62 27,9	81 36,5 77 34,7	20¾ 527 19 483	12¾ 324 10½ 267	14¾ 375 13¾ 349			voltmeter can be switched to monitor any of 3 output voltages: 6.3 v ac ct auxiliary 10 a output; overload protection	$490 $475
−250 to −800 0 to −800 6.3 (adj.)	0-0.1 0-2	716B†	——	331	0.05% —— ——	0.05% 0.05% 1%	1 0.5 2	——	115/230 ±10%	50 to 60	a			√	√	45 20.3	63 28,4	16¾ 425	7½ 191	18⅜ 467			klystron supply; direct reading calibrated voltage controls; choice of internal, external modulation; sync input for internal modulation; sync output for scope; diode protection circuit	$875
0 to 1000	5-50 ma	740A	——	154	± 0.001% ±25 mv	± 0.001%	−120 db below f. s.	——	115/230 ±10%	50 to 1000	digital plus taut-band		√	√	√	47 21,2	60 27	18¾ 476	7 178	16¾ 425	×		0.1% dc standard differential voltmeter analog voltmeter; dc amplifier	$2350
0 to 1000	0-20 ma	741A	——	156	0.002%	0.002%	−100 db below f.s.	——	115/230 ±10%	50 to 1000	push-button switch & taut-band		√	√	√	46 20,7	60 27	18¾ 476	7 178	16¾ 425	×		0.3% dc standard; ac-dc differential voltmeter, analog voltmeter; dc amplifier	$1475
0-1000	0-0.2	6521A	HVR	327	20 mv or 0.005%	20 mv or 0.005%	1	50	105-125	50 to 70	v&a				√	50 22,5	60 27	19 483	5¼ 133	18 457	√		all solid-state circuitry, 3-decade switching with vernier control	$750
0-2000	0-0.1	6522A	HVR	327	20 mv or 0.005%	20 mv or 0.005%	1	50	105-125	50 to 70	v&a				√	50 22,5	60 27	19 483	5¼ 133	18 457	√		all solid-state circuitry; 3-decade switching with vernier control	$750
0-4000	0-0.05	6525A	HVR	327	20 mv or 0.005%	20 mv or 0.005%	1	50	105-125	50 to 70	v&a				√	50 22,5	60 27	19 483	5¼ 133	18 457	√		all solid-state circuitry; 3-decade switching with vernier control	$750

All supplies: Maximum operating ambient, 50°C; 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 semi-conductor except as noted by ‡.

Solid-state supplies: glass-epoxy printed circuit board construction, fully automatic overload protection—short circuit proof.

* Time required for output voltage recovery to within "Y" millivolts of the nominal output voltage, where "Y" is of the same order as the load regulation, and the nominal output voltage is defined as the mean between the no load and full load voltages.

† Chopper stabilized units also available at $125 extra.

** Units with "√" in this column feature automatic crossover between constant voltage and constant current operation; whereas units with "×" are converted from constant voltage to constant current or from constant current to constant voltage operation by means of substituting plug-in printed wiring card and rearranging straps on rear barrier strip.

*** Units with "R" in rack model column can be rack mounted utilizing optional panels.

LAB SERIES DC POWER SUPPLIES

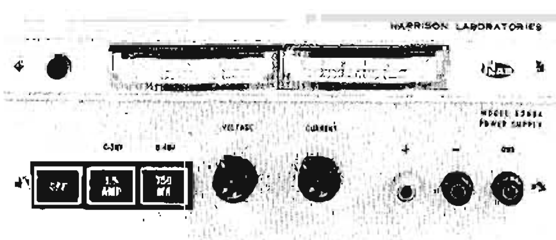
Compact, high-performance, multi-purpose supplies

These low-price, high-performance power supplies have a unique combination of electrical and mechanical features which make them the most versatile laboratory power supplies available. All units are highly regulated, feature low ripple and noise and freedom from drift. The supplies automatically regulate with respect to either the front or rear terminals, according to where the load is attached.

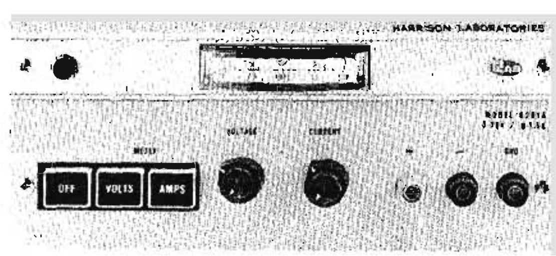
All supplies are floating, and either the positive or negative output terminal may be connected to chassis through a separate terminal. Included on the rear barrier strip are terminals for remote sensing, remote programming, Auto-Series, Auto-Parallel and Auto-Tracking operation. All power supply components are mounted directly on a single glass epoxy printed wiring board which is an integral part of the supply.

Further advantages include voltage ratings to 160 volts, current ratings to 3 amps, output wattage to 32 watts; Constant Voltage/Constant Current and Constant Voltage/Cur-

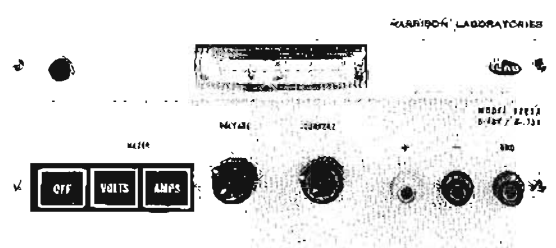
Volts	Amps	Harrison model
0 to 7.5	0 to 3	6203A
0 to 18 0 to 36	0 to 0.6 0 to 0.3 dual range	6204A,AM
0 to 20	0 to 1.5	6201A
0 to 20 0 to 40	0 to 1.5 0 to 0.75 dual range	6200A
0 to 40	0 to 0.75	6202A
0 to 32 0 to 64	0 to 1 0 to 0.5 dual range	6206A,AM
0 to 160	0 to 0.2	6207A



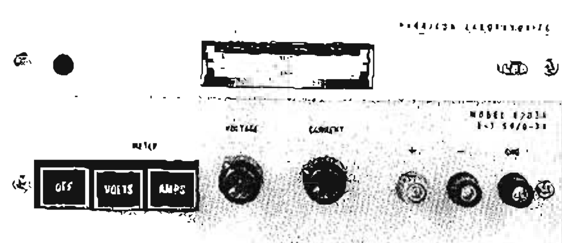
6200A



6201A



6202A



6203A

Specifications, all models

Output terminals: front and rear panels.
Transient recovery time: less than 50 μsec to within 10 mv (20 mv for 6203A).
Maximum operating temperature: 50°C.
Temperature coefficient: less than 0.02% + 1 mv/°C.
Stability: less than 0.1% + 5 mv for 8 hours.

Clip-on accessories for LAB series supplies

Unique clip-together features, utilizing keyways and solder rivets, simplify rack mounting and accessory attachment. The illustrations indicate the versatility of the Harrison LAB supplies.

Part no.	Description	Price
R6200-1	for mounting one unit	$20
R6200-2	for mounting two units	$5
620060	handle	$7
620070	twin carrier	$19

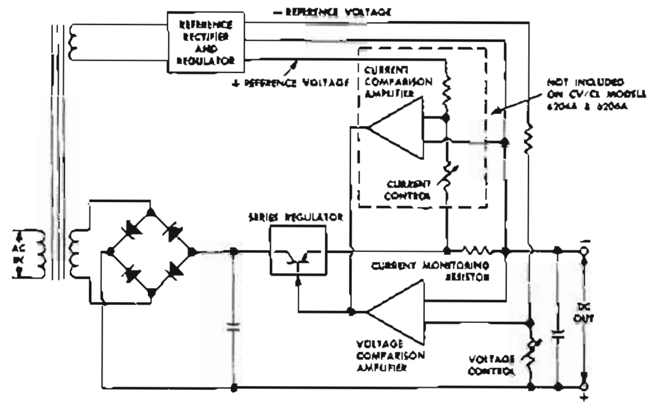
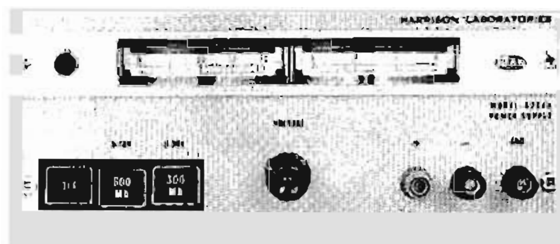


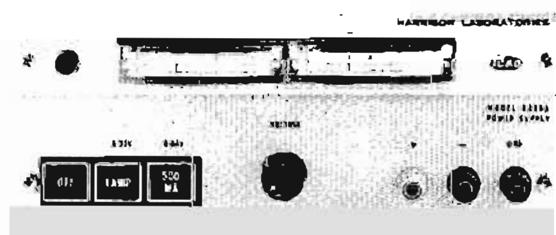
Figure 1. This block diagram is typical of all models below 100 volts. Dual-range operation is accomplished by paralleling or seriesing two rectifier and power regulator circuits while using one comparison amplifier and control circuit.

6204A

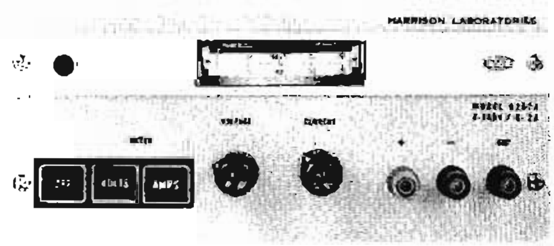


6204AM

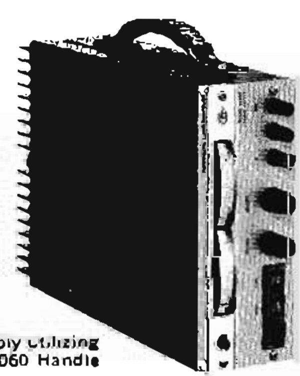
6206A



6206AM



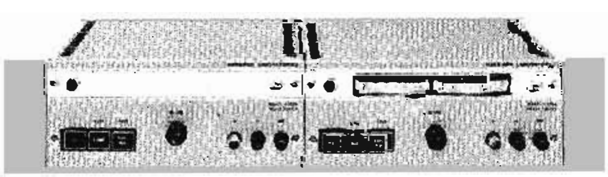
6207A



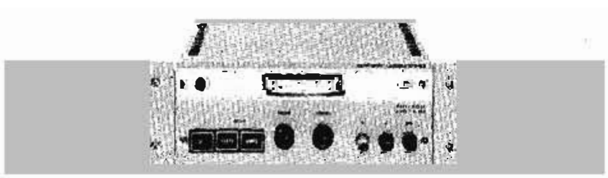
Portable supply utilizing Part No. 620060 Handle

Harrison model		6200A (dual-range output)	6201A	6202A	6203A	6204A** (dual-range output)	6206A** (dual-range output)	6207A
Output	dc voltage	0 to 20 v, 0 to 40 v	0 to 20 v	0 to 40 v	0 to 7.5 v	0 to 18 v, 0 to 36 v	0 to 32 v, 0 to 64 v	0 to 160 v
	dc current	0 to 1.5 a, 0 to 0.75 a	0 to 1.5 a	0 to 0.75 a	0 to 3 a	0 to 0.6 a, 0 to 0.3 a	0 to 1 a, 0 to 0.5 a	0 to 0.2 a
Input		105 to 125 or 210 to 250 v ac, 50 to 400 cps						105 to 125 or 210 to 250 v ac, 57 to 63 cp
Load regulation	cv*	0.01% +4 mv			5 mv	0.01% +4 mv	0.01% +4 mv	0.02% +2 mv
	cc*	0.03% +250 μa				—	—	0.05% or 200 μa
Line regulation	cv	0.01% +4 mv			3 mv	0.01% +4 mv	0.01% +4 mv	0.02% +2 mv
	cc	0.01% or 250 μa				—	—	0.05% or 200 μa
Ripple and noise	cv				200 μv rms			500 μv rms
	cc	500 μa rms				—	—	200 μa rms
Remote programming	cv						300 ohms/volt	
	cc	500 ohms per amp/ 100 ohms per amp	1000 ohms/amp		500 ohms/a	—	—	3750 ohms/amp
Overload protection						fixed current limit for complete protection for any overload condition; this limit set at approx. 700 ma for the 18 v range and 350 ma for the 36 v range	fixed current limit for complete protection for any overload condition; this limit is set for approx. 1.2 a for the 32 v range and 600 ma for the 64 v range	same as 6200A
Controls		front-panel pushbuttons are used to turn supply on and select one of the two output ranges; coarse and fine voltage and current controls	front-panel pushbuttons turn supply on and are used to select whether meter monitors output voltage or output current; coarse and fine voltage and current controls			front-panel pushbuttons are used to turn supply on and select one of two output ranges; coarse and fine voltage controls		same as 6201A
Meters		0 to 40 v, 0 to 1.8 a	0 to 20 v, 0 to 2 a	0 to 40 v, 0 to 1 a	0 to 10 v, 0 to 4 a	0 to 40 v, 0 to 0.6 a	0 to 64 v, 0 to 1.2 a	0 to 200 v, 0 to 0.2 a
Dimensions						18¼" w, 3½" h, 10" d (210 x 89 x 254 mm)	8¼" w, 3½" h, 13" d (210 x 89 x 330 mm)	
Weight (net/shipping)						12/16 lbs (5,4/7,2 kg)	18/20 lbs (8,1/9 kg)	
Price		Harrison 6200A, $210	Harrison 6201A, $179	Harrison 6202A, $179	Harrison 6203A, $179	Harrison 6204A (without meters), $124; 6204AM (with meters), $144	Harrison 6206A (without meters), $164; 6206AM, (with meters) $184	Harrison 6207A, $194

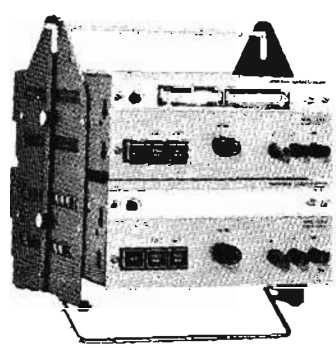
*cv = constant voltage; cc = constant current. **constant current/current limiting.



Double rack mounting in 3½" (89 mm) utilizing Part No. R6200-2 rack adapter.



Single rack mounting in 3½" (89 mm) utilizing Part No. R6200-1 rack adapter.



Dual supply utilizing Part No. 620070 Twin Carrier accessory.

800A-2, 800B-2, 880, 802B, 801C POWER SUPPLIES

Heavy-duty bench supplies; dual supplies; strain gage supply

800A-2, 800B-2, 880

These three Harrison models are highly regulated solid-state power supplies intended for general lab use. All are short circuit proof and exhibit no output overshoot when the ac power is turned on or off at any line voltage or load current. Model 800A-2 contains two identical power supplies which are completely independent except for the common ac power input. Model 800B-2 is a 2.5 amp supply which provides a continuously adjustable output of 0 to 36 volts. Model 880 is a compact supply providing 0 to 100 volts at 0 to 1 amp.

Rack-mounting panels

The mounting panels listed below permit the 800A-2, 800B-2 or 880 to be adapted to relay rack use. Both panels are 19" wide and 10½" high (483 x 267 mm). Price: Harrison 800R1, allows one supply to be mounted in center of panel, $20; Harrison 800R2, allows two supplies to be mounted side by side, $20.

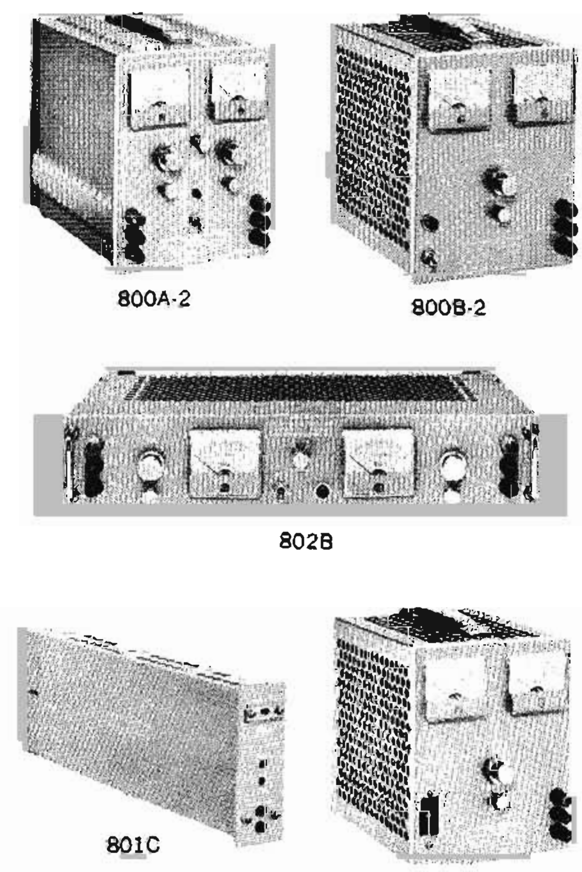
802B Twin Solid-State Power Supply

The 802B furnishes two independent outputs, 0 to 36 volts at 0 to 1.5 amps. These units have provision for remote error sensing, as well as full protection against a direct short across the output of the power supply. Front and rear output terminals are provided for each of the two supplies.

801C Strain Gage Supply

Designed to operate primarily as a power supply for strain gage applications, the 801C is a solid-state power supply whose design, construction and size permit extreme isolation from ground and the ac power line—greater than 10,000 megohms to ground or ac input and less than 1 pf capacity from output terminals to input power line. Remote error sensing provision is included. Using many supplies to feed a large number of strain gages provides excellent isolation capabilities, and the shorting of a single strain gage will not disrupt the entire test setup.

A rack mounting panel 5¼" high and 19" wide (133 x 483 mm) permits nine 801C modules to be rack mounted side by side. All necessary hardware for mounting nine supplies is included. Provision is made on this panel for a label for each power supply. This label receives rear illumination for the pilot light when ac power is applied. Price: Harrison R-801C Rack Mounting Panel, $18.



800A-2 800B-2

802B

801C 880A

Specifications

Harrison model		800A-2		800B-2	880	802B		801C
Output		2 independent supplies				2 independent supplies		
	voltage	0 to 36 v	0 to 36 v	0 to 36 v	0 to 100 v	0 to 36 v	0 to 36 v	0 to 25 v
	current	0 to 1.5 a	0 to 1.5 a	0 to 2.5 a	0 to 1 a	0 to 1.5 a	0 to 1.5 a	0 to 0.2 a
Input		105 to 125 v, 50 to 65 cps		105 to 125 v, 50 to 440 cps				105 to 125 v, 55 to 65 cps
Load regulation		5 mv		10 mv	0.02% or 5 mv	0.01% or 3.6 mv		2 mv
Line regulation		5 mv		5 mv	0.02% or 5 mv	0.01% or 3.6 mv		2 mv
Ripple and noise		<200 μv rms		<250 μv rms	<500 μv rms	<200 μv rms		<100 μv rms
Maximum ambient operating temperature		50°C		50°C	50°C	50°C		50°C
Stability		less than 0.05%, plus 10 mv drift for 8 hours after 30-min. warm-up						0.1% plus 5 mv
Controls		coarse and fine voltage control; meter switch		coarse and fine voltage control	coarse and fine voltage control	coarse and fine voltage control; meter switch		coarse and fine voltage control
Meters		0 to 40 v and 0 to 1.8 a		0 to 36 v and 0 to 3 a	0 to 100 v and 0 to 1 a	0 to 40 v and 0 to 1.8 a		——
Dimensions		7" w x 9" h x 10½" d (177 x 228 x 266 mm)				19" w x 3½" h x 15" d (483 x 88 x 381 mm)		1⅝" w x 5" h x 15-5/16" d (41 x 127 x 389 mm)
Weight (net/shipping)		29/32 lbs (13/14,4 kg)		25/30 lbs (11,2/13,5 kg)	25/30 lbs (11,2/13,5 kg)	28/34 lbs (12,6/15,3 kg)		4/8 lbs (1,8/3,6 kg)
Price		$580		$339	$375	$580		$149

721A, 723A, 6224A, 6226A POWER SUPPLIES

Low-voltage, medium-power supplies

721A Power Supply

The hp 721A Power Supply is designed to produce dc voltages for transistor investigation. Its fully regulated output voltages of 0 to 30 volts are 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, or the supply may be stacked on another voltage, giving the hp 721A maximum output versatility. An outstanding feature of the hp 721A is a circuit which limits the output current to a nominal value determined by a front-panel switch. In case of accidental overloads, this feature can prevent costly damage to transistors under test.

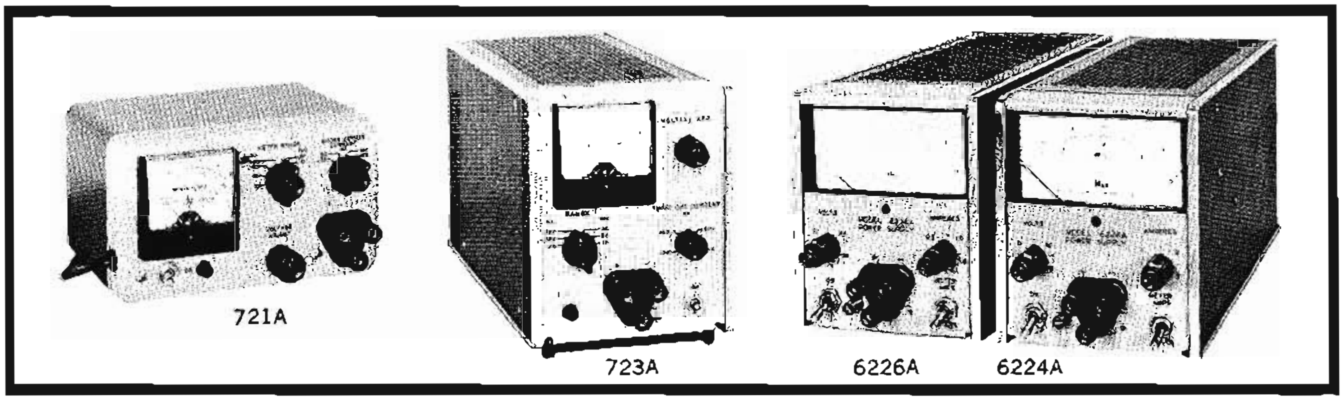
723A Power Supply

Low noise and ripple make the 723A particularly useful in low-level applications. Output terminals are isolated from the chassis and power line ground, so that you may ground either the positive or negative terminal, or operate several units in cascade or parallel for higher voltages, currents. Output voltage of Model 723A may be changed by a front-panel control or simply by changing the value of an external resistance. Thus, output voltage may be programmed remotely by using stepping switches to change the value of the external resistance in accordance with programmed tests. A meter which monitors voltage or current allows you to set output voltage and observe load conditions conveniently. The variable current-limit control may be set to any value from 60 to 600 ma to protect test circuits from damage.

6224A, 6226A Bench Supplies

These two Harrison medium-power dc laboratory supplies are specifically packaged as 1/3 width modules for use in the hp enclosure system (pages 13, 14). The 6224A is a 0-to-18 volt supply at 3 amps and the 6226A is a 0-to-36 volt supply at 1.5 amps. Both front and rear output terminals are provided. All interconnections for Auto-Series, Auto-Parallel, remote programming and remote error sensing operation are made entirely on the rear barrier strip terminals. The front-panel meter is especially easy to read.

Other advantages include Constant Voltage/Constant Current operation with automatic crossover; continuous one-knob output control, with no range switching; no overshoot on turn-on, turn-off or ac power removal; short circuit proof in constant voltage use; open-circuit proof in constant current use; maximum operating temperature of 50°C; temperature coefficient of 0.01% +2 mv/°C; 0.05% +10 mv stability.



721A 723A 6226A 6224A

Specifications

hp Model	721A	723A
Output voltages:	0 to 30 v dc, continuously variable	0 to 40 v dc, continuously variable
Full load output current:	150 ma over entire voltage range	500 ma over entire voltage range
Ripple and noise:	less than 150 μv rms	less than 150 μv rms
Regulation:	load: less than 30 mv; line: less than 15 mv (over entire voltage range and ±10% power line fluctuation)	load: less than 20 mv; line: less than 10 mv (over entire voltage range and ± 10% power line fluctuation)
Output impedance:	less than 0.2 ohm in series with 30 μh	40 milliohms in series with 20 μh
Metering:	current meter: four ranges, 0 to 300 ma, 0 to 100 ma, 0 to 30 ma, 0 to 10 ma; voltage meter: two ranges, 0 to +10 volts, 0 to +30 volts	current meter: three ranges, 0 to 500 ma, 0 to 200 ma, 0 to 100 ma, voltage meter: three ranges, 0 to +50 v, 0 to +20 v, 0 to +10 v
Overload protection:	maximum current selected by front-panel switch; 25 ma, 50 ma, 100 ma, 225 ma; current limiter	maximum current selected by front-panel control variable from 60 to 600 ma; current limiter
Dimensions:	4⅜" high, 7" wide, 5¼" deep (111 x 178 x 133 mm)	6-17/32" high, 5⅛" wide, 11" deep (167 x 130 x 279 mm)
Weight:	net 4 lbs (1.8 kg); shipping 7 lbs (3.2 kg)	net 11 lbs (4.9 kg); shipping 21 lbs (9.5 kg)
Price:	hp 721A, $145	hp 723A, $240

Harrison model		6224A	6226A
Output	voltage	0 to 18 volts	0 to 36 volts
	current	0 to 3 amps	0 to 1.5 amps
Input		105 to 125 or 210 to 250 v, 50 to 70 cps, single phase	
Load regulation	cv*	0.03% or 2 mv	0.02% or 2 mv
	cc*	0.05% or 600 μa	0.05% or 300 μa
Line regulation	cv	0.02% or 2 mv	0.02% or 2 mv
	cc	0.03% or 250 μa	0.03% or 250 μa
Ripple and noise	cv	500 μv rms	500 μv rms
	cc	200 μa rms	200 μa rms
Remote programming	cv	200 ohms/volt	200 ohms/volt
	cc	150 ohms/amp	300 ohms/amp
Controls		both coarse and fine voltage and current controls are provided; a meter switch makes possible the monitoring of either output voltage or current	
Meters		0 to 20 v/0 to 4 a	0 to 40 v/0 to 2 a
Dimensions		5⅛" wide, 6¾" high, 11" deep (67 x 171 x 279 mm)	
Weight		net 15 lbs (6.8 kg); shipping 20 lbs (9 kg)	
Price		Harrison 6224A, $340	Harrison 6226A, $325

*cv indicates constant voltage operation; cc indicates constant current operation

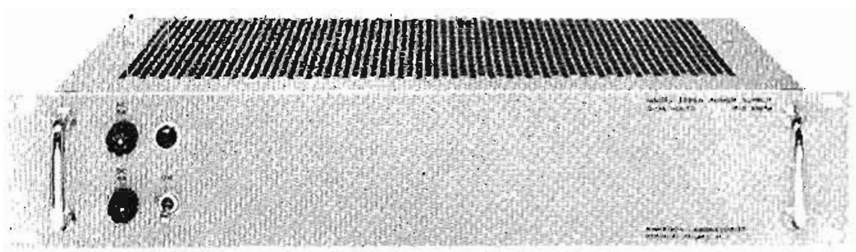
LVR SERIES POWER SUPPLIES

High-performance, low voltage, rack mounting supplies

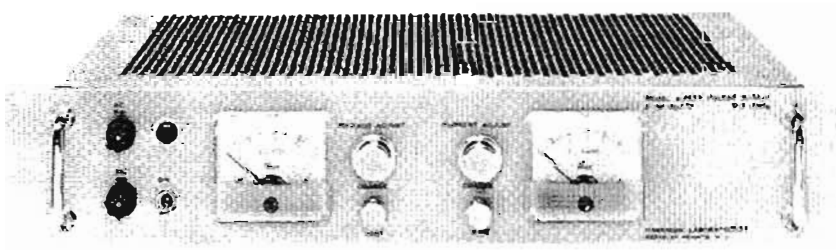
The Harrison LVR Series power supplies are versatile, compact, high-performance supplies designed for both lab and system use. Design and construction of these two groups of supplies are similar except for constant current features, front-panel controls and meters. They offer 0.01% +200 μv regulation, and ripple less than 500 microvolts.

Advantages include Auto-Series, Auto-Parallel and Auto-Tracking operation; remote programming (voltage and current can be programmed by resistance or control voltages); remote error sensing; continuously variable voltage and current adjustments, no range switching; superior output impedance over a wide frequency band; differential amplifier front end; use of silicon transistors where leakage and stability are critical; transient recovery time of less than 50 microseconds (in constant voltage operation) to within 10 millivolts of the nominal output voltage; operating temperature range of 0 to 50°C (storage −20 to +71°C).

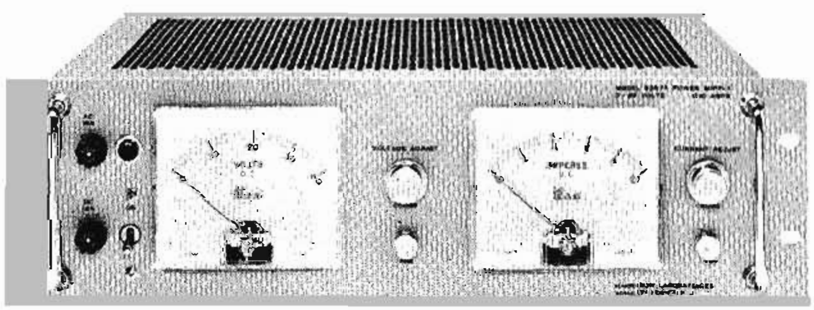
In addition, the following features are included on the 6263A, 6264A, 6265A, 6266A, 6267A and 6271A: Constant Voltage/Constant Current with automatic crossover; coarse and fine controls on the front panel; silicon differential amplifier packages in the constant current and constant voltage circuits; sharp cutover from constant voltage to constant current operation.



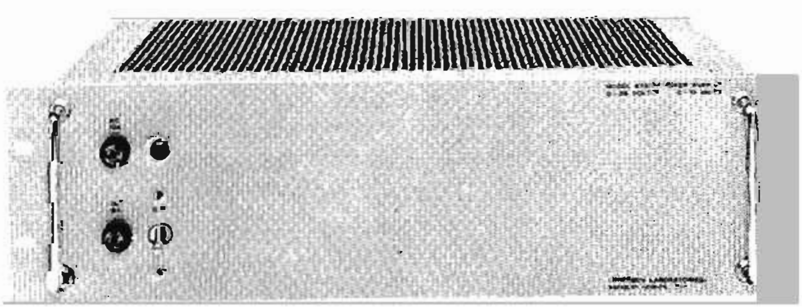
6363A
6365A
6366A
6371A



6263A
6265A
6266A
6271A



6264A
6267A



6364A
6367A

Specifications, LVR Series

Harrison model		6263A	6363A	6264A	6364A	6265A	6365A
DC output		0 to 18 volts at 0 to 10 amps		0 to 18 volts at 0 to 20 amps		0 to 36 volts at 0 to 3 amps	
AC input		105 to 125/210 to 250 v ac, 48 to 63 cps					
Load regulation	cv*	0.01% +200 μv					
	cc*	0.02% +500 μa	——	0.02% +500 μa	——	0.02% +500 μa	——
Line regulation	cv	0.01% +200 μv					
	cc	0.02% +500 μa	——	0.02% +500 μa	——	0.02% +500 μa	——
Ripple and noise	cv	500 microvolts rms					
	cc	3 milliamps rms	——	5 milliamps rms	——	3 milliamps rms	——
Temperature coefficient (output change per degree C change in ambient following 30 min warm-up)	cv	0.01% +200 μv	0.02% +500 μv	0.01% +200 μv	0.02% +500 μv	0.01% +200 μv	0.02% +500 μv
	cc	0.01% +2 ma	——	0.01% +2 ma	——	0.01% +1 ma	——
Stability (under constant ambient conditions total drift for 8 hr following 30 min warm-up)	cv	0.03% +2 mv	0.05% +5 mv	0.03% +2 mv	0.05% +5 mv	0.03% +2 mv	0.05% +5 mv
	cc	0.03% +5 ma	——	0.03% +5 ma	——	0.03% +2 ma	——
Remote programming (all programming terminals are located on rear barrier strips)	cv	200 ohms/volt					
	cc	100 ohms/amp	——	25 ohms/amp	——	300 ohms/amp	——
Meters		0 to 20 v and 0 to 12 amp	no meters	0 to 20 v and 0 to 20 amp	no meters	0 to 40 v and 0 to 3 amp	no meters
Controls		front panel coarse and fine	rear panel voltage	front panel coarse and fine	rear panel voltage	front panel coarse and fine	rear panel voltage
Dimensions		19″ w, 3½″ h, 17½″ d (483 x 88 x 444 mm)		19″ w, 5¼″ h, 17½″ d (483 x 133 x 444 mm)		19″ w, 3½″ h, 17½″ d (483 x 88 x 444 mm)	
Weight (net/shipping)		36/47 lbs (16,2/21,2 kg)	34/45 lbs (15,3/20,2 kg)	54/66 lbs (24,3/29,7 kg)	52/64 lbs (23,4/28,8 kg)	36/47 lbs (16,2/21,2 kg)	34/45 lbs (15,3/20,2 kg)
Price		Harrison 6263A, $435	Harrison 6363A, $359	Harrison 6264A, $525	Harrison 6364A, $450	Harrison 6265A, $350	Harrison 6365A, $279

Specifications, LVR Series

Harrison model		6266A	6366A	6267A	6367A	6271A	6371A
DC output		0 to 36 volts at 0 to 5 amps		0 to 36 volts at 0 to 10 amps		0 to 60 volts at 0 to 3 amps	
AC input		105 to 125/210 to 250 v ac, 48 to 63 cps					
Load regulation	cv*	0.01% +200 μv					
	cc*	0.02% +500 μa	——	0.02% +500 μa	——	0.02% +500 μa	——
Line regulation	cv	0.01% +200 μv					
	cc	0.02% +500 μa	——	0.02% +500 μa	——	0.02% +500 μa	——
Ripple and noise	cv	500 microvolts rms					
	cc	3 milliamps rms	——	3 milliamps rms	——	3 milliamps rms	——
Temperature coefficient (output change per degree C change in ambient following 30 min warm-up)	cv	0.01% +200 μv	0.02% +500 μv	0.01% +200 μv	0.02% +500 μv	0.01% +200 μv	0.02% +500 μv
	cc	0.01% +2 ma	——	0.01% +2 ma	——	0.01% +1 ma	——
Stability (under constant ambient conditions, total drift for 8 hr following 30 min warm-up)	cv	0.03% +2 mv	0.05% +5 mv	0.03% +2 mv	0.05% +5 mv	0.03% +2 mv	0.05% +5 mv
	cc	0.03% +5 ma	——	0.03% +5 ma	——	0.03% +2 ma	——
Remote programming (all programming terminals are located on rear barrier strips)	cv	200 ohms/volt			300 ohms/volt		
	cc	200 ohms/amp	——	100 ohms/amp	——	300 ohms/amp	——
Meters		0 to 40 v and 0 to 6 amps	no meters	0 to 40 v and 0 to 10 amps	no meters	0 to 60 v and 0 to 3 amps	no meters
Controls		front panel coarse and fine	rear panel voltage	front panel coarse and fine	rear panel voltage	front panel coarse and fine	rear panel voltage
Dimensions		19″ w, 3½″ h, 17½″ d (483 x 88 x 444 mm)		19″ w, 5¼″ h, 17½″ d (483 x 133 x 444 mm)		19″ w, 3½″ h, 17½″ d (483 x 88 x 444 mm)	
Weight (net/shipping)		36/47 lbs (16,2/21,2 kg)	34/45 lbs (15,3/20,2 kg)	54/66 lbs (24,3/29,7 kg)	52/64 lbs (23,4/28,8 kg)	36/47 lbs (16,2/21,2 kg)	34/45 lbs (15,3/20,2 kg)
Price		Harrison 6266A, $435	Harrison 6366A, $359	Harrison 6267A, $525	Harrison 6367A, $450	Harrison 6271A, $435	Harrison 6371A, $359

*cv = constant voltage; cc = constant current.

726AR, 808A, 809A, 810B, 814A, 881A, 6242A, 6244A SUPPLIES

Rack mounted dc power supplies

These eight general-purpose rack-mounting power supplies provide highly regulated dc output suitable for a variety of instrumentation and system applications. Three use a plug-in card to determine whether operation is in the constant voltage or the constant current mode. One is a constant voltage supply with current limiting, and four have automatic crossover between constant voltage and constant current operation, depending upon the settings of the front-panel controls as compared with the load resistance value.

Harrison 808A, 809A, 881A

These precision power supplies require only the insertion of a printed circuit plug-in card for determination of constant voltage or constant current mode of operation. Plug-in circuit cards furnished with each instrument provide for selecting the mode of operation and for Auto-Series and Auto-Parallel operation.

Units provide remote programming, remote error sensing and a continuously adjustable current limit control. Output of the 808A is 0 to 36 volt, 0 to 5 amp; of the 809A, 0 to 36 volt, 0 to 10 amp; of the 881A, 0 to 100 volt, 0 to 1 amp.

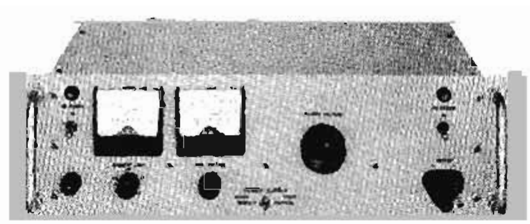
hp 726AR

Two-ampere current capacity and remote programming make this 0-60 v dc power supply ideal for large scale component and module testing. Continuously adjustable current limiter protects external components. Floating output, voltage and current continuously metered.

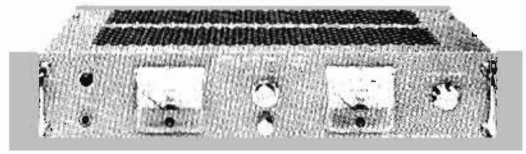
Harrison 810B, 814A, 6242A, 6244A

Offered in rack-mount enclosures, these power supplies provide automatic crossover between constant voltage and constant current operation, no overshoot on turn-on and turn-off, short circuit and open circuit protection, remote programming, remote error sensing, continuously adjustable limit controls, optional chopper amplifier for improved stability.

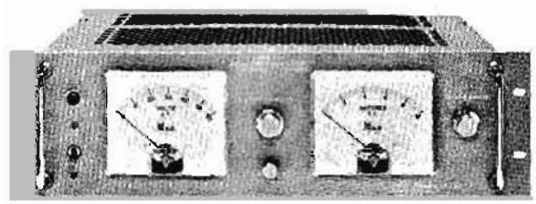
The 6242A provides two ranges, 0 to 32 volts at 0 to 2 amps or 0 to 64 volts at 0 to 1 amp, selectable by changing a single plug-in printed circuit card. Model 6244A provides a standard output of 0 to 36 volts, 0 to 3 amps. The 810B furnishes 0 to 60 volts at 0 to 7.5 amps, and the 814A is a heavy-duty instrument providing 0 to 36 volts at 0 to 25 amps. Common to the supplies is the automatic crossover feature. Each includes a continuously adjustable constant current control which, when the supply is being used as a constant voltage source, allows the maximum output current to be set at any value up to the maximum current rating. All may be used in Auto-Series, Auto-Parallel operation to increase total voltage and current output, with one-knob master control, automatic current and voltage equalizing and full range control from any selected instrument in the series.



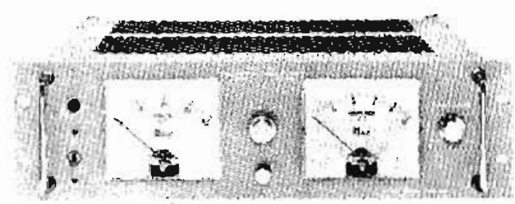
726AR



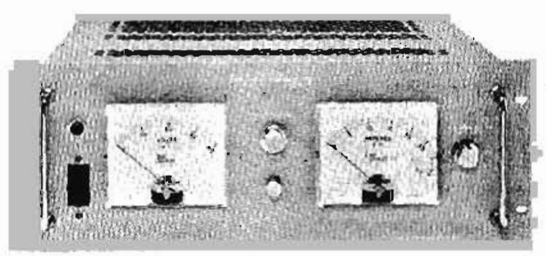
808A



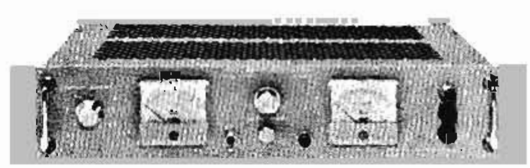
809A



810B



814A



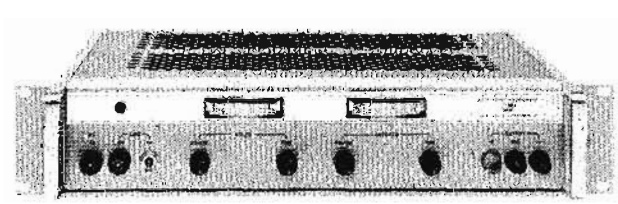
881A

Specifications

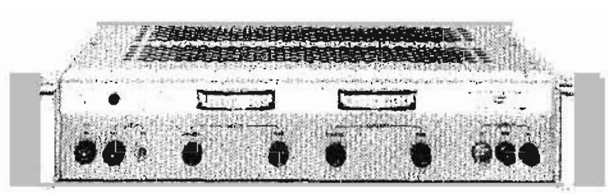
Model	808A	809A	881A	726AR	6242A	6244A	810B	814A
DC output	0 to 36 v, 0 to 5 a	0 to 36 v, 0 to 10 a	0 to 100 v, 0 to 1 a	0 to 60 v, 0 to 2 a	0 to 32 v at 0 to 2 a or 0 to 64 v at 0 to 1 a selectable by plug-in circuit card	0 to 36 v at 0 to 3 a	0 to 60 v at 0 to 7.5 a	0 to 36 v at 0 to 25 a
Load regulation cv / cc	0.01% or 3.6 mv / 0.1% or 5 ma	0.02% or 7.2 mv / 0.2% or 10 ma	0.02% or 5 mv / 0.02% or 200 μa	<5 mv / —	0.02% or 3 mv / 0.1% or 2 ma	0.02% or 5 mv / 0.1% or 3 ma	0.02% or 10 mv / 0.05% or 3.5 ma	0.03% or 10 mv / 0.05% or 12 ma
Line regulation cv / cc	0.01% or 3.6 mv / 0.1% or 5 ma	0.02% or 7.2 mv / 0.2% or 10 ma	0.02% or 5 mv / 0.05% or 100 μa	<2.5 mv / —	0.03% or 5 mv / 0.1% or 2 ma	0.01% or 2 mv / 0.1% or 3 ma	0.01% or 5 mv / 0.05% or 3.5 ma	0.03% or 10 mv / 0.05% or 12 ma
Ripple and noise (rms) cv / cc	500 μv / 3 ma	500 μv / 5 ma	200 μv / 100 μa	<250 μv / —	200 μv / 2 ma	1 mv / 3 mv	1 mv / 3 ma	1 mv / 15 ma
Max. operating temperature	50°C	50°C	50°C	55°C	50°C	50°C	50°C	50°C
Overload protection	current limiter provides protection against overload, including direct short; front-panel control permits continuous adjustment of current from 0 to 110% of current rating (100 ma to 2 amps on hp 726AR)							
Controls	coarse and fine voltage controls; coarse current control				coarse and fine voltage and current controls		coarse and fine voltage controls; coarse current control	
Meters	0 to 40 v and 0 to 6 a	0 to 40 v and 0 to 10 a	0 to 100 v and 0 to 1.2 a	0 to 60 v and 0 to 2.5 a	0 to 64 v and 0 to 2.4 a	0 to 40 v and 0 to 3 a	0 to 60 v and 0 to 10 a	0 to 40 v and 0 to 25 a
Error sensing	normally accomplished at output terminals; extra terminals permit remote sensing				rear- or front-panel terminals or remote		rear terminal or remote	
Remote programming (rear terminal strip)	200 ohms/v 200 ohms/a	200 ohms/v 100 ohms/a	200 ohms/v	100 ohms/v	300 ohms/v 125/250 ohms/a	200 ohms/v 80 ohms/a	300 ohms/v 20 to 25 ohms/a	200 ohms/v 10 ohms/a
Power	105 to 125 v, 57 to 63 cps, single phase			115 or 230 v ±10%, 50 to 60 cps	105 to 125, 210 to 250 v ac, 50 to 400 cps	105 to 125, 210 to 250 v ac, 50 to 70 cps	105 to 125 v ac, 57 to 63 cps	
Dimensions	3½" high x 16¾" deep x 19" wide (88 x 425 x 483 mm)	5¼" high x 16¾" deep x 19" wide (132 x 425 x 483 mm)	3½" high x 16¾" deep x 19" wide (88 x 425 x 483 mm)	5¼" high x 12" deep x 19" wide (132 x 305 x 483 mm)		3½" high x 16¾" deep x 19" wide (88 x 425 x 483 mm)	5¼" high x 16¾" deep x 19" wide (132 x 425 x 483 mm)	7" high x 18⅜" deep x 19" wide (177 x 467 x 483 mm)
Weight (net/shipping)	35/42 lbs (15,7/18,9 kg)	55/63 lbs (24,7/28,3 kg)	35/42 lbs (15,7/18,9 kg)	25/38 lbs (11,2/17,1 kg)	25/30 lbs (11,2/13,5 kg)	25/30 lbs (11,2/13,5 kg)	60/67 lbs (27/30,1 kg)	90/100 lbs (40,5/45 kg)
Price	Harrison 808A*, $475	Harrison 809A*, $575	Harrison 881A*, $475	hp 726AR, $595	Harrison 6242A*, $435	Harrison 6244A*, $460	Harrison 810B*, $695	Harrison 814A*, $775

*Models available with chopper-stabilizer amplifier and cascaded reference diode for improved stability; chopper stabilization improves only constant voltage operation in 6242A, 6244A and 810B, and designation "X" should be added to model number when ordering; on 814A, either designation "XV" or "XC" should be used to indicate whether improvement in performance is desired in constant voltage operation or constant operation; designate "X" on model number (i.e., 808AX), add $125.

Key: cv indicates constant voltage operation
cc indicates constant current operation



6242A

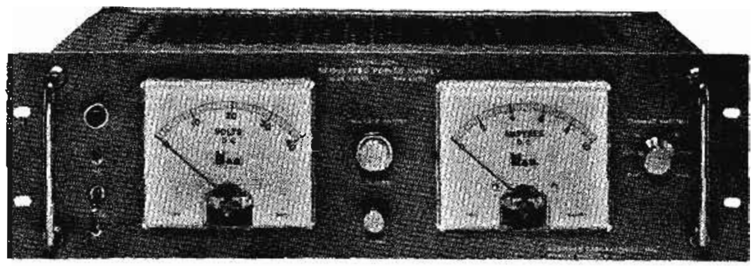


6244A

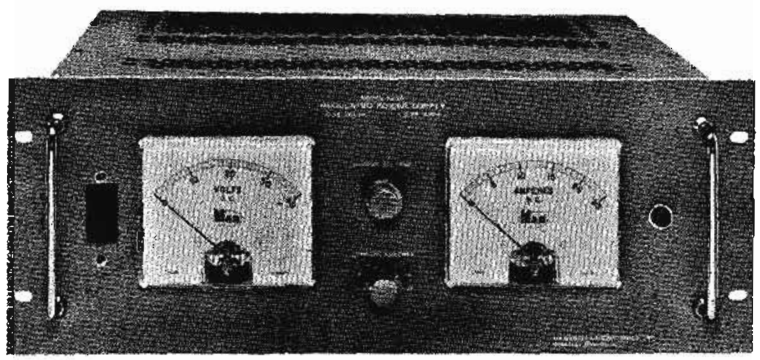
SCR-1 SERIES POWER SUPPLIES

505A, 510A, 520A Supplies

The Harrison SCR-1 Series consists of three compact, high-current, regulated power supplies intended for applications which require a fixed or continuously variable dc source with a moderate degree of regulation, combined with high efficiency and reliability. In this series, silicon-controlled rectifiers located on the secondary of the power transformer perform simultaneously the rectifier and series regulating functions, with resulting regulation of less than 0.5%. The unique "Ramp-Lock" control circuitry has a degree of immunity to line voltage transients and sudden load changes far in excess of conventional Magamp power supplies.



505A, 510A



520A

Specifications

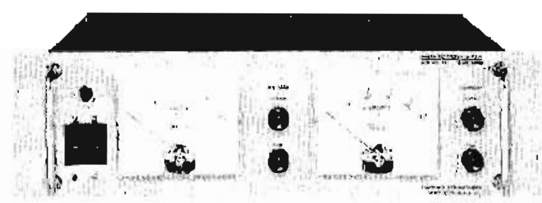
Harrison model	505A	510A	520A
DC volts out	0 to 72 v	0 to 36 v	0 to 36 v
DC amps out	0 to 5 a	0 to 10 a	0 to 25 a
AC power in	105 to 125 v ac; single phase, 57 to 63 cps		
Combined load and line regulation — constant voltage	360 mv (0.5%)	180 mv (0.5%)	180 mv (0.5%)
Combined load and line regulation — constant current	50 ma (1%)	100 ma (1%)	250 ma (1%)
Ripple and noise (rms max., specified as % of max. output voltage)	1%	1%	1%
Remote programming (all programming terminals are located on rear barrier strips)	1000-ohm potentiometer	1000-ohm potentiometer	1000-ohm potentiometer
Transient recovery time (<50 msec is required for output voltage recovery to within A mv of the nominal output voltage following a load change from full load to half load or half load to full load)	A = 400	A = 200	A = 200
Meters	80 v and 5 a	40 v and 10 a	40 v and 25 a
Input terminals	3-wire power cord	3-wire power cord	barrier strip
Output terminals	barrier strip	barrier strip	barrier strip
Cooling	convection	convection	internal fan
Dimensions	5¼" h x 12" d x 19" w (132 x 305 x 483 mm)	5¼" h x 12" d x 19" w (132 x 305 x 483 mm)	7" h x 16½" d x 19" w (177 x 419 x 483 mm)
Weight (net/shipping)	50/60 lbs (22,5/27 kg)	48/58 lbs (21,6/26,1 kg)	85/101 lbs (38,3/45,5 kg)
Price	$475	$450	$575

SCR-1P POWER SUPPLIES

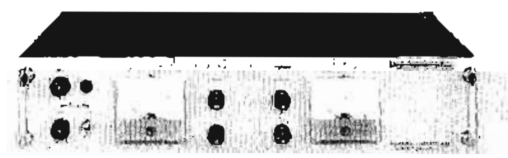
Compact, lightweight supplies

The Harrison SCR-1P Series of regulated power supplies are suitable for medium power applications requiring a fixed or variable dc source with a moderate degree of regulation. Silicon-controlled rectifiers in series with the primary of the power transformer perform the series regulating functions—with resulting voltage regulation of less than 0.25% for combined line and load changes. The following features are found in the SCR-1P Series:

Minimum size, reduced weight; useful in systems with limited space; all-silicon circuitry; Constant Voltage/Constant Current with automatic crossover; continuously variable to zero volts for gradual turn-on of delicate load devices and for continuous curve plotting; excellent line transient immunity; short circuit proof; continuously variable current limit control; remote programming of constant current and constant voltage by resistance, voltage or current; remote error sensing; Auto-Series and Auto-Parallel operation; up to 75% efficiency at full load assures operating economy in large systems; low ripple.



6428A, 6439A



6427A, 6433A, 6438A, 6443A

Harrison model		6427A	6428A	6433A	6438A	6439A	6443A
DC volts out		0 to 18 v	0 to 18 v	0 to 32 v	0 to 60 v	0 to 60 v	0 to 120 v
DC amps out		0 to 15 a	0 to 45 a	0 to 10 a	0 to 5 a	0 to 15 a	0 to 2.5 a
AC power in		105 to 125 v ac, 57 to 63 cps					
Combined load and line regulation	cv*	0.15% or 15 mv	54 mv	0.15% or 24 mv	0.15% or 45 mv	180 mv	0.15% or 90 mv
	cc*	150 ma (1%)	450 ma (1%)	100 ma (1%)	50 ma (1%)	150 ma (1%)	25 ma (1%)
Ripple and noise (rms max., specified as per cent of max. output voltage)		0.2%	0.2%	0.1%	0.2%	0.1%	0.2%
Remote programming (all programming terminals located on rear barrier strips)	cv	200 ohms/volt	200 ohms/volt	200 ohms/volt	300 ohms/volt	300 ohms/volt	300 ohms/volt
	cc	15 ohms/amp	5 ohms/amp	25 ohms/amp	50 ohms/amp	15 ohms/amp	100 ohms/amp
Transient recovery time (<300 msec 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 = 180 mv	A = 180 mv	A = 180 mv	A = 300 mv	A = 600 mv	A = 600 mv
Meters		20 v and 16 a	20 v and 50 a	40 v and 12 a	64 v and 6 a	60 v and 15 a	120 v and 3 a
Input terminals		5′ cord	barrier strip	5′ cord	5′ cord	barrier strip	5′ cord
Output terminals		barrier strip					
Cooling		conv.	fan	conv.	conv.	fan	conv.
Dimensions		3½″ h, 19″ w, 17½″ d (89 x 483 x 445 mm)	5¼″ h, 19″ w, 16¾″ d (133 x 483 x 425 mm)	3½″ h, 19″ w, 17½″ d (89 x 483 x 445 mm)	3½″ h, 19″ w, 17½″ d (89 x 483 x 445 mm)	5¼″ h, 19″ w, 16¾″ d (133 x 483 x 425 mm)	3½″ h, 19″ w, 17½″ d (89 x 483 x 445 mm)
Weight (net/shipping)		35/46 lbs (15,7/20,7 kg)	65/78 lbs (29,2/35,1 kg)	33/44 lbs (14,9/19,8 kg)	32/43 lbs (14,4/19,4 kg)	60/73 lbs (27/32,9 kg)	32/43 lbs (14,4/19,4 kg)
Price		Harrison 6427A $380	Harrison 6428A $550	Harrison 6433A $370	Harrison 6438A $360	Harrison 6439A $550	Harrison 6443A $360

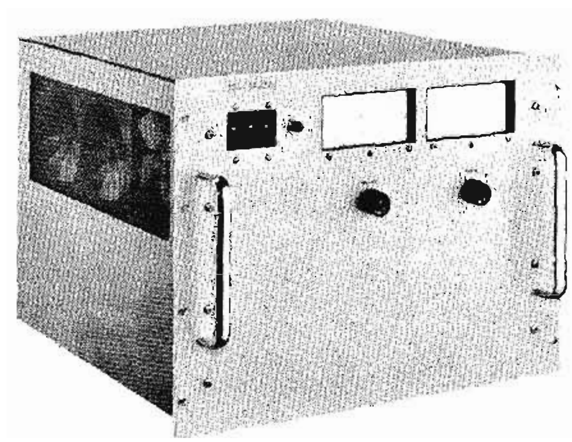
*cc = constant current, cv = constant voltage

SCR-3 POWER SUPPLIES

3 kilowatt dc output

The Harrison SCR-3 Series of regulated supplies are suitable for high-power applications which require up to 300 amps output current and up to 3.2 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 series regulating functions with resulting voltage regulation of less than 0.5%. This series of supplies is similar to the SCR-1 Series (505A, 510A, 520A, page 324), except for three-phase ac input transformer and rectifier circuit.

Advantages include the following features: Constant Voltage/Constance Current with automatic crossover; minimum size, reduced weight, useful in systems with limited space; continuously variable to zero volts, for gradual turn-on of delicate load devices and for continuous curve plotting; excellent line transient immunity, no "poke-through" lasting 5 to 10 cycles; 50 millisecond recovery for load current changes, instead of the 100 to 200 milliseconds typical of Magamp supplies; short circuit proof, continuously variable current limit control (useful for battery charging applications); remote programming; remote error sensing; Auto-Series and Auto-Parallel operation; 75% efficiency at full load, for operating economy in large systems.



Specifications, SCR-3 Series

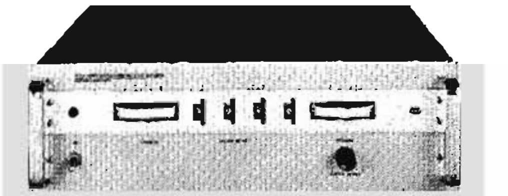
Harrison model		6450A	6453A	6455A	6456A	6459A
DC volts out		0 to 8 v	0 to 15 v	0 to 36 v	0 to 32 v	0 to 64 v
DC amps out		0 to 300 a	0 to 200 a	0 to 75 a	0 to 100 a	0 to 50 a
AC power in		208/230/460 ± 10%, 3 phase, 57 to 63 cps		208/230 ± 10%, 3 phase, 57 to 63 cps	208/230/460 ± 10%, 3 phase, 57 to 63 cps	
Combined load and line regulation	cv*	25 mv	0.2% +10 mv	180 mv	0.2% +10 mv	0.2% +10 mv
	cc*	3 a (1%)	2 a (1%)	750 ma (1%)	1 a (1%)	500 ma (1%)
Ripple and noise (rms max., specified as percent of max. output voltage)		1%	1%	0.5%	0.5%	0.25%
Remote programming (all programming terminals located on rear barrier strips)	cv*	200 ohms/volt	200 ohms/volt	1000 ohms pot	200 ohms/volt	300 ohms/volt
	cc*	2/3 ohm/amp	1 ohm/amp	3.3 ohms/amp	2 ohms/amp	4 ohms/amp
Transient recovery time (less than 50 msec 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 = 150	A = 200	A = 300	A = 600
Meters		10 v and 300 a	20 v and 200 a	40 v and 80 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 (356 x 483 x 476 mm)	19" w, 14" h, 18¼" d (356 x 483 x 476 mm)	19" w, 14" h, 17" d (356 x 483 x 431 mm)	19" w, 14" h, 18¼" d (356 x 483 x 476 mm)	19" w, 14" h, 18¼" d (356 x 483 x 476 mm)
Weight (net/shipping)		238/275 lbs (107/124 kg)	238/275 lbs (107/124 kg)	220/255 lbs (99/114 kg)	238/275 lbs (107/124 kg)	238/275 lbs (107/124 kg)
Price		Harrison 6450A	Harrison 6453A	Harrison 6455A	Harrison 6456A	Harrison 6459A
	208/230 v input	$1550	$1550	$1450	$1450	$1450
	460 v input	$1590	$1590	——	$1490	$1490

*cc = constant current, cv = constant voltage

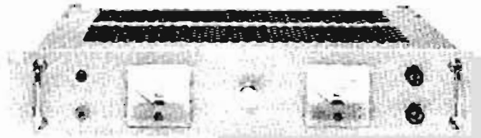
Indicate input ac voltage when ordering 208, 230 or 460 v ac (460 v ac input not available on 6455A).

HVR AND MVR SERIES POWER SUPPLIES

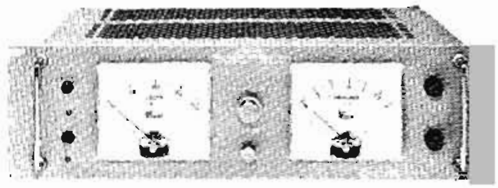
High-, medium-voltage supplies



6521A, 6522A, 6525A



890A



895A, 896A

Advantages, HVR Series:

- All solid-state, compact rack mounting
- 200 watt output
- Short circuit proof
- ± output—grounded or floating up to 2 kv off ground
- Decade voltage switching with 0.022% resolution
- Transient recovery time: less than 50 seconds to within 0.005% or 20 mv, whichever is greater
- 1% calibration accuracy

Advantages, MVR Series:

- All solid-state
- Short-circuit proof
- Remote programming, remote error sensing

The Harrison HVR Series consists of three high-voltage supplies utilizing all silicon semiconductor circuitry—no tubes. All three supplies are tightly regulated and provide sufficient output current for many devices not capable of being powered from conventional low-current, high-voltage supplies. These supplies feature Constant Voltage/Constant Current operation with automatic crossover. Elimination of large series dissipating tube elements allows these supplies to have efficiencies approaching 80%.

The Harrison MVR Series of three dc power supplies 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.

Specifications HVR Series		Harrison 6521A	Harrison 6522A	Harrison 6525A
DC output	voltage	0 to 1000 v	0 to 2000 v	0 to 4000 v
	current	0 to 200 ma	0 to 100 ma	0 to 50 ma
AC input		105 to 125 v ac, 50 to 70 cps		
Load regulation	constant voltage	0.005% or 20 mv		
	constant current	2% or 1 ma		
Line regulation	constant voltage	0.005% or 20 mv		
	constant current	1 ma		
Ripple and noise	constant voltage	1 mv rms		
	constant current	2 ma	1 ma	500 μa
Temp. coefficient (output change per °C change in ambient following 30 min warm-up)	constant voltage	0.02% plus 2 mv	0.02% plus 4 mv	0.02% plus 8 mv
	constant current	0.2% plus 0.2 ma	0.2% plus 0.1 ma	0.2% plus 0.05 ma
Stability (under constant ambient conditions, total drift for 8 hours following 60 min warm-up)	constant voltage	0.05% plus 5 mv	0.05% plus 10 mv	0.05% plus 20 mv
	constant current	0.25% plus 0.5 ma	0.25% plus 0.25 ma	0.25% plus 0.12 ma
Meters		0 to 1 kv and 0 to 200 ma	0 to 2 kv and 0 to 100 ma	0 to 4 kv and 0 to 50 ma
Controls		voltage control—3 decade thumbwheel switches, plus thumbwell vernier; current control—single-turn potentiometer		
Dimensions		5¼" h x 18" d x 19" w (132 x 457 x 483 mm)		
Weight (net/shipping)		50/60 lbs (22.5/27 kg)		
Price		$750	$750	$750

Specifications MVR Series		Harrison 890A*	Harrison 895A*	Harrison 896A*
DC output	volts	0 to 320	0 to 320	75 to 160
	amps	0 to 0.6	0 to 1.5	0 to 2.5
Line or load regulation		0.007% or 10 mv		
Ripple and noise (rms maximum)		1 mv		
Meters		320 v and 0.8 a	320 v and 1.5 a	200 v and 3 a
Dimensions		3½" h x 16¾" d x 19" w (88 x 425 x 483 mm)	5¼" h x 16¾" d x 19" w (133 x 425 x 483 mm)	5¼" h x 16¾" d x 19" w (133 x 425 x 483 mm)
Weight (net/shipping)		35/43 lbs (15.8/19.4 kg)	50/66 lbs (22.5/29.7 kg)	50/66 lbs (22.5/29.7 kg)
Price		$445	$625	$675

All MVR models

Short circuit proof: all-electronic, continuously acting current limit circuit protects the supply for all overload loads, including a direct short placed across the output terminals; in addition, a fuse will blow when severe overload conditions occur.

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: 105 to 125 v, 57 to 63 cps.

MOD SERIES REGULATED PLUG-IN POWER SUPPLIES

Highly regulated, fixed or variable

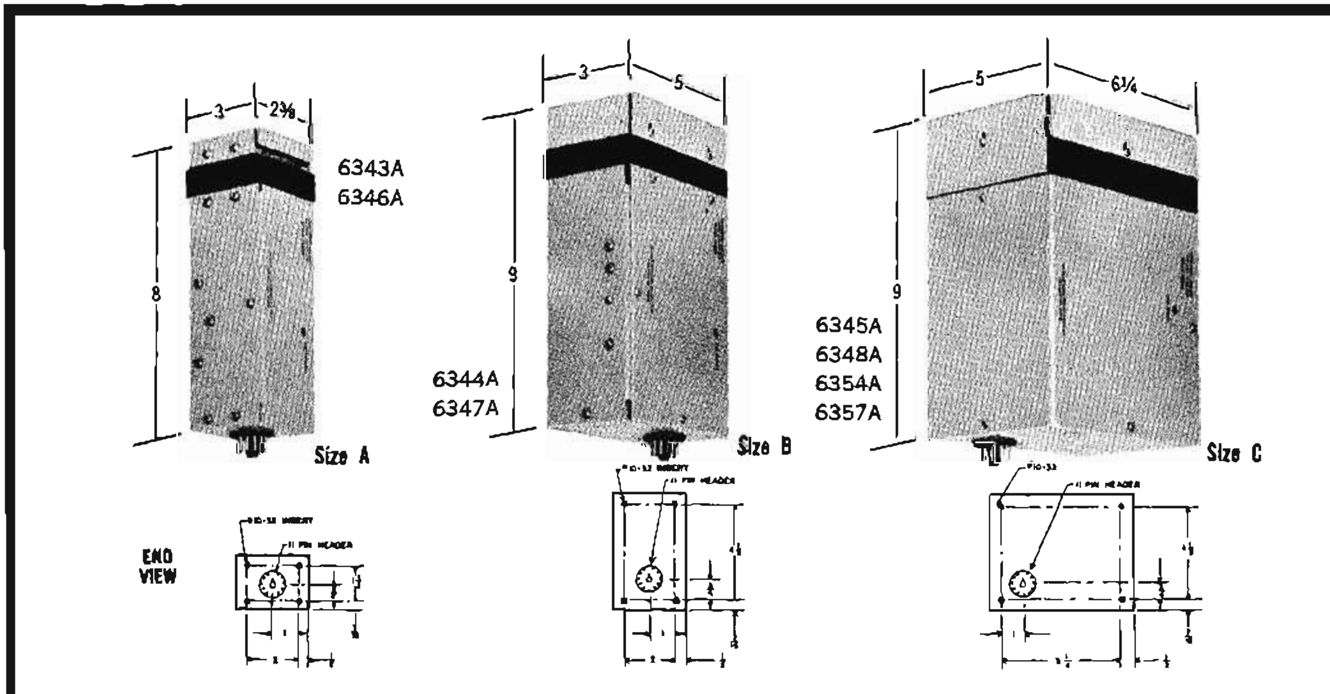
The Harrison MOD Series of plug-in modular power supplies has been designed to meet the need for well regulated, inexpensive chassis-mounting supplies and the need for a line of dc supplies of low power rating capable of being efficiently grouped on rack panels. All input, output and control connections are accomplished via the 11-pin plug mounted at one end of the supply. Since the output voltage is determined by the value of a resistor connected between two of these terminals, these supplies can be made to be continuously variable over their entire output voltage range, or variable over some limited range, or fixed at some predetermined value — depending upon the manner in which the external rheostats and/or resistors are connected to the programming terminals.

A current limiting overload protection circuit is used in all MOD Series supplies. The current limit can be set at any value from zero to some value slightly greater than the current rating of the supply. This current setting is accomplished by means of a screwdriver adjustment slot accessible through a small hole in the side of the supply, thus permitting readjustment of the current limit value without removing the power supply module's cover.

The supply is thus fully protected for any overload condition, including a direct short circuit across the output terminals, and the current limit control can be set to the exact value necessary for optimum protection of the load device. No fuses are contained in the MOD Series supplies.

Specifications, MOD Series

Harrison model	Output rating	Load regulation	Line regulation	Input power	Size	Weight (net/shipping)	Price
6343A	0 to 18 v at 0 to 300 ma	3 mv or 0.03%	3 mv or 0.03%	105 to 125 or 210 to 250 v ac, 48 to 440 cps	A	3/5 lbs (1,4/2,3 kg)	$120
6344A	0 to 18 v at 0 to 1 a	3 mv or 0.03%	3 mv or 0.03%	105 to 125 or 210 to 250 v ac, 48 to 63 cps	B	7/10 lbs (3,2/4,5 kg)	$165
6345A	0 to 18 v at 0 to 2.5 a	3 mv or 0.03%	3 mv or 0.03%	105 to 125 or 210 to 250 v ac, 48 to 63 cps	C	13/19 lbs (5,9/8,6 kg)	$225
6346A	0 to 36 v at 0 to 150 ma	3 mv or 0.02%	3 mv or 0.02%	105 to 125 or 210 to 250 v ac, 48 to 440 cps	A	3/5 lbs (1,4/2,3 kg)	$120
6347A	0 to 36 v at 0 to 500 ma	3 mv or 0.02%	3 mv or 0.02%	105 to 125 or 210 to 250 v ac, 48 to 63 cps	B	7/10 lbs (3,2/4,5 kg)	$165
6348A	0 to 36 v at 0 to 1.5 a	3 mv or 0.02%	3 mv or 0.02%	105 to 125 or 210 to 250 v ac, 48 to 63 cps	C	13/19 lbs (5,9/8,6 kg)	$225
6354A	0 to 160 v at 0 to 400 ma	0.005%+2 mv	0.005%+1 mv	105 to 125 or 210 to 250 v ac, 48 to 63 cps	C	13/19 lbs (5,9/8,6 kg)	$259
6357A	0 to 320 v at 0 to 200 ma	0.005%+2 mv	0.005%+1 mv	105 to 125 or 210 to 250 v ac, 48 to 63 cps	C	13/19 lbs (5,9/8,6 kg)	$259



Specifications, all models

Ripple and noise: less than 1 mv rms for any combination of line voltage, output voltage and load current.

Operating temperature range: 0°C to 50°C (70°C for 6354A and 6357A).

Temperature coefficient: less than 0.033%, plus 2 mv/°C.

Stability: less than 0.1% plus 10 mv total drift for 8 hours (after 30 minutes' warm-up) at a constant ambient.

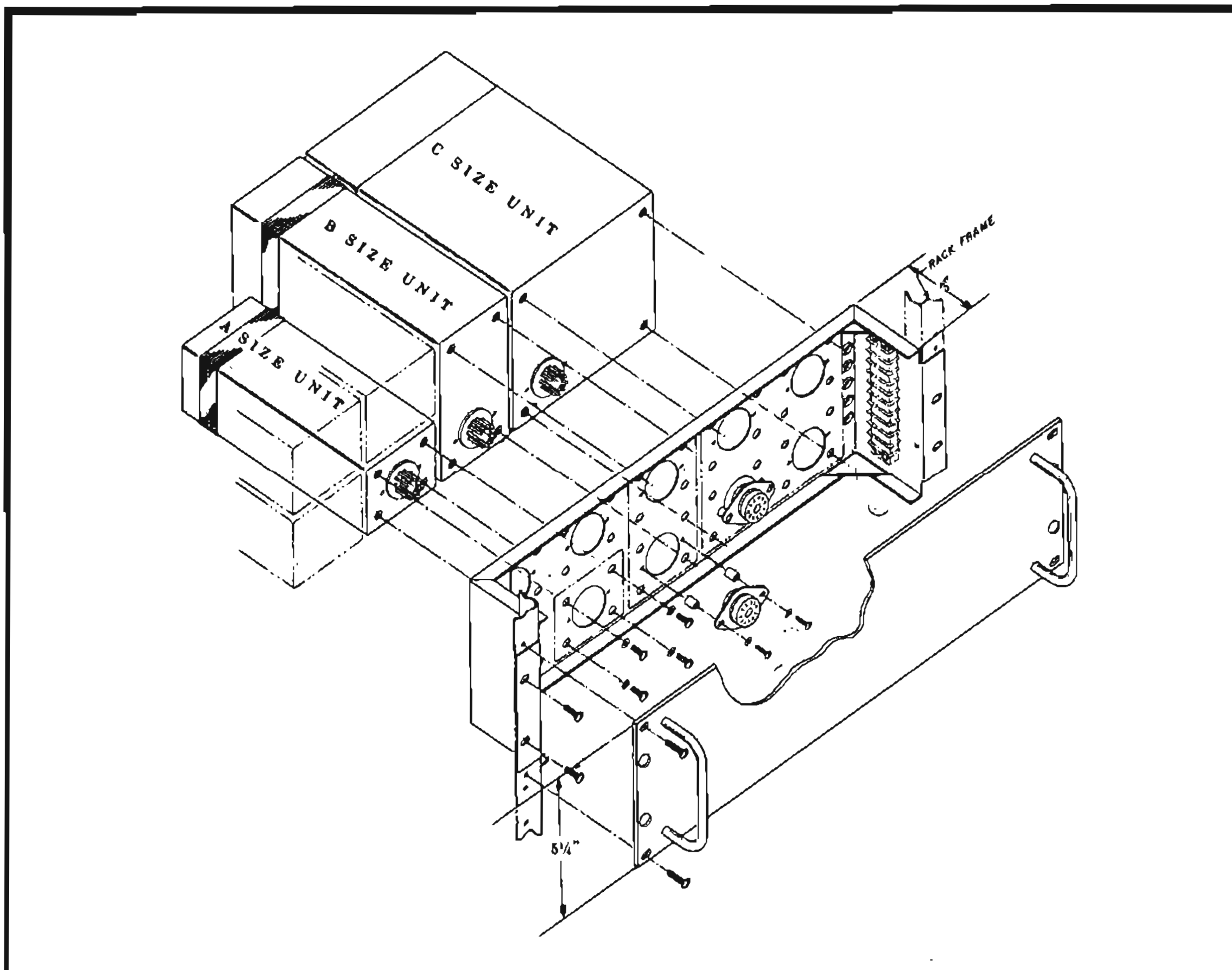
Transient response: less than 50 μsec is required for output voltage recovery to within 10 mv of the nominal output voltage following a full-load change in output current.

Remote error sensing and remote programming: sensing terminals are brought out through the header pins; for local sensing, these terminals are strapped to the output terminals; for remote sensing, leads are connected from the sensing terminals to the remote load terminals; the output voltage is determined by the value of resistance connected between terminals 1 and 2, 1 v out for each 200 ohms connected between these terminals (300 ohms for 6354A and 6357A).

Programming accuracy: 5%.

Cooling: convection cooling is employed.

Finish: light gray.



Efficient rack mounting

Dimensions and efficient mounting techniques are shown in the illustration for Harrison MOD Series plug-in supplies.

The drawing shows R6340-5 rack mounting assembly; R6340-3 is similar except for height—3½" (88 mm) instead of 5¼" (133 mm)—and the fact that it has holes for six 11-pin sockets. Whereas R6340-5 can accommodate "A", "B" or "C" size units as shown, the 3½" high rack mounting assembly can only accommodate "A" and "B" size units. On the 3½" panel these "A" and "B" size modules are rotated 90 degrees along the longest axis as compared with this drawing.

Specifications

Part No. R6340-3: 3½" high (88 mm) assembly 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.

Price: Harrison R6340-3, $19.

Part No. R6340-5: 5¼" high (133 mm), 19" wide (483 mm) rack assembly for 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" modules.

Price: Harrison R6340-5, $29.

711A, 712B, DC SUPPLIES; 6910A, 6916A CROWBARS

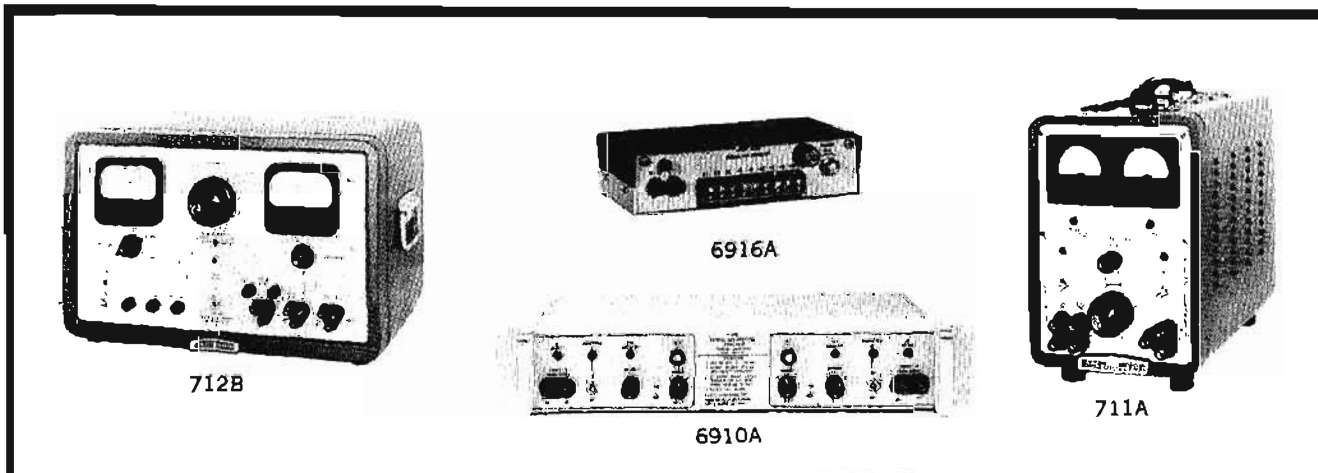
Easy-to-use lab supplies; overvoltage protectors

711A, 712B DC Supplies

The hp 711A and 712B are easy-to-use, general-purpose laboratory supplies particularly suited to powering experimental setups and other basic bench applications. They offer very high regulation and a wide, variable voltage range extending from 0 to 500 volts dc. There are separate current and voltage meters with additional ranges to permit accurate measurement of small power outputs. Full overload protection is provided to protect the instrument even under short-circuit output conditions.

Specifications

hp Model	711A	712B
Output voltages:	0 to +500 v, 100 ma max. load; 6.3 v rms at 6 amps or 12.6 v rms ct. at 3 amps	0 to +500 v, 200 ma maximum load
Regulation:	0.5% or 1 v change, whichever is greater, no load to full load, or for line voltage changes of ±10%	less than 50 mv, no load to full load, at any output voltage; less than ±100 mv for line voltage changes of ±10%
Ripple:	less than 1 mv	less than 500 µv
Metering:	current meter: two ranges 0 to 100 ma; 0 to 10 ma; voltage meter: two ranges 0 to +500 v, 0 to +50 v	current meter: 0 to 200 ma (high-voltage only); voltage meter: three ranges 0 to +500 v, 0 to +150, 0 to −150 v
Power:	115 or 230 v ±10%, 50 to 1000 cps; approx. 145 w	115 v ±10%, 50 to 60 cps; approx. 120 to 450 w
Overload:	ac line fused	ac line fused, dc
Protection:	relay prevents dc output from exceeding current rating of milliameter protecting instrument from overloads	regulated high voltage, dc regulated fixed bias and filament supply separately fused; high voltage drops to a safe value if bias fuse blows
Dimensions:	cabinet: 11½" high, 7⅜" wide, 14¼" deep (292 x 187 x 362 mm); rack: 6-31/32" high, 19" wide, 12-5/16" deep (187 x 483 x 313 mm)	cabinet: 12¾" high, 20¾" wide, 14¾" deep (324 x 527 x 375 mm); rack: 10-15/32" high, 19" wide, 13" deep (266 x 483 x 330 mm)
Weight:	net 20 lbs (9 kg), shipping 26 lbs (11,7 kg)(cabinet); net 24 lbs (10,2 kg), shipping 35 lbs (15,8 kg) (rack)	net 70 lbs (31,5 kg), shipping 81 lbs (36,5 kg) (cabinet); net 62 lbs (27,9 kg), shipping 77 lbs (34,7 kg) (rack)
Price:	hp 711A, $275 (cabinet); 711AR, $280 (rack)	hp 712B, $490 (cabinet); hp 712BR, $475 (rack)



712B 6916A 6910A 711A

6910A, 6916A Crowbars

The Harrison 6910A and 6916A overvoltage units protect expensive or irreplaceable load devices from overvoltages caused by accidental manipulation of controls or power supply failure. After an overvoltage condition occurs, the voltage to the load is quickly reduced to zero by means of a silicon-controlled rectifier. A test button permits verification that the overvoltage protector is ready to detect the occurrence of any overvoltage condition without actually introducing an overvoltage across the load device or initiating action which would short circuit the output. Output terminals allow these units to be interconnected with other overvoltage protectors for tandem firing or for firing of an external SCR.

The 6916A, a compact inexpensive overvoltage protection device, is factory installed (only) directly on the rear of any Harrison power supply with output ratings of 5 amps or less. Final factory test is made after supply and crowbar have been connected and wired together. In many cases, the 6916A can be modified at factory for combination with supplies having greater current ratings—contact your local hp sales office for price and delivery information.

The Model 6910A, which can be used on the bench or rack mounted, provides two identical but independent overvoltage protection circuits in one package. Protection action is similar to the 6916A except that (1) power for the 6910A circuitry is derived from the ac line rather than the power supply being protected, and (2) ac input power to the supply being protected flows through the 6910A.

Specifications, 6910A

Protection action: a virtual short circuit is placed across the load within 5 µsec after the overvoltage margin is exceeded; ac to the power supply and any other measuring devices plugged into the 6910A is removed, and a trip indicator light is activated.

Operating range: 6910A will protect units with an output voltage of less than 72 volts and an output power of less than 450 watts; the 6910AM option provides for the heavier input power requirements of the 520A and 814A.

Overvoltage margin: adjustable 0 to 6 volts from panel control.

AC power input: 105 to 125 v ac, 58 to 63 cps; current input is determined by requirement of protected device plugged into the 6910A.

Dimensions: 3½" high, 19" wide, 11¼" deep (88 x 483 x 228 mm); mounting: unit may be used on the bench or mounted in a standard 19" relay rack.

Weight: net 20 lbs (9 kg); shipping 26 lbs (11.7 kg).

Price: Harrison 6910A, $345; Harrison 6910AM, $375.

Specifications, 6916A

Protection action: a virtual short circuit is placed across the load within 10 µsec of the time when overvoltage margin is exceeded: if power supply has suffered severe failure, the dc fuse in series with the power supply output will open.

Operating range: 10 to 60 v dc at 5 amps max.

Overvoltage margin: 1 to 4 volts, screwdriver adjustable.

Power: 15 ma continuous drain derived from the dc power supply being monitored; 50 ma momentarily required when "Push-to-Test" button is depressed.

Dimensions: 2" high, 7⅞" wide, 4" deep (51 x 200 x 102 mm).

Weight: net 1½ lbs (0.7 kg); shipping 4 lbs (1.8 kg).

Price: Harrison 6916A, $95.

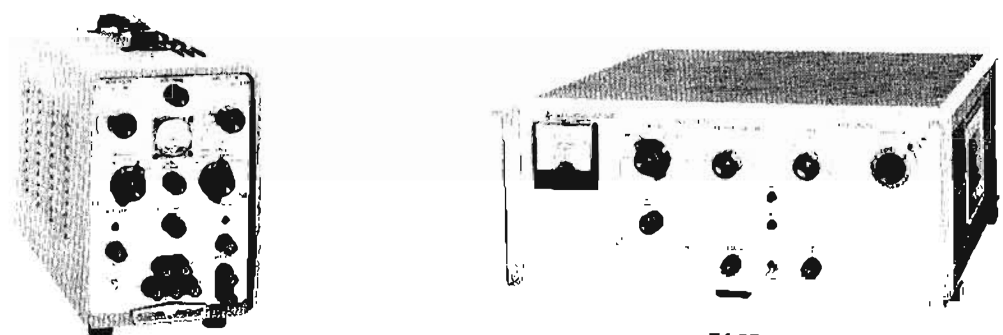
715A, 716B KLYSTRON POWER SUPPLIES

Versatile power sources for wide range of klystrons

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 cps, 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	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% nominal 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 cps, 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 cps to 2.5 kc; 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 K nominal input impedance; sawtooth: 75 cps nominal, 0 to at least 150 v nominal p-p, ac-coupled to reflector
External modulation	terminals provided; input impedance 100 K	max. input 200 v p-p; input impedance 500 K, 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 K output impedance
Meter	monitors beam current 0 to 50 ma	monitors beam current 0 to 100 ma
Power	115 or 230 v ±10%, 50 to 60 cps, 200 w	115 or 230 v ±10%, 50 to 60 cps, 200 to 350 w
Dimensions	7⅜" wide, 11½" high, 13¾" deep (187 x 292 x 349 mm)	16¾" wide, 6-25/32" high, 18⅜" deep (425 x 172 x 467 mm); hardware furnished for rack mounting (5060-0776)
Weight	net 19 lbs (8,6 kg); shipping 24 lbs (10,8 kg)	net 46 lbs (20,7 kg); shipping 63 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, $365	hp 716B, $875

855C, 865C DC POWER SUPPLIES

Supplies offering high-speed programming

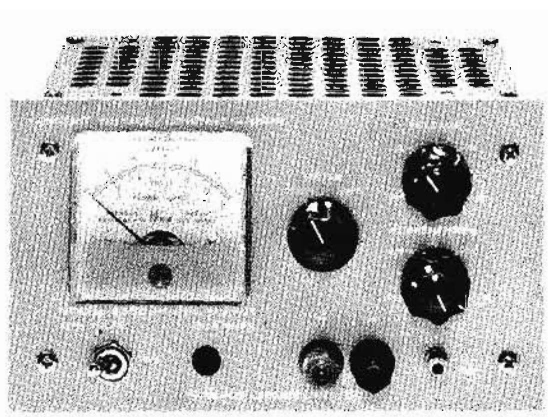
Advantages:

- High-speed voltage programming by resistance, voltage or current
- Useful as an ac or dc power amplifier
- Constant Voltage - Constant Current operation with automatic crossover
- Auto-Series, Auto-Parallel operation; remote sensing
- Short circuit proof in constant voltage use
- Open circuit proof in constant current use

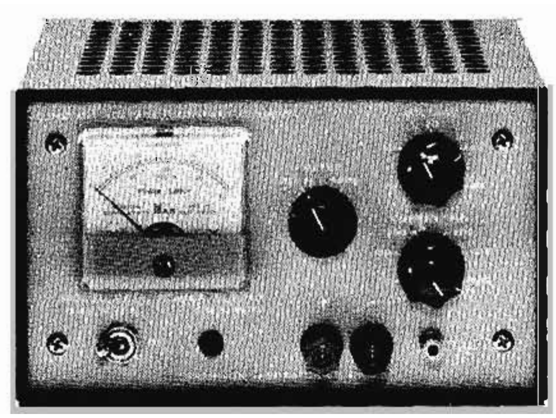
Uses:

- Automatic test sets
- AC power amplification
- DC power amplification
- Lab research and development

New versatility and flexibility are featured in the 855C and 865C. Besides being useful as a general-purpose highly regulated laboratory supply, the 855C and 865C can be used in high-speed programming applications and as amplifiers. The unique aspect of the supplies is that a transistor shunted across the output terminals discharges the output capacitance when programming downward (reducing the output voltage). The down-programming speed thus is comparable with the up-programming speed, resulting in faster response for amplifier and high-speed programming applications.



855C



865C

Specifications

Output: 855C: 0 to 18 v dc; 0 to 1.5 a dc; 865C: 0 to 40 v dc; 0 to 0.5 a dc.

Load and line regulation: constant voltage, 0.01% +2 mv; constant current 0.02% +250 μa.

Ripple and noise: constant voltage, 200 microvolts rms; constant current, 200 microamps rms.

Temperature coefficient: constant voltage, less than 0.015% + 1 mv; constant current, less than 0.02% + 500 μa.

Stability: total drift for 8 hrs. following 30 minute warm-up; constant voltage, 0.1% +5 mv; constant current, 0.05% +1 ma.

Transient recovery time: <50 μsec required for output voltage recovery to within 10 mv of the nominal output voltage.

Maximum operating temperature: 50°C.

High-speed programming: by simply changing a few rear-terminal straps, the power supplies achieve high-speed programming by resistance, voltage or current inputs.

At no load

Rise time: 0 volt to maximum, 30 volts/millisecond.

Fall time: maximum to 1 volt, 30 volts/millisecond; 1 volt to 0 volt, 0.5 volt/millisecond.

Ripple and noise: 2 millivolts rms.

At full rated load

Rise time: 0 volt to maximum, 20 volts/millisecond.

Fall time: maximum to 1 volt, 40 volts/millisecond; 1 volt to 0 volt, 0.7 volt/millisecond.

Ripple and noise: 2 millivolts rms.

Power: 105 to 125 or 210 to 250 v ac, 50 to 440 cps.

Dimensions: 7-13/16" wide, 5-1/16" high, 8½" deep (198 x 129 x 216 mm).

Weight: net 14 lbs (6,3 kg); shipping 16 lbs (7,2 kg).

Rack mounting panels: R855/865-1B (one unit) or R855/865-2B (two units) rack mounting panels, $20 each.

Price: Harrison 855C or 865C, $179 (add $12 for slipover case, standard unit at $179 has top and bottom cover plates and is a completely enclosed power supply).

Typical amplifier specifications

By the addition of several resistors and a small input coupling capacitor connected to the rear terminals, Models 855C and 865C can be used as dc and ac power amplifiers:

Useful frequency range: ac-coupled, 10 cps to 1 kc; dc-coupled, dc to 1 kc (single-ended output only—cannot go through zero).

Voltage gain: equals $-50{,}000/R_x$, where R_x is an externally added "feed-in" resistor.

Input impedance: up to 50,000 ohms; gain-input impedance produce equals 50,000 ohms.

Output power: dc amplifier, 27 watts peak (855C), 20 watts peak (865C); ac amplifier, 5 watts peak (2.5 watts rms).

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 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

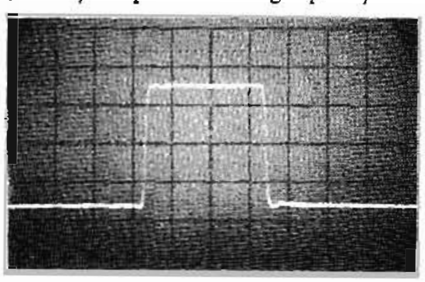


Figure 1. Carefully controlled pulse shapes insure accurate measurements.

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. 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 216A is capable of rep rates to 100 mc 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. Late model hp 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.

Pulse generators are used as modulators for klystrons and other rf sources to obtain high peak power while maintaining low average power.

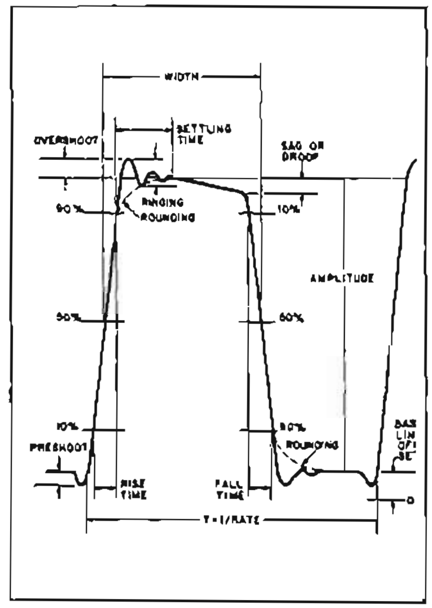


Figure 2. Test pulse description in terms of primary characteristics.

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, discussed in more detail on page 279. Very fast pulse generators (hp Models 213B, 215A) used with an equally fast oscilloscope (hp Model 185B) also can measure the stray inductances and capacitances of components.

Tests of linear systems with pulse or square wave generators and oscilloscopes are dynamic tests which quickly analyze system performance. Because of the Fourier transform relationships between the transient response of a system and its frequency and phase characteristics, overall system response can be evaluated by observing the pulse response on an oscilloscope.

Hewlett-Packard designs pulse generators with the fast rise times, 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.

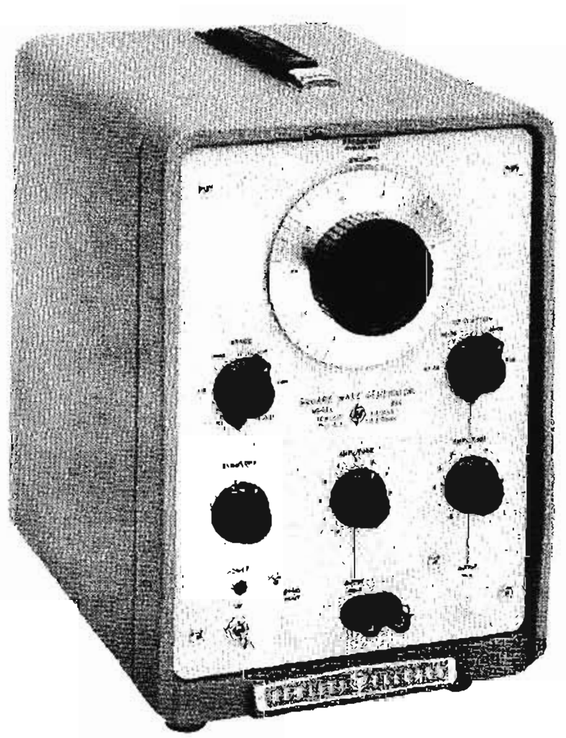
211A SQUARE-WAVE GENERATOR

Convenient audio, video testing 1 cps to 1 mc

The hp Model 211A Square-Wave Generator is a versatile, wide-range instrument particularly designed for testing video and audio amplifier performance,[1] or for use as a trigger generator. It provides complete coverage of all frequencies from 1 cps to 1 mc, 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 high-level work. The generator may be operated free-running or externally synchronized.

Model 211A is ideal for testing amplifiers and networks and for modulating signal generators. It will measure time constants, check oscilloscope sweep circuits and generate harmonics for frequency multiplication. It offers a simple means of controlling an electronic switch or intensity-modulating an oscilloscope. The generator also is a convenient instrument for indicating frequency response and transient effects.

[1]See Hewlett-Packard Application Note 17, "Square Wave and Pulse Testing."



Specifications

Frequency range: 1 cps to 1 mc, 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 μsec.

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 μsec.

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 cps, 225 watts.

Dimensions: cabinet: 9¾" wide, 15¼" high, 14⅝" deep (238 x 388 x 372 mm); rack mount: 19" wide, 8¾" high, 13⅜" deep behind panel (483 x 222 x 340 mm).

Weight: net 26 lbs (11,7 kg), shipping 29 lbs (13,0 kg) (cabinet); net 25 lbs (11,3 kg), shipping 34 lbs (15,3 kg) (rack mount).

Price: hp 211A, $350 (cabinet); hp 211AR, $355 (rack mount).

212A, 213B PULSE GENERATORS

High power and fast rise pulses

The hp 213B Pulse Generator provides 0.1 nsec in rise time pulses at repetition rates to 100 kc for testing sampling oscilloscopes or other fast circuits. The pulse has minimum overshoot and is flat for 100 nsec after the very fast rise. Since the rise time of the 213B is much faster than that of most circuits, step response of these circuits may be measured directly, without considering the rise time of the 213B. External trigger capabilities from 0 to 100 kc and a free-run rate above 100 kc give more versatility to this fast-pulse source.

The fast rise, low overshoot and 50-ohm source impedance of this compact instrument provide matched system capabilities for all fast pulse work. With the hp 185B Sampling Oscilloscope (pages 295-299), this pulse generator may be used to determine cable impedances, locate and measure connector or cable discontinuities and evaluate cable terminations.

A basic test instrument for radar, tv and other fast circuits, the hp 212A Pulse Generator provides positive or negative pulses and may be synchronized to other equipment through built-in delay and advance sync out circuits. It offers pulse lengths continuously variable from 0.07 to 10 microseconds, has a direct-reading pulse length control and provides pulses of 50 watts peak power. Pulses are of high quality, with very fast 0.02 microsecond rise and decay, flat top and minimum overshoot. Double pulses can be obtained by connecting a stub line across the output of the generator.

In addition to radar, tv and nuclear work, the generator is useful for testing response of rf amplifiers, filters, bandpass circuits, oscilloscopes, as well as for checking peak-measuring equipment, modulating rf carriers for pulse-modulating uhf signal generators.

Specifications, 213B

Output

Rise time: less than 100 picoseconds.
Top droop: less than 2% in first 100 nsec following the rise.
Width: approximately 2 μsec.
Amplitude: greater than 175 mv into 50 ohms, 350 mv open circuit, either polarity.
Source impedance: 50 ohms.
Jitter: less than 20 picoseconds when triggered with the 185A or 185B sync pulse.
Repetition rate: free runs at a rate greater than 100 kc, or may be triggered.

Trigger Input

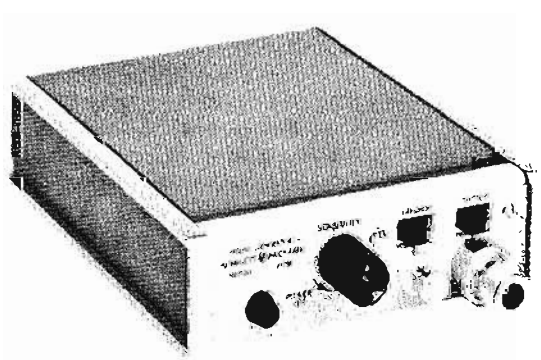
Amplitude: 0.5 volt peak, either polarity.
Rise time: 20 nsec or faster.
Width: at least 2 nsec.
Maximum current: 200 ma peak.
Impedance: 200 ohms for signals less than 0.75 volt peak; limiting lowers impedance to larger signals.
Repetition rate: 0 to 100 kc.

General

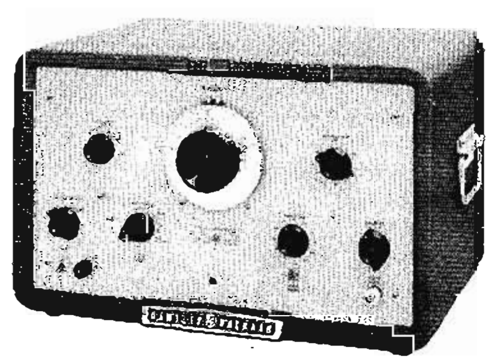
Power: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 1 watt.
Dimensions: 1½" high, 5⅛" wide, 5" deep (38 x 130 x 127 mm).
Weight: net 2 lbs (0,9 kg); shipping 3 lbs (1,4 kg).
Price: hp 213B, $215.

Specifications, 212A

Pulse: length continuously variable 0.07 to 10 μsec; amplitude 50 v peak, positive or negative, into 50-ohm load (50 watts peak).
Amplitude control: 50 db attenuator, variable in 10 db steps; continuously variable amplitude control, 10 db range.
Pulse shape: rise and decay time each approximately 20 nsec; crest variation less than ±5%.
Jitter: less than 10 nsec.
Internal impedance: 50 ohms or less, either pulse polarity.
Repetition rate: internal sync, 50 to 5000 pps; external sync, approx. 2 to 5000 pps.
Sync in: ±5 v peak minimum.
Sync out: +25 v or −15 v into 2000-ohm load; approx. 1 μsec duration at half voltage; rise time approx. 0.25 μsec.
Pulse position: referenced to Sync Out pulse; delay, 0 to 100 μsec (to 2500 pps), 0 to 50 μsec (to 5000 pps); advance, 0 to 10 μsec (to 5000 pps).
Power: 115 or 230 volts ±10%, 50 to 60 cps, 380 watts.
Dimensions: cabinet: 20¾" wide, 12¾" high, 14-3/16" deep (527 x 324 x 362 mm); rack mount: 19" wide, 10½" high, 13⅜" deep behind panel (483 x 267 x 345 mm).
Weight: net 56 lbs (25,2 kg), shipping 68 lbs (30,6 kg) (cabinet); net 50 lbs (22,5 kg), shipping 65 lbs (29,3 kg) (rack mount).
Accessories available: 10503A BNC Cable Assembly, $6.50; 11500A Type N Cable Assembly, $15.
Price: hp 212A, $775 (cabinet); hp 212AR, $775 (rack mount).



213B



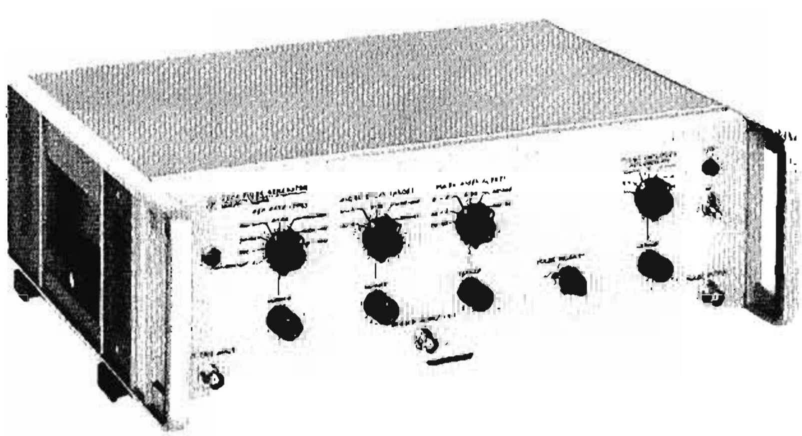
212A

222A PULSE GENERATOR

Economical general-purpose testing

The 222A combines many features normally found only on more expensive instruments to provide an easy-to-use, yet versatile, general-purpose pulse generator. The 5 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 mc, closely specified pulse shape and many other features provide accurate, dependable measurements. The 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 msec for further measurement convenience.

AVAILABLE MID-1965



Tentative specifications

Output pulse

Source impedance: 50 ohms shunted by approximately 15 pf throughout specified output voltage range.

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: 20 nsec to 5 msec in 6 ranges, continuously variable between ranges.

Duty cycle: maximum duty cycle >50% from 100 cps to 10 mc; for maximum stability at high duty cycles, select width range which allows maximum clockwise rotation of width vernier; duty cycle from 10 to 100 cps limited by 5 msec maximum pulse width.

Width jitter: <0.2% of maximum range width.

Pulse shape

Leading edge only

Rise time: <5 nsec.

Overshoot and ringing: <4% peak of pulse amplitude.

Corner rounding: occurs no sooner than 95% of pulse amplitude.

Time to achieve flat top: approximately 20 nsec.

Preshoot: <3%.

Trailing edge only

Fall time: <5 nsec.

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: approximately 20 nsec.

Preshoot: <5%.

Perturbations on flat top: <3% of pulse amplitude.

Pulse delay: pulse delayed from trigger output by 100 nsec to 5 msec in 5 ranges, continuously variable between ranges.

Delay jitter: <0.2% of maximum delay.

Repetition rate and trigger

Internal

Repetition rate: 10 cps to 10 mc in 6 ranges, continuously variable between ranges.

Jitter: period jitter in any frequency range <0.3% of maximum period of that range.

Manual: pushbutton single pulse.

External

Triggering: ac coupled; sine wave from 10 cps to 10 mc, pulse from 0 to 10 mc, either positive or negative slope.

Sensitivity: 1 volt p-p minimum; external pulses must be at least 10 nsec wide: maximum input 20 volts peak; 0.25 watt maximum average power.

Input impedance: approximately 500 ohms.

External trigger delay: approximately 15 nsec between leading edge of external trigger input pulse and leading edge of trigger output pulse.

Trigger output pulse

Width: approximately 10 nsec at 50% points.

Amplitude: >1 volt into 50 ohms.

Rise time: <10 nsec.

Polarity: positive.

General

Power: 115 or 230 v ±10%, 50 to 60 cps, 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 24 lbs (11 kg).

Price: on request.

214A PULSE GENERATOR

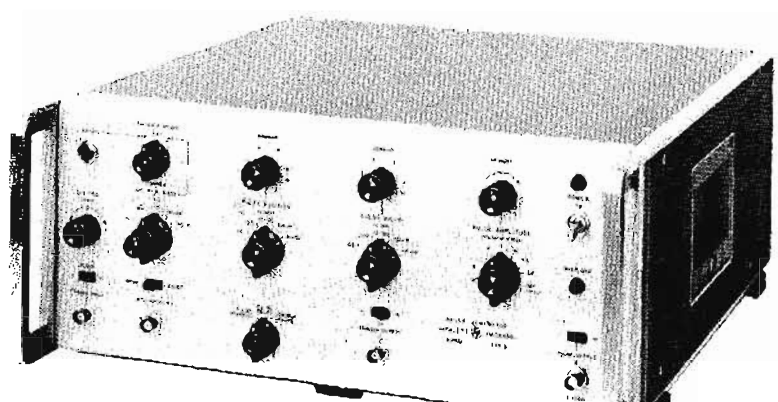
Delivers 200 watts pulse power

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.



Specifications

Output pulse

Source impedance: 50 ohms on the 50 v and lower ranges; approximately 1500 ohms on the 100 v range.

Pulse shape:

Rise and fall time: <13 nsec on the 20 v and lower ranges and the −50 v range, <15 nsec on the +50 v range; typically <10 nsec with the vernier set for maximum attenuation, and typically 15 nsec on 100 v range.

Pulse amplitude: 100 v into 50 ohms; an attenuator provides 0.2 to 100 v in a 1, 2, 5 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: <4%.

Droop: <6%.

Preshoot: <2%.

Pulse width: 50 nsec to 10 msec in 5 decade ranges; continuously adjustable vernier.

Width jitter: <0.05% of pulse width +1 nsec.

Pulse position: 0 to 10 msec advance or delay with respect to trigger output (5 decade ranges) continuously adjustable vernier.

Position jitter: <0.05% of advance or delay setting +1 nsec (between trigger pulse and output pulse).

Repetition rate and trigger

Internal

Repetition rate: 10 cps to 1 mc (5 ranges), continuously adjustable vernier.

Rate jitter: <0.5% of the period.

Manual: pushbutton single pulse, 2 cps maximum rate.

External

Repetition rate: dc to 1 mc.

Sensitivity: <0.5 v peak.

Slope: positive or negative.

Level: adjustable from −40 v to +40 v.

External gating: +8 v signal gates pulse generator on; maximum input, 40 v peak.

Double pulse

Minimum spacing: 1 μsec on the 0.05 to 1 μsec pulse width range and 25% of upper limit of width range for all other ranges.

Trigger output

Amplitude: >10 v open circuit.

Source impedance: approximately 50 ohms.

Width: 0.05 μsec, 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 cps, 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 48 lbs (19,6 kg).

Price: hp 214A, $875.

* Measured on a 50 mc oscilloscope.

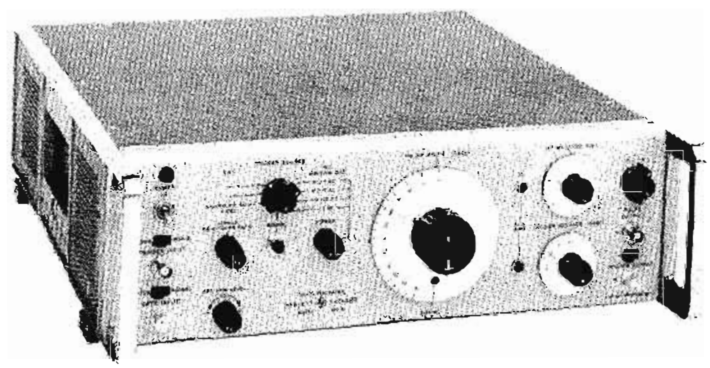
215A PULSE GENERATOR

Controlled, fully specified output pulses

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 215A particularly useful in measuring transition storage times of semiconductors, logic circuits and thin film memory units.

The output pulse of the 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 mc 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.



Specifications

Source Impedance: 50 ohms; 3% maximum reflection when driven by a pulse with 1 nsec rise time from an external 50-ohm system.

Leading edge only
- Rise time: <1 nsec (10 to 90%).
- Overshoot and ringing: <5% peak, less than 10% peak to peak 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 nsec (10 to 90%).
- Overshoot: <5%.
- Rounding: occurs no sooner than 95% of fall.
- Time to settle within 2% of baseline: 10 to 25 nsec, 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 nsec; dial accuracy within ±5% ±3 nsec, width jitter less than 50 psec.

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.

Repetitive rate sources
- Internal repetition rate: <100 cps to >1 mc in 4 ranges, continuously variable between ranges; period jitter $<3 \times 10^{-3}$ of one period.
- Manual: pushbutton single pulse.

Trigger timing: adjustable from 10 nsec delay to 140 nsec advance with respect to leading edge of output pulse; dial accuracy within ±10% ±5 nsec; jitter <50 picoseconds.

External triggering: ac coupled, sine waves from 10 cps to 1 mc; pulses from 0 to 1 mc; 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 nsec wide; max. input 50 v peak, 0.5 w max. average power.
- Input impedance: approx. 50 ohms or High Z available by front-panel switch; High Z is approx. 100 K for negative slope setting, approx. 5 K for positive slope setting.
- Countdown: counts down from frequencies to 100 mc, 2 v rms amplitude; resulting pulse repetition rate is always <1.3 mc; jitter is <10% of one period of the triggering signal.
- External trigger delay: approximately 250 nsec between leading edge of trigger pulse (2 volt step, 2 nsec rise time into 50 ohms) and leading edge of output pulse; <50 psec jitter.
- External gating: gates on with a +1 volt pulse; maximum input 50 v peak, 20 v rms.

Trigger output pulses
- Width: 50 nsec, nominal.
- Amplitude: >1 volt peak into 50 ohms.
- Rise time: <6 nsec.
- Polarity: positive or negative.

Power: 115 or 230 volts ±10%, 50 to 60 cps, 60 watts

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 33 lbs (15,3 kg); shipping 49 lbs (22,1 kg).

Accessories furnished: 10120A cable, 3 feet, BNC-to-BNC, 50 ohms ±0.5 ohm.

Accessories available: 10122A cable, 3 feet, BNC-to-Type N, 50 ohms ±0.5 ohm, $10; 908A, 50-ohm Coaxial Termination, $35; 10451A Multipulser generates pulse bursts to simulate 15 to 200 mc rep rate, $95; 10204A Blocking Capacitor, 0.1 μf, isolates 215A from up to 200 v dc, $70.

Price: hp 215A, $1875.

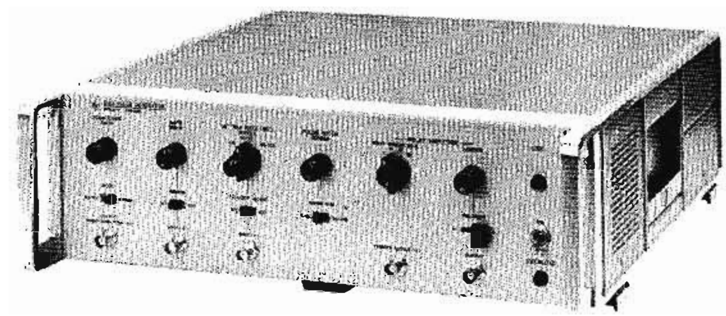
216A PULSE GENERATOR

Fast-rise 100 mc pulses

The Model 216A offers pulse repetition rates up to 100 mc for testing fast circuits, yet retains a nearly ideal pulse shape with 2.5 nsec 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.

NEW



Tentative specifications

Source impedance: approximately 50 ohms shunted by 10 pf throughout specified output voltage range.

Leading edge only (at max. rated output)

- **Rise time:** <2.5 nsec (approx. 1½ nsec with amplitude vernier set to 50% or less of max. output).
- **Overshoot and ringing:** overshoot <4% peak, ringing ±4% p-p of pulse amplitude.
- **Corner rounding:** occurs no sooner than 96% of pulse amplitude.
- **Time to achieve flat top:** approximately 20 nsec.
- **Preshoot:** <3%.

Trailing edge only (at max. rated output)

- **Fall time:** <2.5 nsec (approx. 1½ nsec with amplitude vernier set to 50% or less of max. output).
- **Overshoot:** <4%.
- **Corner rounding:** occurs no sooner than 96% of fall.
- **Time to settle within 2% of base line:** approx. 20 nsec.
- **Preshoot:** <5%.

Perturbations on flat top: <3% of pulse amplitude.

Peak voltage: >10 volts into 50 ohms to 50 mc, >9 volts to 100 mc (15 volts maximum amplitude).

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 5 nsec to 25 nsec and from 25 nsec to 100 nsec; pulse width independent of rep rate up to 50 mc; width jitter <100 psec +0.05% of pulse width.

Maximum duty cycle: >50% up to 50 mc for 10 volts out or less; <40% between 50 mc and 100 mc.

Internal repetition rate: 1 mc to 100 mc in 3 ranges.

External triggering

- **Frequency:** sine waves from 1 mc to 100 mc, pulses from 0 to 100 mc; pulse rise time <100 nsec.
- **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 nsec ±10% between leading edge of input trigger pulse and leading edge of output pulse.

Trigger output pulse

- **Width:** 3.5 nsec ±1 nsec.
- **Amplitude:** >0.5 volts peak into 50 ohms.
- **Polarity:** negative.
- **Trigger timing:** approximately 130 nsec ±10% 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 kc to 450 kc.

Gating of pulse bursts

- **Internal**
  - **Gate width:** variable from approx. 20 nsec to 750 nsec.
  - **Gate repetition rate:** variable from approximately 250 kc to 450 kc.
- **External:** gates on with +2 volt pulse having rise and fall times of <5 nsec; maximum input, 10 volts.
- **Perturbations:** for 10 volts out or less into 50 ohms and rep rate up to 70 mc, perturbations on gate envelope <8%; for 5 volts out or less into 50 ohms and rep rate up to 100 mc, perturbations <8%; above 50 mc width varies slightly from pulse to pulse.

General

- **Power:** 115 or 230 volts ±10%, 50 to 60 cps, 120 watts.
- **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: 10120A Cable, 3 feet, BNC-to-BNC, 50 ohms ±0.5 ohm, $10; 10122A Cable, 3 feet, BNC-to-Type N, 50 ohms ±0.5 ohm, $10; 908A 50-ohm Coaxial Termination, $35; 10204A Blocking Capacitor, 0.1 μf, isolates 216A from up to 200 v dc, $70.

Price: hp 216A, $1775.

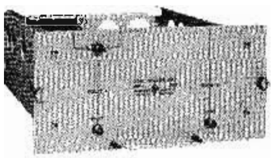
218AR DIGITAL DELAY GENERATOR

±1 count ambiguity eliminated in digital time interval, pulse generation

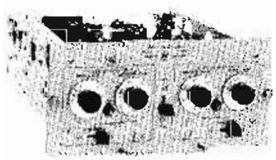
The hp 218AR Digital Delay Generator is designed to generate precise time intervals and single, double or superimposed pulses. It is useful as a general-purpose laboratory pulse generator and because of its versatile plug-in pulse generators, it often can take the place of several special-purpose instruments.

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.

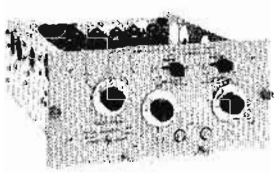
Plug-ins include the 219A Dual Trigger Unit to supply trigger pulses for controlling auxiliary equipment, $125; the 219B Dual Pulse Unit to deliver fast-rise-time, high-power pulses that are digitally delayed, $490; and the 219C Digital Pulse Duration Unit, which produces a high-power output pulse whose delay and duration may be digitally controlled, $375. 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 50-ohm source. Pulses from the 219C are 90 v peak (or more), open circuit, from a 500-ohm source or adjustable from 0 to 15 v peak from a 90-ohm source. The positive excursion of the pulses is clamped to ground, and both positive- and negative-going pulses are available simultaneously.



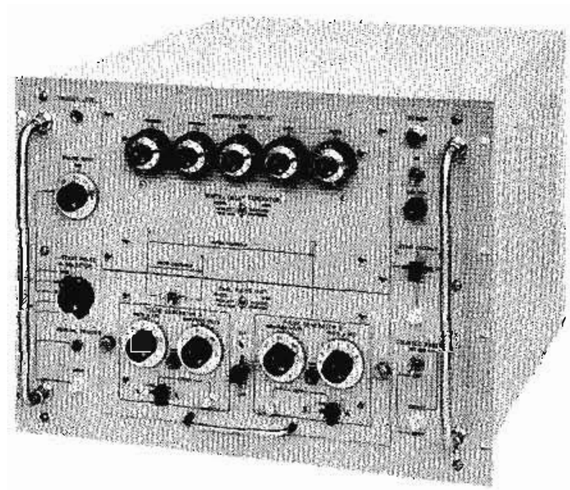
219A



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 μsec; accuracy ±0.1 μsec ±0.001% of time interval selected.

Digital adjustment: 1 to 9999 μsec in 1 μsec steps.

Interpolation: continuously adjustable; adds 0 to 1 μsec to digital setting.

Input trigger: internal: 10 cps to 10 kc, 3 decade ranges; external: sine wave, 10 to 100 cps, 2 to 40 v rms, 100 cps to 10 kc, 2 to 40 v rms; pulse, 0 to 10 kc, positive or negative, 2 to 40 v peak; for trigger rise time of 0.05 μsec or less, delay between external trigger and T_0 is less than 0.5 μsec; manual: pushbutton operation.

Jitter: 0.02 μsec or less.

Recovery time: 70 μsec or 10% of selected interval, whichever is greater.

Sync output: positive pulse, 50 to 70 v peak, open circuit, 0.1 μsec rise time; width more than 1.5 μsec; available at T_0, T_1, or T_2.

1 mc output: 1 mc positive pulses (1 v from 500-ohm source) provide timing comb synchronized to start pulses; available at panel connector for duration of longer delay when counting internal 1 mc oscillator.

External counting: external sine waves, 100 cps to 1 mc, 2 v rms minimum; 10 to 100 cps, 5 v rms minimum, and positive pulses, periodic or random, 0 to 1 mc, 2 v peak, can be counted instead of internal standard; time interval range becomes 1 to 9999 periods in 1-period steps, and accuracy is ±0.1 μsec ±1 period.

Power: 115 or 230 v ±10%, 50 to 60 cps, 555 w.

Dimensions: 14" high, 19" wide, 21¾" deep behind panel (355 x 483 x 524 mm).

Weight: net 74 lbs (34 kg); shipping 103 lbs (47 kg).

Price: hp 218AR, $2250 (requires hp 219A,B,C Series plug-in units).

X-Y RECORDERS

The Cartesian coordinate graph is one of the most efficient means ever devised to portray related data clearly. Modern x-y recorders speed data interpretation by producing such graphs quickly. 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. When equipped with a curve follower, an x-y recorder also can read a previously recorded graph, feeding out a pair of analog signals.

The present generation of Moseley graphic recorders is the result of many years of pioneering experience. This experience provided accessories which make Moseley instruments the most useful of their kind. Among advanced features are:

- AUTOGRIP® electric paper hold-down, with no moving parts
- inputs with 1-megohm null loading
- calibrated multi-scale ranges
- dc sensitivity to 100 µv/inch
- ac sensitivity to 5 mv/inch
- zero offset up to 4 scale lengths
- 140 db dc common mode rejection
- 120 db ac common mode rejection

The range of accessories offered for Moseley recorders exceeds that offered by any other manufacturer and is constantly being augmented. The user may be sure his Moseley recorder will be adaptable to the widest possible variety of future needs, without added initial cost.

Basic operation of x-y recorders

The x-y recorder uses electrical servo systems to produce a pair of crossed motions, moving a pen so as to write precise x-y plots. It consists of basic balancing circuits, plus auxiliary elements to make the instrument versatile.

The self-balancing potentiometer circuit (A) compares an unknown external voltage with a stable internal reference voltage. The difference between these voltages is amplified and applied to a servo motor to drive a potentiometer in a direction that will null any difference or error voltage. Accuracy of plots made by this principle is typically 0.1%. The full-scale range of the recorder for each axis is obtained with input signals as low as fractions of a millivolt. Thus, the output of many low-level devices, such as thermocouples and strain-gages, may be plotted directly without additional amplification.

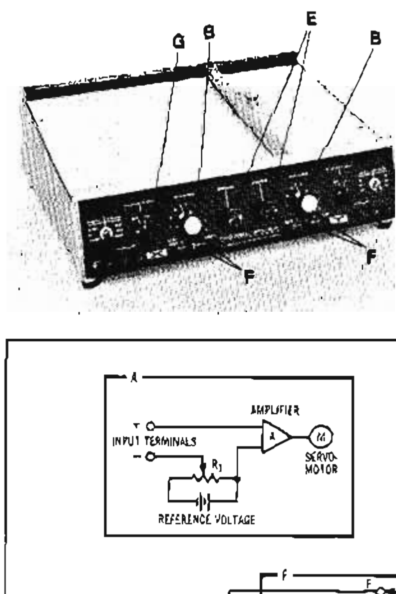
A stepped attenuator or range selector (B) is included for each axis, so voltages as high as 500 may be handled directly. Input resistance is at least 200,000 ohms per volt, with higher values, including constant 1-megohm input resistance, available on some models. Sensitivity may be as high as 100 µv per inch for dc, 5 mv per inch for ac. The feedback potentiometer, R_1, is critical, and its manufacture at Moseley is a highly refined process, so that self-generated noise will not appear on the trace. New Moseley multi-contact flat mandrel potentiometers have greatly reduced noise and extended life.

A chopper (C) converts the dc error signal into a reversible-phase alternating current, which is fed into a servo amplifier. The amplified signal is then applied to the control phase of the servomotor.

Servo damping (D) is commonly applied. A phase-lead network anticipates electrical balance or null just before mechanical balance is achieved, preventing overshoot. Full-scale traverse time for most x-y recorders is in the range 0.5 to 1 second.

Zeroing potentiometers (E) permit the user to locate the plotting origin as desired by inserting an offset voltage. With these controls the zero of either axis, or both, can be extended or suppressed up to four full-scale lengths on some models, so plotting may be carried out in any desired quadrant.

To fit the range of the recorder's response exactly to the coordinates of the paper in use, or to the units of measurement desired, a continuously adjustable range control (F) may be switched in as a substitute for the calibrated control. Thus, the response range of the recorder can be adjusted smoothly to match, for example, some calibrated maximum from a transducer, so the paper's coordinates directly correspond to the desired units of measurement (psi, °C, etc.).

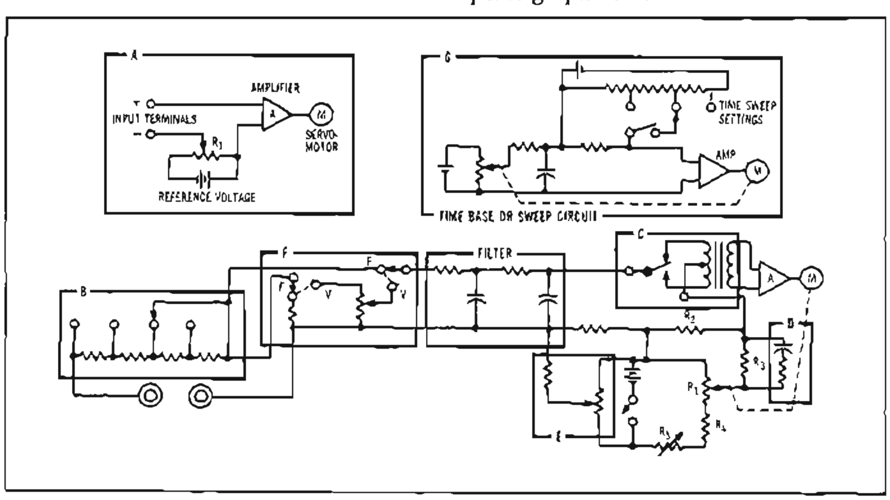


Since it is often desirable to plot a function against time, a time base or sweep circuit (G) is a valuable feature. To accomplish this, the charging rate of a capacitor is kept constant by continuously changing the applied voltage. The voltage created by the constant charging current is balanced against a manually selected reference voltage, whose value determines the sweep time. The difference, an error signal of constant magnitude, is then applied to the chopper, thus driving one axis of the recorder at a constant rate.

Options and accessories

Moseley x-y recorders may be selected among models in three basic sizes, those for paper of maximum size 8½" x 11", 11" x 17" or 32" x 32". Two-pen models are available, capable of simultaneously plotting two curves. Certain models have high sensitivity, high common mode rejection and high input resistance. Models are available with and without ac capability. Options include rack mounting, metric calibration and scaling, special input characteristics, rear connections and others. Single-character or multi-character automatic printers for point plotting are offered for use with 11" x 17" recorders.

Available accessories include line followers, ac-dc converters, logarithmic converters, waveform translators to enable plotting of scope traces, and keyboard control for plotting of tabular data in point graph form.



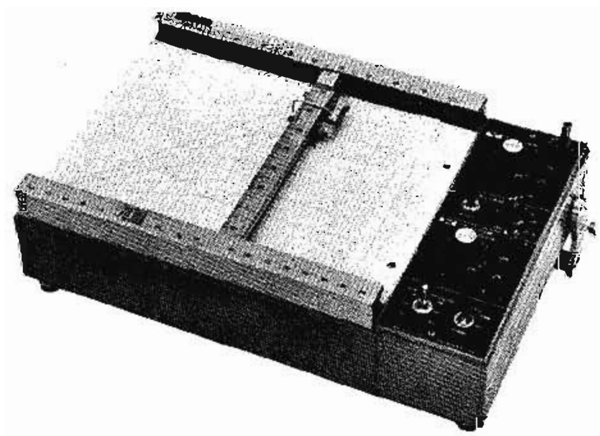
7030A HIGH-SENSITIVITY X-Y RECORDER, 8½" x 11"

Most sensitive range 100 microvolts per inch

Assembled on a sturdy aluminum cast frame, the Moseley 7030A X-Y Recorder accepts dc signals with much greater sensitivity and higher common mode rejection than previously possible in one instrument. Guarded and shielded input circuitry has 1-megohm resistance at null on each of 17 ranges, with continuous flexibility of each range for arbitrary full-scale voltages. The lowest range is sensitive to 100 μv/inch, and the 5 most sensitive ranges also may be operated in potentiometric mode which draws no current at null.

Special multi-contact flat mandrel balancing potentiometers maintain trouble-free operation without frequent cleaning. Zero offset controls for each axis are calibrated in continuously adjustable 5-inch steps which cover 3 full scale lengths on x and 4 full scale lengths on y. Recording accuracy is better than 0.2% of full scale on all ranges, this accuracy being maintained from range to range. Extremely good retrace performance assures high dynamic accuracy and resettability.

The paper holddown system is the new exclusive Moseley AUTOGRIP which operates on an electronic principle, has no moving parts, is quiet, reliable and effective on any paper size up to the capacity of the platen.



Specifications

Input circuits: dc, floating, guarded and shielded; may be operated up to 500 v dc above ground.

DC voltage ranges (each axis): 7030A (standard, inch): 17 calibrated ranges: 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; 7030AM (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; each range continuously variable.

Input resistance: one megohm at null on all calibrated ranges; potentiometric input on six most sensitive ranges by disconnecting strap on input attenuator.

Interference rejection: dc common mode rejection is 140 db; ac common mode rejection is 120 db at line frequency.

Slewing speed: 20 in/sec, each axis.

Time sweeps: may be applied to x or y axis in 8 ranges: 7030A (standard, inch): 0.5, 1, 2, 5, 10, 20, 50, 100 sec/in; 7030AM (metric): 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 sec/cm; sweep length is adjustable and may be reset at any point of operation either manually or automatically.

Accuracy: 0.2% of full scale; resettability and linearity 0.1% of full scale; time sweeps: 2% of full scale with linearity 1% of full scale.

Repeatability: 0.1% of full scale.

Position transducer: multi-contact, flat mandrel potentiometers in each axis.

Zero offset: zero suppression may be established in 5-inch calibrated steps with continuous control on each step up to 3 full scales on x and 4 full scales on y.

Reference voltage: zener-controlled continuous supply.

Paper holddown: AUTOGRIP electric; no moving parts; equally effective on all size charts 8½" x 11", or smaller.

Servo motors: acceleration constant is a minimum of 22,800 radians/sec².

Power: 115 or 230 volts, 50 to 60 cps, 75 volt-amps.

Dimensions: bench model: 16⅛" long, 10½" wide, 4½" deep (407 x 267 x 114 mm); rack model: 16⅛" inside rack clearance, 19½" panel width, 4½" maximum depth (407 x 495 x 114 mm).

Weight: net 20 lbs (9 kg); shipping 32 lbs (14,4 kg).

Compatible accessories: 60D Logarithmic Converter; Type A-1 AC-to-DC Converter; 101 Waveform Translator.

Price: Moseley 7030A (standard bench), Moseley 7030AR (standard rack), Moseley 7030AM (metric bench), Moseley 7030AMR (metric rack): $1795

Options

- 01. Potentiometric switch for five most sensitive ranges — Prices on request
- 02. Zero check switch on each axis — Prices on request
- 03. Automatic recycling for time sweep — Prices on request
- 04. With both carrying handle and rack brackets, add $15.

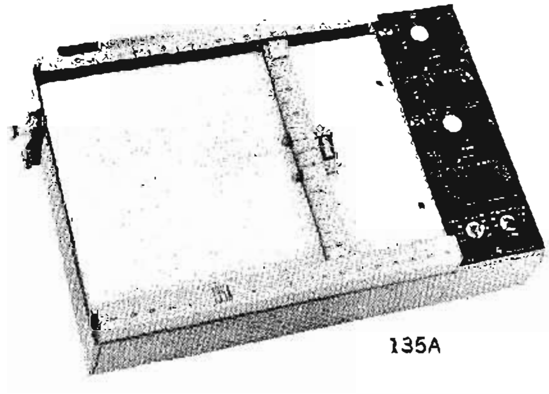
135 SERIES X-Y RECORDERS, 8" x 11"

Multi-range, portable or rack, general-purpose plotter

Available in two basic models, these Moseley 8½" x 11" x-y plotters are adaptable to almost any laboratory, field or system application. In the first group, the 135 and the 135M (metric) feature 16 dc input ranges on each axis with a minimum input resistance of 200,000 ohms/volt full scale (10"); in the second group, the 135A and 135AM (metric) feature 11 calibrated ranges with 1-megohm resistance at null.

Unique construction permits instant adaptation to desk or bench positioning in a horizontal, inclined or vertical plane, or rack mounting by the addition of brackets in only 10½" of panel space. A detachable handle doubles as a tilt support or carrying aid. Standard features include advanced transistor circuitry, calibrated time base on the x-axis, zero set and zero suppression, potentiometric input mode, scale factor vernier and new AUTOGRIP electric paper holddown, which has no moving parts, holds any chart 11" x 17" or smaller, is quiet and maintenance-free.

Modular construction of major assemblies insures maximum flexibility and ease of maintenance. The control module incorporates all input circuitry with conveniently grouped operating controls. A panel group for each axis includes input terminals which accept either open wire or banana plugs, ground terminal, range selector with scale factor vernier, function switch and zero control. High-gain servo amplifiers are plug-in units, isolated and free of ground. Special Moseley servo motors control the ink pen through a "drafting machine" type mechanism which is accurate and non-interacting. The pen may be controlled locally or remotely by an electric lift. The "drop-in" pen mounting facilitates easy changing or cleaning. Calibrated scales along each axis align with standard paper markings.



135A

Specifications

Recording mechanism: independent servo-actuated drives for x and y axes; isolated and free of ground.

Paper size: standard 8½" x 11" graph paper with 7" x 10" recording area; metric paper has 18 x 25 cm recording area.

Paper holdown: AUTOGRIP electric, no moving parts; holds charts 11" x 17" or smaller.

Slewing speed: 20 in/sec (50 cm/sec) maximum pen speed, each axis.

DC voltage ranges (each axis): 135 (standard, inch): 16 ranges, 0.5, 1, 2, 5, 10, 20, 50 mv/div; 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 v/div; 135M (metric): 16 ranges, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100 mv/cm; 0.2, 0.5, 1, 2, 5, 10, 20 v/cm; 135A (1-megohm, inch): 11 ranges, 0.5, 1, 5, 10, 50 mv/div; 0.1, 0.5, 1, 5, 10, 50 v/div; 135AM (1-megohm, metric): 11 ranges 0.2, 0.5, 2, 5, 20, 50 mv/cm; 0.2, 0.5, 2, 5, 20 v/cm; on all models, continuous range expansion control, potentiometric mode on y axis (obtainable on x by removing strap on input circuit board); operates on most sensitive range on 135 and 135M and on four most sensitive ranges of 135A, 135AM.

Time base intervals: 135 (standard, inch): 7 calibrated sweeps on x axis, 0.5, 1, 2, 5, 10, 20, 50 sec/div; 135M (metric): 7 calibrated sweeps on x axis, 0.2, 0.5, 1, 2, 5, 10, 20 sec/cm; 135A (1-megohm, inch): 5 calibrated sweeps on x axis, 0.5, 1, 5, 10, 50 sec/div; 135AM (1-megohm, metric): 5 calibrated sweeps on x axis, 0.2, 0.5, 2, 5, 20 sec/cm.

Input resistance: 135 (standard, inch): 200,000 ohms/volt, full scale (10") through 1 v/div range, 2 megohms on all higher ranges; 135M (metric): 200,000 ohms/volt, full scale (25 cm) through 0.5 v/cm range; 2.5 megohms on all higher ranges; 135A, 135AM (1-megohm, inch and 1-megohm, metric): 1 megohm at null on all calibrated ranges; when in variable range control mode, 100,000 ohms on four most sensitive ranges and 1 megohm on all others; potentiometric input draws essentially zero current at null.

Accuracy: better than 0.2% of full scale with 0.1% resettability; time base accuracy better than 5% of full scale, adjustable to 1%.

Standardization: continuous electronic reference from zener-regulated power supply.

Power: 115 or 230 volts ±10%, 50 to 60 cps, approximately 80 volt-amperes.

Dimensions: 16⅛" long, 10½" wide, 4½" deep (410 x 267 x 114 mm).

Weight: net 25 lbs (11,3 kg); shipping 32 lbs (14,4 kg).

Price: Moseley 135 (bench) and 135R (rack), standard; Moseley 135M and 135MR, metric; Moseley 135A and 135AR 1-megohm, standard; Moseley 135AM and 135AMR 1-megohm, metric — $1650

Options

01. With both handle and rack brackets, add $15.
02. With rear inputs (rack units only), add $15.
03. With mechanical paper holddown in place of AUTOGRIP, no extra charge.
04. With cartridge ink supply, no extra charge.

135C X-Y RECORDER

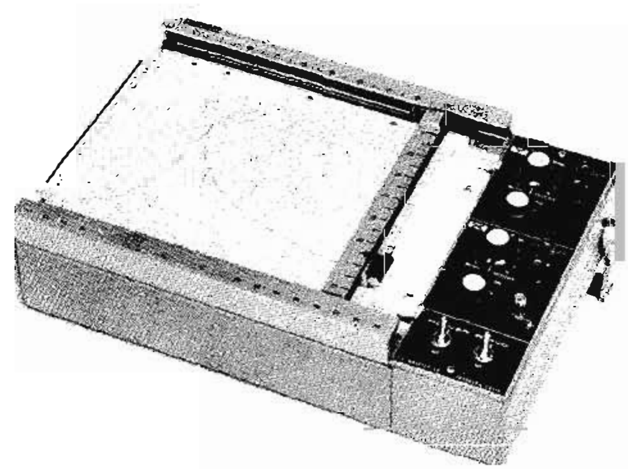
Modified version of the 135 for maximum utility at lower cost

The Model 135C is a lower cost version of the Moseley 135 X-Y Recorder (page 343). It has six fewer input ranges with a lower maximum voltage acceptance, slightly lower slewing speed, manual pen lift and mechanical instead of electric paper holddown for standard 8½" x 11" graph sheets. Physical construction is identical to the 135, ultra-compact and instantly adaptable to horizontal, inclined or vertical positioning, as well as being convertible to rack mounting.

Many other desirable features of the more versatile 135 are retained, including full-scale zero adjustment and suppression, continuous expansion controls for arbitrary full-scale range settings and potentiometric input capability.

Electrically isolated, all solid-state amplifiers control special Moseley high-performance 2-phase servo motors mechanically coupled to balance potentiometers and a cartridge fed ink pen. Input filters in each axis reject undesirable noise in applied dc signals to produce smooth recordings. Accuracy up to 0.1% of full scale may be obtained on any one range by an easily accessible control, the most sensitive range being factory adjusted to this figure.

Slightly extra cost options include rear-mounted input terminals, electric pen lift with local and remote control, installed retransmitting potentiometers and AUTOGRIP electric paper holddown. Metric calibrated models are available at no extra cost.



Specifications

Recording mechanism: independent servo-actuated drives for x and y axes, non-interacting, transformer isolated, free of ground; liquid ink pen with cartridge ink supply, manual pen lift; local and remote electric pen lift optional at extra cost.

Slewing speed: 15 in/sec (38 cm/sec) maximum pen speed, each axis.

Paper size: standard 8½" x 11" graph paper with 7" x 10" writing area (18 x 25 cm); mechanical paper holddown.

Input voltage ranges: 10 ranges, each axis: 0.5, 1, 5, 10, 50 mv/div (inch), 0.1, 0.5, 1, 5, 10, v/div (inch); metric unit: 0.2, 0.5, 2, 5, 20, 50 mv/cm, 0.2, 0.5, 2, 5 v/cm; continuous range control mode allows arbitrary full-scale voltage setting; removal of internal linkage permits potentiometric operation on most sensitive range.

Input resistance: 200,000 ohms/v, full scale (10") on all calibrated ranges; potentiometric operation draws essentially zero current at null.

Standardization: long-life mercury cell.

Accuracy: factory adjusted to 0.1% of full scale on the most sensitive range (0.5 mv/div); any one range may be adjusted to 0.1% accuracy by an easily accessible control; resettability is 0.1% of full scale.

Interference rejection: dc common mode rejection better than 10^6 to 1 on most sensitive range.

Power: 115 or 230 volts ±10%, 50 to 60 cps, approximately 55 volt-amperes.

Dimensions: bench model: 16⅛" long, 10½" wide, 4½" deep (410 x 267 x 114 mm); rack mount: 16⅛" inside rack clearance, 19½" panel width, 4½" maximum depth (410 x 267 x 114 mm).

Weight: net 18 lbs (8,1 kg); shipping 25 lbs (11,2 kg).

Price: Moseley 135C (standard bench), Moseley 135CR (standard rack), Moseley 135CM (metric bench), Moseley 135CMR (metric rack) — $1190

Options

01. With local and remote electric pen lift, add $60.
02. With rear input connectors (rack models only), add $15.
03. With retransmitting potentiometers on each axis, add $100.
05. With AUTOGRIP electric instead of mechanical paper holddown, add $95.

136A TWO-PEN X-Y_1Y_2 RECORDER, 8½" x 11"

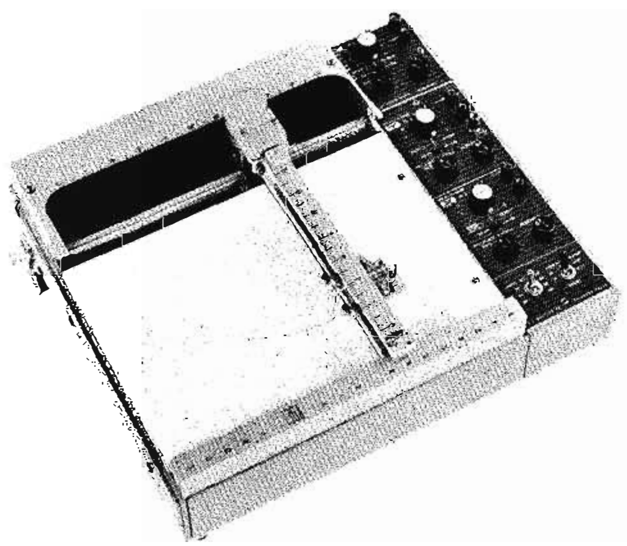
A three-axis graphic recorder for plotting two curves simultaneously

The Moseley Model 136A is a two-pen, three-axis (x, y_1, y_2) version of the Model 135A 8½" x 11" X-Y Recorder (page 343), identical electrically and physically except for the added second pen with its associated circuitry and controls. The two pens traverse the full vertical axis independently with not less than 0.1 inch horizontal separation, and the horizontal axis simultaneously over the complete recording area of the paper. Input circuitry and controls for each axis are constructed in modular form, electrically isolated and free of ground. Advanced transistor circuitry insures high accuracy and stability.

Input ranges

The controls for each axis are conveniently grouped with input connectors accepting either banana plugs or open wire. Eleven calibrated steps cover voltage ranges from 0.5 mv/div (inch) to 50 v/div (inch) with continuously variable expansion control for fitting arbitrary voltage limits within the paper margins. One-megohm input resistance at null is a feature of all calibrated ranges. Five time sweeps are provided on the x axis and potentiometric mode on the four most sensitive ranges of both y axes. Potentiometric operation on the x axis is obtainable by removing an internal strap. Zero controls operate without affecting calibration and provide full scale zero set and one full scale of zero suppression.

Reliable paper holddown is provided by the new AUTOGRIP electric platen, which has no moving parts, is quiet and effective on any size chart 8½" x 11" or smaller. Pens are capillary fed from a generous reservoir, are "drop-in" mounted, easily changed for color variation or cleaning.



Specifications

Recording mechanism: independent servo-actuated drives on three axes, x, y_1 and y_2, free of ground.

Paper size: standard 8½" x 11" graph paper with 7" x 10" writing area (18 x 25 cm); AUTOGRIP electric paper holddown.

Slewing speed: 20 in/sec, maximum pen speed, each axis.

Input voltage ranges: 11 ranges, each axis: 0.5, 1, 5, 10, 50 mv/div (inch), 0.1, 0.5, 1, 5, 10, 50 v/div (inch); continuous range control mode allows arbitrary full-scale voltage setting; potentiometric mode for y_1 and y_2 axes, also available on x axis by removal of internal linkage on attenuator; this mode effective when attenuator is in most sensitive range.

Input resistance: 1 megohm at null on all calibrated ranges; when in continuous range control mode, 100,000 ohms on the four most sensitive ranges and 1 megohm on all others; operation in potentiometric mode draws essentially zero current at null.

Time intervals: 5 calibrated sweeps on x axis only: 0.5, 1, 5, 10, 50 sec/div (inch); these speeds correspond to full-scale times of 7.5, 15, 75, 150, 750 seconds.

Accuracy: better than 0.2% of full scale, with resettability better than 0.1% of full scale; time base accuracy better than 5% of full scale, adjustable to 1%.

Standardization: continuous electronic reference, zener-diode controlled.

Power: 115 or 230 volts ±10%, 50 to 60 cps, approximately 85 volt-amperes.

Dimensions: bench model, 17⅞" long, 14" wide, 4¾" deep (454 x 356 x 121 mm).

Weight: net 39 lbs (17.5 kg); shipping 47 lbs (21 kg).

Price: Moseley 136A (bench) or Moseley 136AR (rack), $2650.

Options

01. With both carrying handle and rack brackets, add $15.
02. With rear input terminals, add $15.

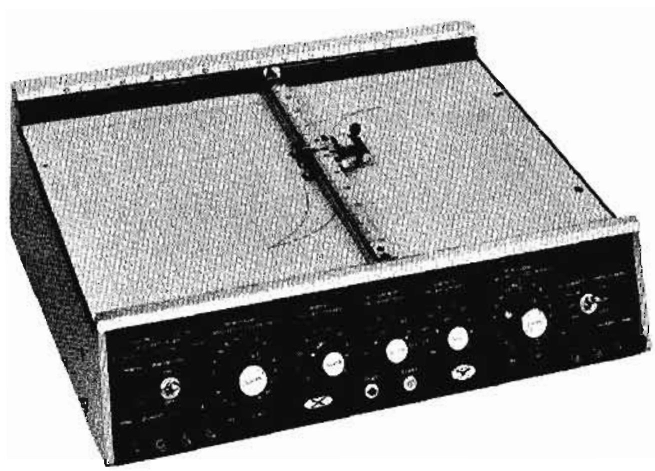
7000A HIGH-SENSITIVITY X-Y RECORDER, 11" x 17"

Plots dc signals to 100 μv/in, ac to 5 mv/in

Moseley Model 7000A Recorders are versatile precision plotters having greater sensitivity, more ranges and higher common mode rejection than previously offered in a single instrument. One-megohm shielded and guarded inputs accept ac and dc signals over a wide voltage range with calibrated step selector or continuous range controls. Extended zero positioning up to 4 scale lengths, a multiple-range time base applicable to either axis, and extremely good retrace characteristics are additional features.

The recording platen is equipped with the Moseley AUTOGRIP paper holddown, which has no moving parts, operates equally well on any chart 11" x 17" or smaller and is maintenance-free. New and useful features include multi-contact flat mandrel balance potentiometers, calibrated zero offset with extended range, and calibrated time sweeps with automatic reset and adjustable sweep lengths which may be used on either axis.

The 20 cps to 100 kc frequency range and 5 mv/inch ac sensitivity of the 7000A are convenient for plotting low currents without extra amplification, using hp 1110A (page 304) and hp 456A Clip-on Current Probes (page 140).



Specifications

Input circuits: dc floating, guarded and shielded; can be operated up to 500 v dc above ground; ac inputs are single-ended, capacitor-coupled.

DC voltage ranges (each axis): 17 calibrated ranges: 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 for standard units; 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, 2, 10 v/cm for metric units; continuously variable mode permits extension of each range.

DC input resistance: one megohm at null on all calibrated and variable ranges; potentiometric input on five most sensitive ranges by disconnecting straps on input attenuators.

AC voltage ranges (each axis): 12 calibrated ranges, full scale: 5, 10, 20, 50 mv/in; 0.1, 0.2, 0.5, 1, 2, 5, 10, 20 v/in on standard units; 2.5, 5, 10, 25 mv/cm, 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10 v/cm for metric units.

AC input impedance: one megohm on all calibrated ranges.

Interference rejection: dc common mode rejection is 140 db; ac common mode rejection 120 db at power line frequency on two most sensitive ranges.

Slewing speed: 20 in/sec, each axis.

Time sweeps: applicable to either or both axes in 8 ranges: 0.5, 1, 2, 5, 10, 20, 50, 100 sec/in on standard units; 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 sec/cm for metric units; sweep length is adjustable and may be reset at any point of operation manually or automatically.

Accuracy: dc, 0.2% of full scale; ac, 0.5% of full scale from 20 cps to 100 kc; dc linearity, 0.1% of full scale; ac linearity, 0.2% of full scale; time sweep accuracy is 2% of full scale; linearity, 1% of full scale.

Repeatability: 0.1% of full scale.

Position transducers: multi-contact flat mandrel potentiometers, each axis.

Zero offset: 3 full scales offset in x and 4 full scales in y in 5 inch calibrated steps; continuously adjustable between steps.

Reference voltage: continuous, zener-controlled.

Paper holddown: AUTOGRIP electric; has no moving parts; firmly grips all charts 11" x 17" or smaller.

Servo motors: acceleration constant 22800 radians/sec^2, minimum.

Power: 115 or 230 volts, 50 to 60 cps, 85 volt-amperes.

Dimensions: bench model: 17½" wide, 15⅛" high, 6½" deep (445 x 382 x 165 mm); rack model: 17½" inside rack clearance, 17½" panel height, 6½" maximum depth (444 x 444 x 165 mm).

Weight: net 38 lbs (17,1 kg); shipping 46 lbs (20,7 kg).

Compatible accessories: F-3B Line Follower; Q Roll Charts; D-1B and D-2 Character Printers; G-2B Null Detectors; 40D Keyboard, 60D Logarithmic Converter; 101 Waveform Translator; Dymec digital-to-analog converters, and hp 1110A or hp 456A Clip-on AC Current Probes.

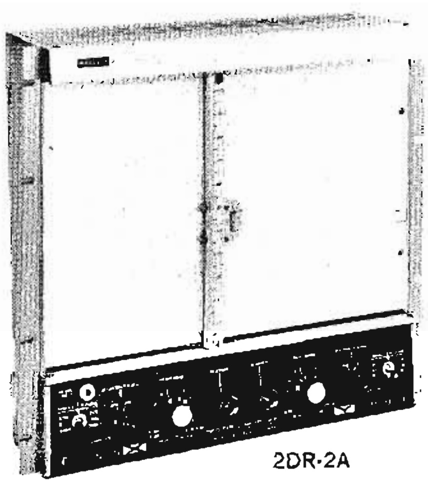
Prices: Moseley 7000A (standard), Moseley 7000AR (standard rack), Moseley 7000AM (metric), Moseley 7000AMR (metric rack): $2575

Options: (prices on request)

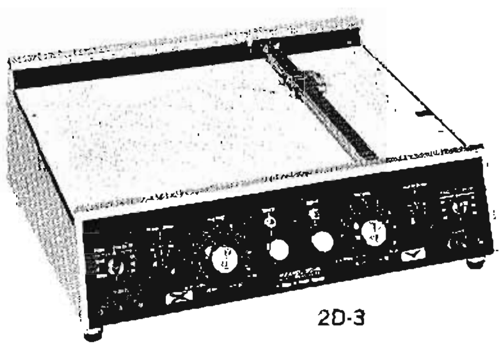
01. Potentiometric switch for five most sensitive ranges.
02. Zero check switches on each axis.
03. Automatic recycling time sweep.
04. Retransmitting slidewires.

2D-2, 2D-3 X-Y RECORDERS, 11"x17"

2D-2 Series high-impedance and time base models; 2D-3 with computer reference feature



2DR-2A



2D-3

Moseley 2D-2 and 2D-3 Series X-Y Recorders offer a wide choice of features in options tailored for almost any application. The 2D-2 Series are basically general-purpose plotters, including models with electronic time base and 1 megohm input resistance. Recorders in the 2D-3 series are specially equipped to accept the standard +100 and −100 volt computer reference as the servo balancing potential; they have an input resistance of 200,000 ohms/volt and do not include a time base. Other features of the two series are electrically and mechanically identical and include the new AUTOGRIP electric paper holddown system, which has no moving parts, is quiet, maintenance-free and grips any size chart 11" x 17" or smaller.

All 2D-2 and 2D-3 recorders are completely solid state except the 1-megohm models which use a single nuvistor in each axis to provide the extra gain required.

As on all Moseley recorders, range selectors include a scale factor vernier which continuously extends the full-scale voltage acceptance of any range to permit on-scale recording of data with arbitrary limits. Potentiometric operation on the most sensitive range of 2D-2 models is possible by making a simple internal circuit board modification and, on 2D-3 models by a function switch selection.

The 2D-3 models include zero check pushbutton switches on each axis for convenience in checking computer reference calibration. Although specially designed for computer table use, 2D-3 recorders also have a standard internal electronic reference which may be utilized when operated as a standard plotter.

Specifications

Recording mechanism: independent servo-actuated drives for x and y axes; inputs floating when operated with internal reference (2D-3 models single-ended to ground when operated from computer reference); ink pen and AUTOGRIP electric paper hold-down.

Paper size: standard 11" x 17" graph paper with 10" x 15" writing area (metric, 25 x 38 cm writing area); when equipped with Type Q roll chart accessories, 10" roll charts 120' long.

Slewing speed: 20 in/sec (50 cm/sec) max. pen speed, each axis.

DC voltage ranges (each axis): standard models (2D-2 and 2D-3): 16 calibrated ranges, 0.5, 1, 2, 5, 10, 20, 50 mv/div (inch); 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 v/div (inch); standard metric models (2D-2M and 2D-3M): 16 calibrated ranges, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100 mv/cm; 0.2, 0.5, 1, 2, 5, 10, 20 v/cm; 1-megohm models (2D-2A): 11 calibrated ranges, 0.5, 1, 5, 10, 50 mv/div (inch); 0.2, 0.5, 1, 5, 10, 50 v/div (inch); 1-megohm metric models (2D-2AM): 11 calibrated ranges, 0.2, 0.5, 2, 5, 20, 50 mv/cm; 0.2, 0.5, 2, 5, 20 v/cm; all models have scale factor vernier with potentiometric input available by removal of straps on input circuit board; potentiometric operation effective on most sensitive range of standard models; 4 most sensitive ranges of 1-megohm models.

Time intervals (2D-2 Series only): standard models: 7 calibrated sweeps, 0.5, 1, 2, 5, 10, 20, 50 sec/div (inch); standard metric models: 7 calibrated sweeps, 0.2, 0.5, 1, 2, 5, 10, 20 sec/cm; 1-megohm models: 5 calibrated sweeps, 0.5, 1, 5, 10, 50 sec/div (inch); 1-megohm metric models: 5 calibrated sweeps, 0.2, 0.5, 2, 5, 20 sec/cm.

Input resistance: standard models: 200,000 ohms/v (full scale 10") through 1 v/div (inch) range; 2 megohms on all higher ranges; standard metric models: 200,000 ohms/v (full scale 25 cm) through 0.5 v/cm range; 2.5 megohms on all higher ranges; 1-megohm models: 1 megohm at null on all fixed ranges (when using scale factor vernier, 100,000 ohms on the 4 most sensitive ranges and 1 megohm on all others); all models: potentiometric operation draws essentially zero current at null.

Accuracy: better than 0.2% of full scale with 0.1% resettability on all ranges; time base accuracy better than 5% on full scale, adjustable to 1%.

Standardization: continuous zener-controlled electronic reference; 2D-3 series will operate from external ±100 v computer reference.

Power: 115 or 230 volts, 50 to 60 cps, approx. 143 volt-amps.

Dimensions: bench models: 17½" wide, 6¾" high, 16" deep (445 x 165 x 406 mm); rack models: 17¾" inside rack clearance, 17½" panel height, 5½" max. depth (551 x 445 x 140 mm).

Weight: net approx. 30 lbs (13,5 kg); shipping 50 lbs (22,5 kg).

Prices

Moseley 2D-2 or 2DR-2 (standard)	$1950
Moseley 2D-2M or 2DR-2M (metric)	$1950
Moseley 2D-2A or 2DR-2A (1-megohm)	$1950
Moseley 2D-2AM or 2DR-2AM (metric and 1-megohm)	$1950
Moseley 2D-3 or 2DR-3 (standard)	$2050
Moseley 2D-3M or 2DR-3M (metric)	$2050

Options

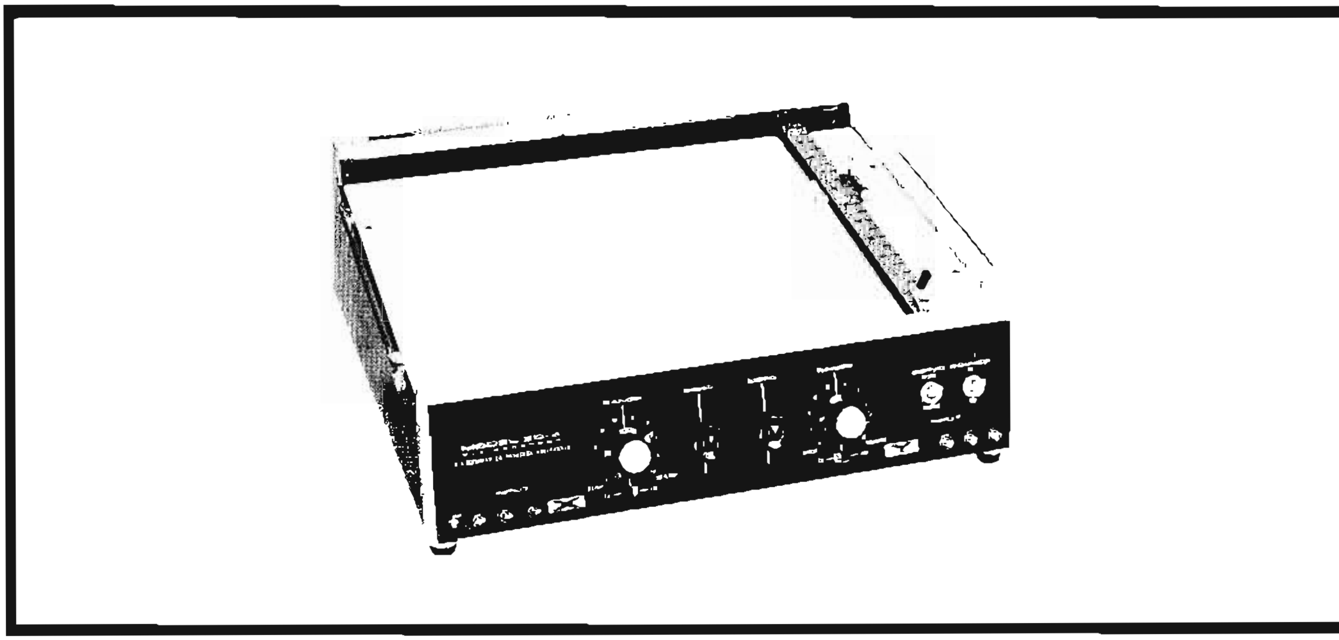
01. Any rack model with rear inputs, add $15.
02. With event marker on lower margin of x axis, add $100.
03. With 5000-ohm, 1% linearity retransmitting potentiometer on either axis, add $50.
04. With cartridge ink supply, no charge.

2D-4 X-Y RECORDER, 11" x 17"

High-accuracy recorder for utility x-y plotting

The Moseley Model 2D-4 is designed to meet the need for a lower cost precision x-y recorder in specific applications not requiring the overall versatility of the Model 2D-2. Maintaining high-quality workmanship and accuracy, economy has been achieved by using a mechanical paper holddown, eliminating ac and time sweep features and reducing inputs to 10, instead of 16 ranges. Still included as standard features are full-scale zero controls, variable range expansion mode, input filters, potentiometric capability and cartridge ink supply. The 2D-4 versatility may be increased by the addition of compatible Moseley accessories such as the Type A-1 AC-to-DC Converter, Model 60D Logarithmic Converter, Type 101 Waveform Translator and Type Q Roll Chart Adapters.

Operating simplicity is an outstanding characteristic of the 2D-4. All controls are located in functional positions on a sloping panel across the front of the instrument. Inputs for each axis accept either open-wire or plug-type connectors. Zero controls have a range of one full scale above or below the lower left origin. Each range may be adjusted for an arbitrary full-scale voltage to fit variable data, and the most sensitive range may be operated potentiometrically to draw essentially zero current at null.



Specifications

Recording mechanism: independent servo-actuated drives for x and y axes, non-interacting, transformer isolated and free of ground; liquid ink pen with cartridge ink supply, manual pen lift; electric pen lift with local and remote control optional at extra cost.

Slewing speed: 15 in/sec (38 cm/sec) max. pen speed, each axis.

Paper size: standard 11" x 17" graph paper with 10" x 15" writing area; metric unit: 25 cm x 38 cm; mechanical paper holddown; 10" x 120' roll charts when equipped with roll chart accessories.

DC voltage ranges: ten calibrated ranges, each axis: 0.5, 1, 5, 10, 50 mv/div (inch) and 0.1, 0.5, 1, 5, 10 v/div (inch); metric unit: 0.2, 0.5, 2, 5, 20, 50 mv/cm and 0.2, 0.5, 2, 5 v/cm, each axis; stepless range control allows arbitrary full-scale voltage setting; potentiometer input may be established on most sensitive range.

Input resistance: 200,000 ohms/volt full scale (10") on all fixed ranges; potentiometric mode draws essentially zero current at null.

Standardization: long-life mercury cell.

Interference rejection: dc common mode rejection better than 10^6 to 1 on most sensitive range.

Accuracy: the most sensitive range, 0.5 mv/div (0.2 mv/cm on metric unit) is factory-adjusted to 0.1% of full scale; accuracy and resettability may be adjusted to 0.1% on any one range at a time by an easily accessible control.

Dimensions: bench models: 17½" wide, 16" high, 6¾" deep (445 x 406 x 165 mm); rack models: 17¾" inside rack clearance, 17½" panel height, 5½" maximum depth (551 x 445 x 140 mm).

Weight: net 25 lbs (11.3 kg); shipping 40 lbs (18 kg).

Power: 115 or 230 v, 50 to 60 cps, approx. 110 volt-amps.

Price: Moseley 2D-4 (standard bench), Moseley 2D-4M (metric bench), Moseley 2DR-4 (standard rack), Moseley 2DR-4M (metric rack) — $1490

Options

01. Local and remote electric pen lift, add $60.
02. Installed 5000-ohm retransmitting potentiometer, per axis, add $50.
03. Rear-mounted input connectors, (available on rack units only), add $15.
04. Event marker on lower margin, add $100.
05. AUTOGRIP electric instead of mechanical paper holddown, add $95.

2FRA TWO-PEN X-Y RECORDER, 11" x 17"

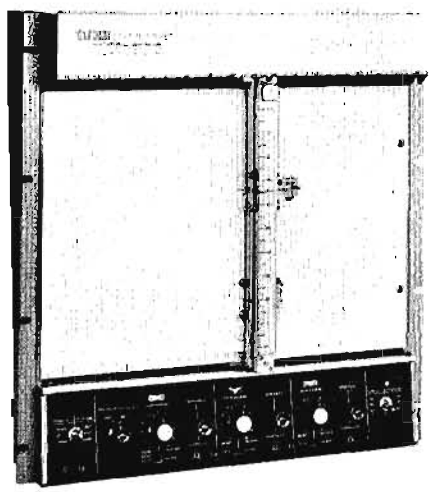
A three-axis graphic recorder for plotting two curves simultaneously

The 2FRA is a three-axis, two-pen 11" x 17" graphic recorder, each axis presenting 1-megohm input resistance at null. It is available only in a rack mounting configuration but may be furnished with metric (2FRAM) instead of English scaling. Standard facilities include a time base on the x axis, 11 voltage ranges with continuous expansion feature, full scale zero set and suppression, local and remote electric pen lift and potentiometric capability.

Two drop-in mounted pens with integral ink reservoir traverse the full y axis with no less than 0.1 inch horizontal separation. Writing range for both pens is 10 inches vertically and 15 inches horizontally. Servo drives are independent and free of electrical ground. Servo amplifiers and power supply are hybrid design combined in a single plug-in unit, compact and easily maintained. A simplified self-balancing system uses linear slidewires and a continuous zener-controlled reference.

Each input range has a calibrated (fixed) and continuously variable mode. The variable mode may be used to fit arbitrary maximum voltages within the recording limits of the paper. Potentiometric operation on the four most sensitive ranges of each axis may be easily established by removing linkages on the input circuit boards. The built-in time base operates on the x axis only, with five calibrated sweeps from 7.5 to 750 seconds for full-scale pen travel.

A useful extra cost option provides a third pen which is fixed in a position near the bottom of the pen carriage. It may be operated by a remote contact closure to identify significant events in an operation procedure.



Specifications

Recording mechanism: independent servo-actuated drives on three axes, x, y_1, and y_2, free of ground; liquid ink "drop-in" pens.

Paper size: standard 11" x 17" graph paper with 10" x 15" writing area; metric paper has 25 x 38 cm writing area; AUTOGRIP electric paper holddown.

Slewing speed: 10 in/sec (25 cm/sec) on x axis; 20 in/sec (50 cm/sec) on y_1 and y_2 axes.

DC input voltage ranges: 11 calibrated ranges, each axis: 0.5, 1, 5, 10, 50 mv/div (inch) and 0.1, 0.5, 1, 5, 10, 50 v/div (inch); metric ranges: 0.2, 0.5, 2, 5, 20, 50 mv/cm and 0.2, 0.5, 2, 5, 20 v/cm; potentiometric input available on four most sensitive ranges of all axes by removal of internal linkage on attenuator.

Input resistance: one megohm at null on all fixed ranges, each axis; when in variable range mode, 100,000 ohms on the four most sensitive ranges and one megohm on all others; potentiometric input draws essentially zero current at null.

Time Intervals: 5 calibrated sweeps on x axis only: 0.5, 1, 5, 10, 50 sec/div (inch); metric: 0.2, 0.5, 2, 5, 20 sec/cm; these speeds correspond to 7.5, 15, 75, 150, and 750 sec for full-scale travel.

Accuracy: better than 0.2% of full scale with resettability better than 0.1% of full scale; time base accuracy better than 5% of full scale, adjustable to 1%.

Standardization: continuous zener-controlled electronic reference.

Power: 115 or 230 v, 50 to 60 cps, approx. 200 volt-amps.

Dimensions: 17¾" inside rack clearance, 17½" panel height, 5⅝" maximum depth (445 x 444 x 143 mm).

Weight: net 47 lbs (21 kg); shipping 55 lbs (25,7 kg).

Price: Moseley 2FRA (standard) or 2FRAM (metric), $3575.

Options

01. With rear input terminals (Amphenol 165-14 and 165-15), add $15.

02. With installed event marker on lower end of y axis, add $100.

6SA X-Y RECORDER, 10" x 10"; 7 X-Y RECORDER, 30" x 30"

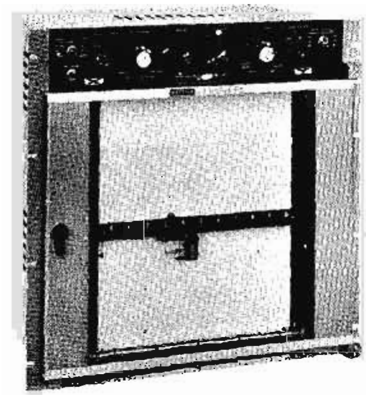
Automatic chart advance recorder, plus display-type instrument

The Moseley Model 6SA is a rack mounting x-y recorder featuring automatic frame advance of a continuous roll of individual charts, each providing a 10" x 10" plotting area. A precise and automatic transport mechanism positions a new chart whenever initiated by a manually operated momentary contact switch or corresponding remote circuit. Completed charts may be cut free on a serrated edge, or they may be stored on a takeup spool.

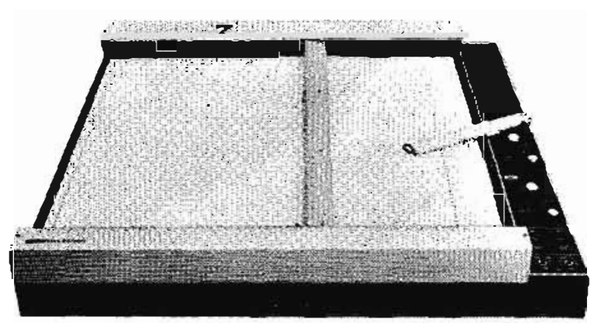
A plug-in control module has the advantage of range and function substitution without internal modification of the recorder. For each axis the standard module provides 11 calibrated fixed input ranges from 0.5 mv/div (inch) to 50 v/div (inch), with 1-megohm input resistance at null, continuously variable mode for each range, and resettable full-range zero adjustment. A time sweep mode on the vertical axis provides 5 calibrated speeds from 0.5 to 50 div (inch)/sec. Potentiometric input may be established on the x-axis by function switch selection and on the y axis by removal of an internal linkage.

The Moseley Model 7 is an over-size x-y recorder specially designed for large systems display in console, wall or special floor stand mountings. Incorporation of standard Moseley recorder features provides maximum versatility, flexibility, speed and high accuracy. The vacuum grip, flat-bed platen accepts regular 32" x 32" graph paper which presents a plotting area of 30" x 30", an ideal size for display of data plotted with digital-to-analog conversion accessories. Thirteen calibrated ranges on each axis accept dc inputs from 30 mv to 300 v full scale, with a minimum input resistance of 200,000 ohms/v and minimum recording speed of 20 in/sec. A continuously variable mode allows expansion of any range to fit arbitrary data values.

Other standard features include full-range resettable zero controls, continuous zener-controlled reference supply, and potentiometric operation on the most sensitive range. Compatible Moseley accessories include the Type A-1R AC-to-DC Converter (page 355), Model 60D Log Converter (page 354), Type G-2B Null Detector (page 356), and Model 101 Waveform Translator (page 355).



Model 6SA



Model 7

Specifications, Model 6SA

Recording mechanism: two independent servo-actuated drives for x and y axes, free of ground; "drop-in" ink pen.
Chart requirements: roll type with 10" x 10" grids; 12" chart advance; vacuum holddown automatically cycled with frame advance.
Slewing speed: 1 sec or less for full-scale pen travel, each axis.
DC voltage ranges: 11 calibrated ranges, each axis: 0.5, 1. 5, 10, 50 mv/div (inch); 0.1, 0.5, 1, 5, 10, 50 v/div (inch); variable range control permits arbitrary full scale range settings.
Time intervals: 5 sweeps on y axis: 0.5, 1, 5, 10, 50 sec/div (in.). 50 sec/div (inch).
Input resistance: 1 megohm at null on all fixed ranges; when in variable range mode, 100,000 ohms on 4 most sensitive ranges and 1 megohm on all others; potentiometric input capability.
Zero control: resettable zero set; one full scale of offset.
Accuracy: better than 0.2% of full scale; resettability 0.1%.
Standardization: continuous zener-controlled electronic reference.
Power: 115 or 230 v, 50 to 60 cps, approx. 132 volt-amp.
Dimensions: 17¼" inside rack clearance, 19¼" panel height, 11⅞" maximum depth (438 x 488 x 302 mm).
Weight: net approx. 80 lbs (36 kg); shipping 110 lbs (49,5 kg).
Price: Moseley 6SA, with 12" chart advance, $3150.
Options
01. Chart advance of 6, 4, 3, 2 or 1 inch (specify one only), add $25.
02. With special 10" chart advance, add $50.

Specifications, Model 7

Recording mechanism: two independent servo-actuated drives for x and y axes, free of ground; electric pen lift with local and remote control.
Paper size: standard 32" x 32" graph paper with 30" x 30" (762 x 762 mm) plotting area; vacuum holddown.
Slewing speed: 20 in/sec maximum pen speed, each axis.
DC voltage ranges: 13 calibrated ranges, each axes: 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 (30") up to 0.5 v/in; 3 megohms on all higher ranges.
Zero control: resettable full-scale zero set and one full scale of zero offset in each axis.
Accuracy: better than 0.1% of full scale; resettability better than 0.05% of full scale.
Standardization: continuous zener-controlled reference supply with stability better than 0.05%.
Power: 115 v, 60 cps, approx. 185 volt-amp; other voltages and frequencies available on special order.
Dimensions: 40⅜" wide, 7-1/16" high, 37-5/16" deep (1026 x 180 x 948 mm).
Weight: net approx. 90 lbs (40.5 kg); shipping, 180 lbs (81 kg).
Price: Moseley 7, $3950.

7050A BASIC SYSTEMS X-Y RECORDER

Simplified single range x-y recorder for system integration

Advantages:

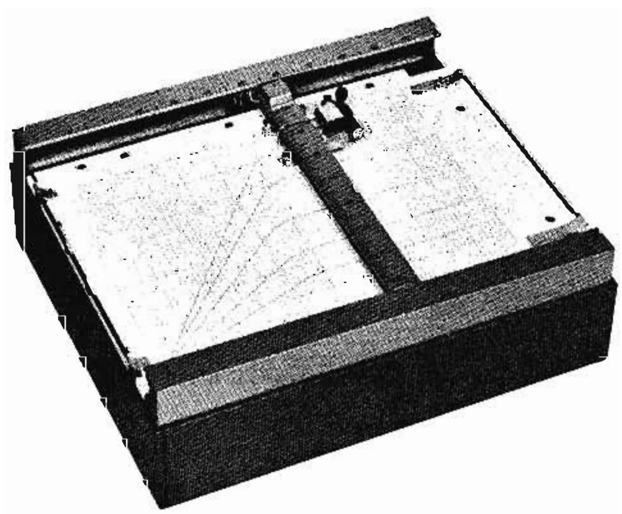
- Ultra-compact construction
- 1 megohm input resistance (at null)
- High accuracy and repeatability
- Simplified operation
- Low cost for system integration
- All solid-state circuitry

Uses:

- X-Y readout
- Bench or rack system integration

The Moseley Model 7050A is a single-range basic systems x-y recorder designed to meet specific system requirements in applications requiring integrated high-accuracy readout at minimum cost. The standard instrument has a single fixed range of 100 mv/in on each axis but is available in quantity orders with a single range sensitivity up to 10 mv/in.

Having only one range, the 7050A requires no control panel, resulting in a compact package only slightly larger than the graph paper itself. Finger-operated clamps hold standard 8½" x 11" paper on a flatbed recording platen. High accuracy is achieved by locating the linear balance potentiometer contact at the point of recording, eliminating backlash between the servo drive system and recording pen. Special Moseley slidewire potentiometers are long-lived and require minimum attention. Reference voltage is continuous and zener-regulated. Zero adjustments may be made with a screwdriver on controls at the rear of the instrument. A similar internal control is provided for calibration. Inputs are floating up to 500 v above ground, with both electrical and mechanical damping applied to the servo motors. Ink supply for the recording pen is contained in a replaceable plastic cartridge which can be visually monitored. At slightly greater cost the standard manually operated pen lift may be replaced by an electrically operated lift which is remotely controlled. Another option provides a rack mounting kit.



Specifications

Recording mechanism: 2 independent servo-actuated drives for x and y axes, non-interacting; liquid ink pen with transparent cartridge ink supply; manual pen lift; optional extra cost electric pen lift with remote control.

Slewing speed: 15 in/sec, maximum.

Paper size: standard 8½" x 11" graph paper with writing area of 7" x 10" (18 x 25 cm); mechanical paper holddown; AUTOGRIP electric holddown available at extra cost.

DC voltage range: single range of 100 mv/in, each axis; inputs floating, free of ground; quantity orders have option of single range with sensitivity up to 10 mv/in.

Input resistance: 1 megohm at null, each axis.

Standardization: continuous reference, zener-regulated.

Accuracy: 0.1% of full scale; resettability 0.1% of full scale.

Dimensions: 13" long, 10½" wide, 4½" deep (330 x 267 x 114 mm).

Weight: net 14 lbs (6,3 kg); shipping 22 lbs (9,9 kg).

Power: 115 or 230 volts ±10%, 50 to 60 cps, approximately 65 volt-amperes.

Price: Moseley 7050A (single 100 mv/in range, each axis), $975.

Options

01. Electric pen lift with remote control, add $60.
02. With 19" rack mount kit, add $30.
03. With 1% linearity retransmitting potentiometer on on each axis, add $100.
05. With AUTOGRIP electric paper holddown, add $95.

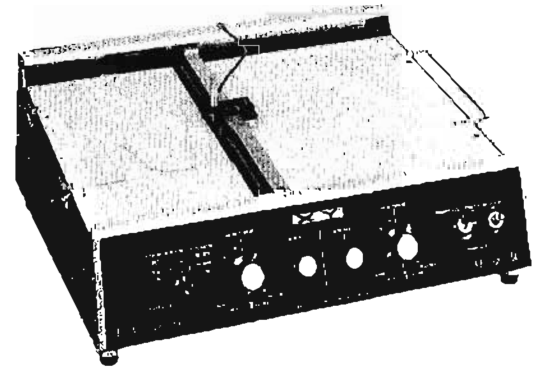
7590A AUTOMATIC DATA PLOTTING SYSTEM, 11" x 17"

Automatically plots electrical information in point or line form

The Model 7590A is a specially equipped x-y recorder for automatically plotting electrical information in line or point form at a rapid rate. The basic recorder is similar to the Model 2D-4 (page 348), with its standard features of 10 input ranges on each axis, all solid-state circuitry, floating inputs, drift-free servo mechanisms and mechanical paper holddown. Added to achieve automatic point or line plotting capability are a built-in null detector and a solenoid-actuated character printer. Character printer and pen are interchangeable, the one used being dependent on whether digital or analog information is being recorded.

The built-in 5-mode null detector is similar to the Type G-2 (page 356) and is capable of plotting up to 360 points per minute. Mute mode requires a command from the data source to unmute the recorder servos. Any signal at the input which unbalances the servo will reposition the plotting carriage until a null or balanced condition is reached, at which time the servos are muted, a plot is accomplished, and a completed plot pulse is issued to an external control, causing the system to assume a standby status ready for the next command. No-mute mode is similar to mute mode except that a command is not required to unmute the servos. This allows the recorder to seek null as soon as an input signal is applied. Upon reaching balance, a plot is made, a completed plot pulse issued and the system returns to standby. A calibrated mode accepts a signal, balances but does not plot. This mode is useful in pre-run procedures. Line or point plotting, using pen or character printer, respectively, is established by a function selector.

The character printer supplied is similar to the Type D-1B (page 356) with cylindrical die and actuating solenoid. Each end of the die has a different symbol. Three dies, totaling six symbols, are furnished. Special characters are available at moderate cost.



Specifications

Recording mechanism: independent servo-actuated drives for x and y axes, non-interacting, transformer isolated and free of ground; liquid ink pen with cartridge ink supply for line plotting; solenoid plunger type character printer for point plotting.

Slewing speed: 15 in/sec (38 cm/sec) maximum speed, each axis.

Paper size: standard 11" x 17" graph paper with 10" x 15" writing area; metric unit, 25 cm x 38 cm; mechanical paper holddown; 10" x 120' roll charts when equipped with roll chart accessories.

DC voltage ranges: 10 calibrated ranges, each axis: 0.5, 1, 5, 10, 50 mv/div (inch) and 0.1, 0.5, 1, 5, 10 v/div (inch); metric unit: 0.2, 0.5, 2, 5, 20, 50 mv/cm and 0.2, 0.5, 2, 5 v/cm, each axis; stepless range control allows arbitrary full-scale voltage setting; potentiometric input may be established on most sensitive range.

Input resistance: 200,000 ohms/volt full scale (10") on all fixed ranges; potentiometric mode draws essentially zero current at null.

Standardization: long-life mercury cell.

Interference rejection: dc common mode rejection better than 10^6 to 1 on the most sensitive range.

Accuracy: the most sensitive range, 0.5 mv/div (0.2 mv/cm on metric unit) is factory-adjusted to 0.1% of full scale; accuracy and resettability may be adjusted to 0.1% on any one range at a time by an easily accessible control.

Character printer accuracy: 0.05% (approx. 5/1000"); overall recorder accuracy not affected.

Null detector sensitivity: better than 0.4% of full scale.

Forced plot: if null is not reached within approximately 2 seconds, a plot is forced.

Enable-disable: required disable voltage: −3 volts dc (a contact closure may be substituted for the disable bias by inserting a resistor between existing terminals on the printed circuit board); required enable voltage: from 0 volts to any plus dc potential; voltage or contact closure requirements can be reversed by moving jumpers on the printed circuit board.

Seek signal: min. pulse height, ±3 v; +10 to −20 v, max. range.

Completed plot signal: pulse height, 20 v; pulse width, 100 μsec; rise time, less than 1 μsec; max. permissible capacitive load, 0.002 microfarad; output impedance, less than 200 ohms (capacitor-coupled).

Dimensions: bench: 17½" wide, 16" high, 6¾" deep (445 x 406 x 165 mm); rack: 17¾" inside rack clearance, 17½" panel height, 5½" maximum depth (551 x 445 x 140 mm).

Weight: net 38 lbs (17,1 kg); shipping 46 lbs (20,7 kg).

Power: 115 or 230 v, 50 to 60 cps, approx. 110 volt-amperes.

Price:

		Price
Moseley 7590A	(standard)	$1985
Moseley 7590AR	(standard, rack)	$1985
Moseley 7590AM	(metric)	$1985
Moseley 7590AMR	(metric, rack)	$1985

Option 01: with AUTOGRIP electric paper holddown, add $95.

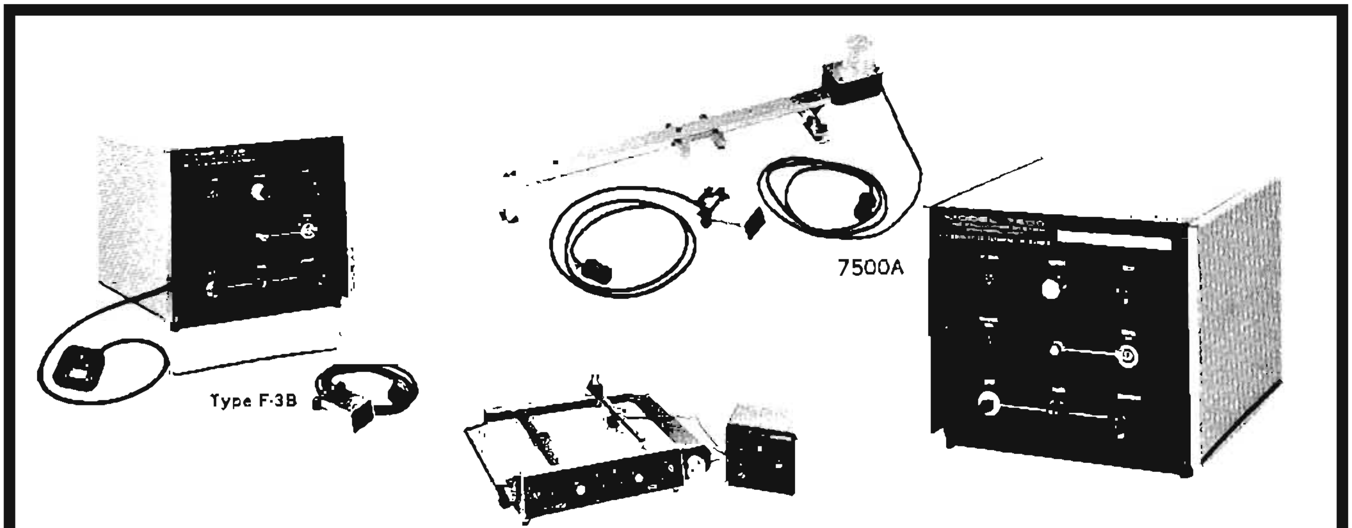
F-3B, 7500A, 7501A LINE FOLLOWER SYSTEMS

Regenerate original electrical data directly from previously recorded curves

The F-3B Line Follower is an accessory available as a factory-installed device on Moseley 2D Series X-Y Recorders (page 347) to permit the regeneration of original electrical data directly from previously recorded curves. Any line prepared with pencil or pigment-type ink will be followed automatically with high accuracy by means of an optical photo-electric sensing element which replaces the pen of the recorder. The unit does not impair normal recording characteristics of the recorder. The F-3B system uses an existing slidewire in the 2D series recorders for displacement analog output.

Models 7500A and 7501A line follower systems convert Moseley 2D and 680 Series Recorders (pages 347, 360, 361), respectively, for use as chart readers or transport delay simulators.

When a 2D Recorder is equipped with a Model 7500A, a Q-3 Roll Chart Accessory (page 363) also is required. These line follower systems consist of two assemblies, a control unit and a tracking unit. The control unit contains all control circuits for the system, the power supply, servo positioning amplifier and all the electronics except the photo diodes which are in the tracking head. The tracking unit in each system is specially designed for installation on a particular series of Moseley recorders. The unit consists of the positioning servo motor, the line follower head and the readout potentiometer.



7500A installed on 2D-3 recorder

Specifications

Components: F-3B: scanning and pick-up unit which replaces pen of x-y recorder; 7500A and 7501A: tracking unit with positioning servo, pick-up and readout potentiometer; all three systems include a control unit, containing a power source and control elements.

Compatibility: F-3B and 7500A for use with 2D Series X-Y Recorders; 7501A for 680 Series Strip-Chart Recorders.

Displacement analog output: F-3B: external voltage is applied to existing slidewire in 2D Series Recorders; 7500A and 7501A: approximately 0 to 6 v dc, or variable resistance change selected by internal switch; also output potentiometer of 5000 ohms, 0.1% linearity, 3 w.

Straight-line accuracy: 0° to 45° will be followed at time sweeps through 0.5 sec/in with an accuracy of ±0.03 inch; a straight line will remain within the scanned area at angular ranges from 0° to 70° at time sweeps up to 2 sec/in and 0° to 85° up to 5 sec/in (angles are measured with respect to the x axis); square waves or spike functions of 0.1 inch maximum amplitude will remain within the scanned area at time sweeps up to 10 sec/in.

Scanned area: the head scans 0.1 inch on either side of its center line and 0.05 inch along its center line.

Alarm circuit: can be set to detect excess tracking errors of less than 0.1 inch; internal relay has multiple contacts for controlling internal and external functions.

Temperature effects: no resetting of controls is required for temperature variations of ±15°F.

Function controls: sensitivity control for adjustment of error alarm; gain control for attenuating signals to recorder or position servo; pushbutton-reset to restore operation after alarm shut-off; balance control to compensate for uneven light field.

Power: F-3B: 115 or 230 volts, 50 to 60 cps, single phase, approximately 5 watts; 7500A and 7501A: 115 volts, 60 cps, single phase, approximately 30 volt-amperes.

Prices

Moseley F-3B, $795; factory installation on 2D Series Recorder, $50.

Moseley 7500A (for use with 2D Series), $1650.

Moseley 7501A (for use with 680 Series), $2100.

60D LOGARITHMIC CONVERTER

Converts ac or dc signals to logarithmic scale over 60 db dynamic range

Advantages:

20 to 20,000 cps ac frequency range
AC or dc input selector
±0.5 db accuracy and stability
60 db dynamic range
English or metric calibration and scaling

Uses:

Logarithmic conversion element in decibel systems
Semi-log or log-log plotting
Automatic gain-frequency plotting with x-y recorder

The Moseley Model 60D is a self-contained instrument which accepts ac or dc signals over an extended voltage and frequency range and produces a dc output proportional to the logarithm of the positive peak amplitude of the input. Since the logarithmic scale compresses the higher amplitudes and expands the lower ones, the resulting graphic presentation has the advantage of covering a wide range of levels with maximum accuracy at the lower amplitudes.

The converter is especially useful in evaluating the frequency characteristics of amplifiers, filters, transmission networks and related devices. An automatic gain-frequency plotting system, Model 7598A, utilizes the 60D in conjunction with a Moseley x-y recorder and an hp 207A-M7 Audio Generator which is equipped with a motor drive and output potentiometer to activate the x axis as a funtion of the frequency.

A dynamic range of more than 60 db, accuracy and long-term stability of better than ±0.5 db, ac or dc input selector, 5 input attenuator steps, and 3 output scale factor steps are major features valuable in a variety of applications. Model 60DM is the metrically scaled and calibrated version. Physical design adapts readily to bench use (with tilt bar) or rack mounting by installation of included brackets.

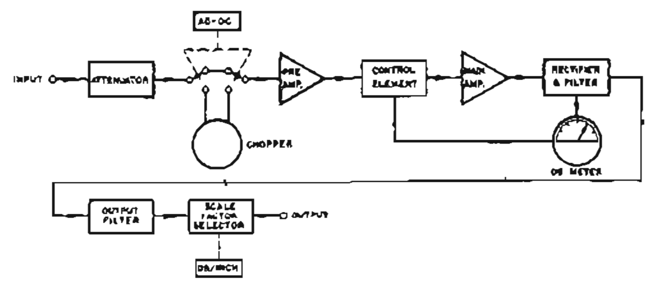


Figure 1. Block diagram, 60D.

Specifications

Input ranges

Attenuator setting (db)	AC input range (rms)	DC input range
0	1 mv to 1 v	3.16 mv to 3.16 v
—10	3.16 mv to 3.16 v	10 mv to 10 v
—20	10 mv to 10 v	31.6 mv to 31.6 v
—30	31.6 mv to 31.6 v	100 mv to 100 v
—40	100 mv to 100 v	316 mv to 316 v

AC frequency range: 20 to 20,000 cps.

Dynamic range: 60 db (1000 to 1), either ac or dc.

Output ranges: 5, 10, 20 db/div (inch) into 20,000-ohm load (10 mv/div (inch) recorder range); metric model (60DM): 2, 5, 10 db/cm into 10,000 ohm load (2 mv/cm range of metrically scaled recorder).

Response speed: 20 db/sec (normal maximum); 60 db/sec (absolute maximum).

Accuracy: ±0.5 db.

Calibration stability: ±0.5 db (better than ±0.2 db over any 24-hour period).

Input impedance: approximately 2 megohms, 35 pf (either ac or dc).

Power: 115 or 230 volts, 50 to 60 cps, approximately 42 volt-amperes.

Dimensions: 16¾" wide, 3-9/16" high, 11½" deep (425 x 91 x 292 mm).

Weight: net approx. 14 lbs (6,3 kg); shipping 20 lbs (9 kg).

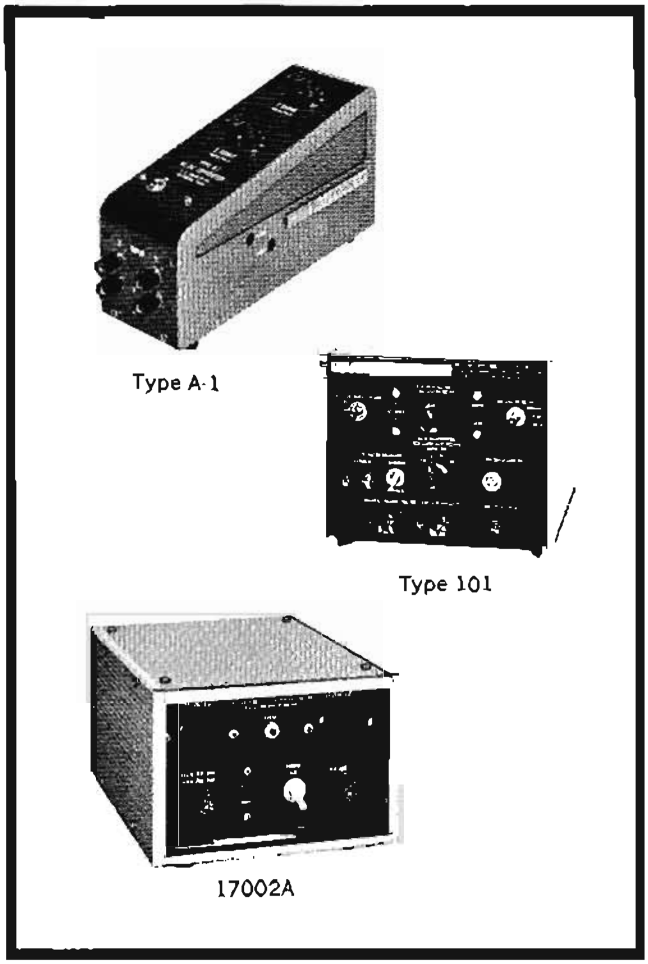
Price: Moseley 60D (standard) or Moseley 60DM (metric), $575.

Options

01. 5 cps lower limit and 5 kc upper limit with 2 db/sec (normal), 6 db/sec (max.) response speed, add $250.
02. 70 db dynamic range (by special production selection) with standard 60 db calibration markings, add $100.

A-1 AC-TO-DC CONVERTER, 101 WAVEFORM TRANSLATOR 17002A INVERTER

Accessories for x-y recording



Type A-1

Type 101

17002A

A-1 AC-to-DC Converter

The Type A-1 is a dual-channel ac-to-dc converter for use with dc input Moseley recorders to allow plotting of signals in the frequency range from 20 to 100,000 cycles. For a 20,000-ohm load (10 mv/div recorder range), the output is calibrated in rms units proportional to the average value of a sinusoidal input. The metric model is calibrated for a 25,000-ohm load (5 mv/cm range). Each channel has a single-ended input, differential output, 8 voltage ranges, frequency compensation and constant 2-megohm input resistance.

Specifications, Type A-1

Channels: two identical conversion channels for x and y axes.

Frequency range: 20 to 100,000 cycles useful range, useable to 200,000 cycles with degraded accuracy.

AC voltage ranges: with Moseley recorders in 10 mv/div range (20,000 ohms input), calibrated ranges are: 0.1, 0.2, 0.5, 1, 2, 5, 10, 20 volts/inch; metric unit with Moseley metric recorder in 5 mv/cm range (25,000 ohms input), calibrated ranges are: 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 volts/cm.

Linearity: 0.1% from 20 to 20,000 cps; 0.3% from 20 to 50 kc; 0.5% from 50 to 100 kc; 1% from 100 to 200 kc.

Input impedance: 2 megohms on all ranges, shunted by <25 pf.

Accuracy: 0.5% from 20 to 20,000 cps; 1% from 20 to 50 kc; 2% from 50 to 100 kc; 10% from 100 to 200 kc.

Power: 115 volts $\pm 10\%$, 60 cps, 11 volt-amperes.

Dimensions: bench model: 3¼" wide, 4" high (front), 5½" high (rear), 9⅝" deep (83 x 102 x 140 x 245 mm); rack mount: 15¾" inside rack clearance, 3½" panel height, 5-13/16" maximum depth (400 x 89 x 148 mm).

Weight: net 7 lbs (3,2 kg); shipping 10 lbs (4,5 kg).

Price: Moseley A-1 (bench); A-1R (rack); A-1M (metric bench); A-1MR (metric rack): $585.

Options

01. For operation on 230 v, 50 to 60 cps, add $15.
02. 10 cps low-frequency limit; 2 sec response speed, add $50.

101 Waveform Translator

The 101 is a translating device for use with Moseley x-y recorders to make permanent graphic tracings of high-speed repetitive waveforms displayed on an oscilloscope. Horizontal and vertical deflection plate voltages are sampled at the waveform period by amplitude comparators which equate the voltage amplitudes to reference potentials derived from ramp generators. The resulting strobe pulses traverse the oscilloscope trace causing x and y clamps to produce dc measures of the instantaneous coordinates of the strobe position. These representative coordinate signals may be applied to the axes of an x-y recorder which draws a permanent record of the waveform.

Specifications, Type 101

Input impedance: 300,000 ohms.

Output impedance: 500 ohms.

Input source: single-ended from deflection plates and ground.

Input signal amplitude: ac coupling: 600 v dc max. (60 v ac p-p for y, 100 v ac p-p for x); dc coupling: 400 v dc max. (60 v ac p-p for y, 100 v ac, p-p for x).

Output signal amplitude: ± 2 volts.

Recording scan rate: adjustable from 1 second to 5 minutes.

External trigger: -10 v pulse; 1.5 μsec long, 0.15 μsec rise time.

Bandwidth: 4 samples/sec min.; 50 kc max.; 3 db down at 200 kc.

Accuracy: $\pm 1\%$ of full scale, exclusive of recorder and oscilloscope errors, with line variation of $\pm 10\%$.

Internal power supply: zener diode controlled.

Power: 115 or 230 v, 50 to 60 cps, approx. 22 volt-amperes.

Dimensions: 7¾" w, 6½" h, 8⅝" d (197 x 165 x 220 mm).

Weight: net 12 lbs (5,4 kg); shipping 17 lbs (7,7 kg).

Price: Moseley 101, $675.

17002A Inverter Power Supply

The 17002A is an all solid-state auxiliary device for operation of selected Moseley recorders and accessories from low-voltage dc sources. It also may be used as a dc-to-ac power source of 45 volt-amperes or less. Within this range, output is constant at 115 or 230 volts ac for any dc input between 11 and 32 volts. The standard unit delivers a single frequency which may be specified either 50 or 60 cps.

Specifications, Model 17002A

Input: may be any dc source from 11 to 32 volts.

Input power: dependent on output load; efficiency is up to 70%.

Input connections: rear terminal strip with provision for positive or negative ground, or floating input; protected against reverse polarity by a transistor operated as a diode.

Output voltage: 115 or 230 v ac, by panel selector switch.

Output power: 45 volt-amperes max. for continuous operation.

Output frequency: 50 or 60 cps, as specified by customer.

Frequency accuracy: better than $\pm 0.1\%$ over a temperature range of 0° to 50°C; long-term drift less than $\pm 0.1\%$ per year.

Regulation: $< \pm 10\%$ of output voltage, no load to full load.

Wave shape: square wave.

Temperature limits: operating: 0 to 50°C; storage: -45 to 85°C.

Dimensions: 6-7/16" w, 4¾" h, 8⅝" d (164 x 120 x 220 mm).

Weight: net 12 lbs (4,4 kg); shipping 15 lbs (6,8 kg).

Price: Moseley 17002A (specify either 50 or 60 cps), $350.

40D KEYBOARD; G-2 NULL DETECTOR; D-1B, D-2 CHARACTER PRINTERS

Accessories for use with x-y recorders

40D Keyboard

The Moseley 40D is a full keyboard-type accessory for use with compatible Moseley x-y recorders in plotting tabular data in point-graph form. Operating power is derived from an x-y recorder through a cable and plug connector which also carries servo-positioning information back to the recorder. Keyboard for each axis includes polarity, hold, clear and calibrate keys. Panel selectors control circuits for zero suppression, points/inch calibration and logarithmic plotting.

Keyboard: two 3-column, nine-row arrays and unit "1000" keys will plot numbers from 0 to ±1999 on each axis; function keys provide x hold, y hold, calibrate, clear and main clear.

Function switch: selects linear or logarithmic mode in either or both axes; logarithmic operation requires one or more Moseley 60D Logarithmic Converters.

Output attenuator (linear mode): 5 fixed steps at 10, 20, 50, 100, 200 pts/inch (5, 10, 25, 50, 100 pts/cm on metric model); provision for variable attenuation between steps up to 500 pts/inch (200 pts/cm on metric model).

Zero suppression (linear mode): up to 900 points in 100-pt steps (up to 450 points in 50-pt steps on metric model).

Calibration: individual potentiometers on each axis for calibration to specified accuracy; controls for null detector sensitivity and reference supply output voltage.

Accuracy: self-contained regulated solid-state power supply for precision voltage to resistor matrix; digital-to-analog conversion accuracy in either linear or logarithmic mode is ±0.1%; basic accuracy of a recorder or log converter is not degraded.

Power: 115 or 230 v; 50 to 60 cps, single phase; approximately 12 volt-amperes (derived from associated recorder).

Dimensions: 9⅝" wide, 4-3/16" high, 13-11/16" deep (244 x 132 x 348 mm).

Weight: net 16 lbs (7.2 kg); shipping 30 lbs (13.5 kg).

Price: Moseley 40D or 40DM (metric), $975; when ordering for use with existing Moseley x-y recorders, specify model and serial number (compatible recorders must have digital or point plotter receptacles).

G-2 Null Detector

The Moseley G-2 Null Detector is an accessory for use with Moseley x-y recorders to control the operation of the recorder in any one of five modes when plotting continuous, discontinuous or point function data. The source may be any analog signal producing system, or digital system with conversion accessories. Available in two versions, the G-2A mounts internally as a plug-in unit in Moseley 2D-2 and 2D-3 Recorders; G-2B is a cabinet model with cable and plug for connection to all Model 2D Series (except 2D-4), and existing Models 2A, 2S and 4S Recorders. For optimum performance, the G-2A should be factory installed.

Plot rate: in point mode, 6 plots/sec, max., using D-1B Character Printer; in line mode, 7 pts/sec, max., when points are displaced an average of 0.05 in. and using regular recorder pen.

Seek signal: ±3 v min. pulse height, +10 to −20 v max. range; 2 μsec min. pulse width; 15,000 ohms input impedance, capacitor coupled; provision for contact closure to ground.

Completed plot signal: 20 v pulse height; 100 μsec pulse width; 1 μsec or less rise time; 0.002 mfd max. permissible capacitive load; < 200 ohms output impedance, capacitor coupled.

Sensitivity: better than 0.4% of full scale.

Forced plot: if null is not reached within approx. 2 sec, a plot is forced.

Enable-disable: required disable voltage is −3 v dc; enable voltage, from 0 to any plus potential; a contact closure may be substituted for the disable bias by inserting a resistor between existing terminals on the printed circuit board; voltage or contact closure requirements can be reversed by moving jumpers on the printed circuit board.

Controls: function selector provides 5 operating modes.

Power: 115 v, 50 to 60 cps, 1 w single phase.

Price: Moseley G-2A or G-2B, $265; when ordering for existing recorders, specify model and serial numbers; G-2A requires factory installation.

D-1B, and D-2 Character Printers

The Moseley D-1B and D-2 Character Printers may be used to replace the pen of Moseley 11" x 17" x-y recorders to identify families of points in digital plotting. An actuating solenoid prints symbol impressions through an inked ribbon suspended on the recorder pen carriage over the chart. The D-1B uses a manually reversible cylindrical die, each end of which has a different symbol. The D-2 uses a wheel with six symbols which are sequenced automatically with each plot. A completely automatic programmed printer, DY-2733A, similar to the D-2, is available from Dymec Division.

Plotting rate: 360 points per minute, maximum.

Accuracy: 0.05% (approximately 5/1000th inch); overall recorder accuracy is not affected.

Actuating source: internally supplied from associated recorder; compatible mating receptacles standard equipment on most Moseley 11" x 17" x-y recorders.

Symbols furnished: D-1B: 3 cylindrical dies (total of 6 standard symbols); D-2: 1 wheel (total of 6 standard symbols); special symbols and symbol sequences available at extra cost.

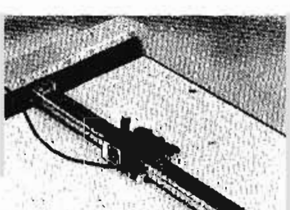
Installation kits: complete kits with installation instructions available in either type printer (not available for 8½" x 11" x-y recorders or for Model 2 recorders prior to serial number 450).

Prices: Moseley D-1B (cylindrical die type), $120; Moseley D-2 (wheel type, 6 standard symbols), $525.

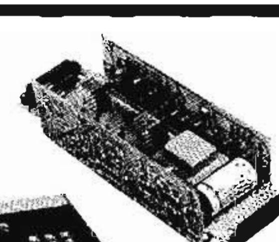
Options

01. D-2 with any 6 special symbols in specified sequence from symbol chart, add $100.
02. D-1B with special symbols on die (select 2 symbols from symbol chart for each die), per die, add $25.

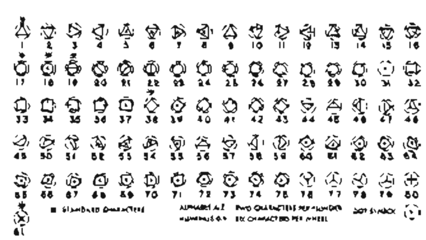
Important: when ordering complete kits, specify model and serial number of recorder on which it will be installed.



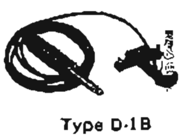
Type D-2



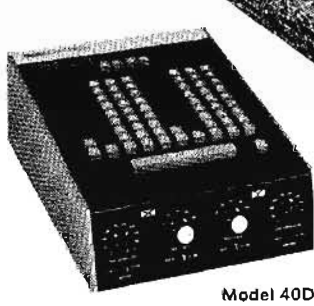
Type G-2A



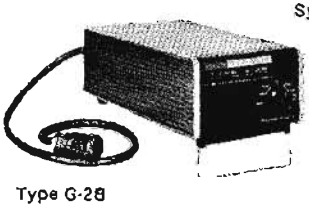
Symbol chart



Type D-1B



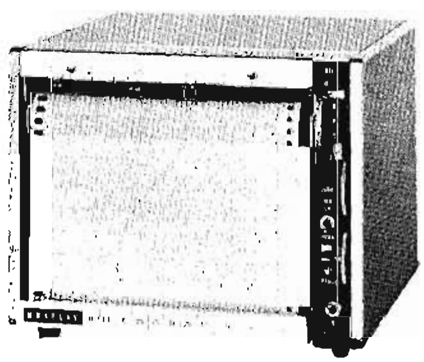
Model 40D



Type G-2B

CONTINUOUS ANALOG 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, often required. Electrical data acquired in serial fashion, comprising a chain of meaningful changes in a signal, record naturally on continuous media, frequently strip charts or magnetic tape. The purpose of the records and the character of the signals will determine the appropriate recording instruments. It may be necessary to produce a visible record, and it may or may not be necessary to observe the record as it is written; the data may consist only of slowly changing signals, or it may contain significant frequency components up to 30, 150, 5000 cps or more. The needed record may be of a single train of signals, or of two or more related channels, sometimes numbering to hundreds. The records may be needed only for human inspection, or may be acquired for later machine processing. Means exist to satisfy all these needs.



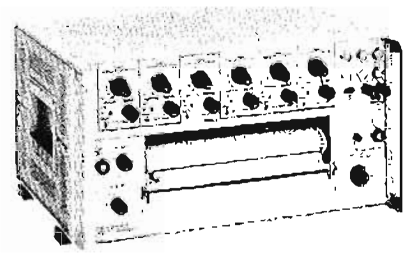
Moseley 680

Direct-writing recorders

Among the least costly, both in equipment and recording medium, are visible analog records of slowly changing (<1 cps) values. These are made in rectilinear coordinates with considerable accuracy (typically 0.1%) with ink markings on ordinary paper by the servo-driven strip-chart recorders of Hewlett-Packard's Moseley line. Some may optionally be equipped to use pressure-sensitive paper. Single-channel models are available with chart widths of 5" or 10"; two-pen models are available in the 10" chart size. Two-pen models permit both channels to realize the full resolution of the 10" chart-width simultaneously, since the pens can overlap on the same chart without interference.

Moseley servo-driven strip-chart recorders share the same servo operating principle as the x-y recorders of this make. Recorders of this class are characterized by extraordinary reliability, in addition to high accuracy (typically 0.1%). The Moseley line is all solid-state circuitry.

A wide variety of special-purpose chart paper is offered, and custom services are available to provide other special papers as needed. A variety of options and accessories is available.



Hewlett-Packard/Sintef 3500A

High accuracy, low cost-per-channel

Unique among strip-chart recorders, in operating principle and characteristics, is the Hewlett-Packard/Sintef Model 3500A. Its *accuracy* and *frequency response* are of the same order as the potentiometric types, although paradoxically its *response* time is less than 20 msec. The difference is in *method of writing* and *medium*, since it plots its chart in sequential dots on electro-sensitive paper. A revolving band rapidly traverses electrically chargeable styli continuously across the slowly-moving electro-sensitive paper. The rate is 100 passes per second. Each of as many as 12 channels is sampled and compared with a precision voltage ramp on each pass. With each pass a corresponding dot for each channel is recorded on the paper at the appropriate point by a high-voltage pulse. To add a channel, no new mechanical element is required. Only another Model 3501A electronic plug-in need be added. Its operating principle makes it easily and inexpensively capable of recording as many as 12 channels simultaneously, so Model 3500A satisfies a long-unfilled need for *highly-accurate* multi-channel strip-chart recorders of *low per-channel cost.*

Direct-writing galvanometer recorders

A considerable proportion of data recording requirements is for continuous, visible analog records of signals with maximum significant frequency content in the range 30 to 150 cps. These needs are well filled by direct-writing instruments operating on the galvanometer principle. In the Hewlett-Packard family are three extensive series of Sanborn recorders in this category. All produce inkless, rectilinear traces on matched thermo-sensitive Permapaper® by the hot stylus method. Linearity of 0.5% full scale, resolution of 4 cycles/mm of paper travel even at small amplitudes, and reliable operation without attention to the writing medium are significant advantages of the Sanborn thermal writing method. Standard versions are available with 1, 2, 4, 6, 8 and 16 channels. The Sanborn product line also includes smaller one- and two-channel recorders, some of the portable type, which uniquely fill many purposes. Among these, Model 7701A achieves two to three times the resolution of conventional direct-writing recorders by offering response of 30 cps across the full 100 mm of its chart width.

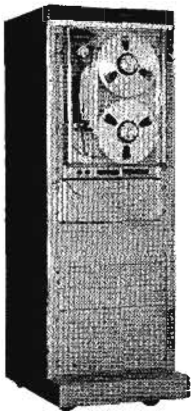
A broad line of amplifiers and signal-conditioners matches the Sanborn thermal direct-writing recorders to transducers, including direct and carrier types. These amplifiers include: individual-channel plug-ins of (1) a highly versatile, maximum-signal-control design using tube and solid-state circuitry (11 models) and (2) miniaturized all solid-state versions available in seven models; and 6 or 8 identical amplifier channels on a common plug-in chassis, available in four types.

There also are important needs for continuous, visible analog records of signals with significant content in the frequency range 0 to 5 kc or more. These are well met by Sanborn direct-wiring high-speed optical recorders. They employ compact, high-speed galvanometers to direct light beams, recording at amplitudes up to 8" on photo-sensitive paper. Rectilinear charts are produced, and traces may overlap. Standard versions are available up to 25 channels. One series of these high-speed Sanborn optical recorders writes with high-intensity ultra-violet light, to produce almost-immediately visible traces which require no chemical development; another series writes with light originating in incandescent lamps, producing traces of high contrast on photosensitive paper stock of lower cost, but requiring chemical development. This, however, may be accomplished rapidly and continuously by an optional automatic attachment to the recorder.

The same wide options among amplifiers and signal-conditioners are offered both for optical and for thermal-writing instruments.

Excellence of performance in all types of galvanometric recorders depends heavily upon the paper medium used.

Sanborn quality-controlled papers play a large part in determining the resolution and reliability of these instruments. Standard papers are available in a wide variety to suit a broad range of general and special applications, and custom services are offered where needed.



Sanborn 3900

Magnetic tape instrumentation

Although magnetic tape instrumentation has in the past been considered a costly means of accomplishing its purposes, its great growth has come about largely because of its *low cost per unit of information handled.* This comes about because the technique is capable of recording data at high speed with high density on a medium which is not only of reasonable initial cost but is also erasable and reusable. While capital equipment costs have been high and in general have tended constantly to rise, the Hewlett-Packard family of Sanborn magnetic recorders constitutes a significant exception to the trend. It will be seen that these recorders, in the most important respects, match the performance of the costliest instruments, and even exceed them in reliability, yet are priced so low that magnetic tape instrumentation now is well within reach for a broad new range of industrial and scientific applications.

Analog electrical data are not, of course, readily visible in any easily interpretable fashion directly on the magnetic tape medium. Meters and oscilloscopes are commonly used to view the electrical signals as they are being magnetically recorded or reproduced. Many kinds of data need not be viewed during the recording process; many are of interest only after processing and reduction. Magnetic tape recording is the most used and most convenient medium for automatic data processing.

An important advantage of the magnetic technique is that the data are recoverable at any later time, on the same machine which recorded them or from other machines like it, in their original form, with no substantial limit on number of replays and without significant degradation. Tapes may readily be duplicated by dubbing. Magnetic recorders exist which can thus treat data with frequency content beyond a megacycle; these use tape at high velocity. Where less frequency range is needed, tape velocity may be reduced, with resulting reduction in costs.

Any channel of any member of the Hewlett-Packard family of Sanborn magnetic recorders for analog instrumentation may be connected so as to record in either of two ways, i.e., by *direct* or by *FM* means. Accurate FM recordings may be made, on Sanborn magnetic instruments, of information whose frequency content ranges from dc to some high frequency which is directly proportional to the selected tape velocity. At 60 inches per second, for example, the recording bandwidth is dc to 20 kc. If the *direct* mode of recording is selected, the *uppermost* recoverable frequency, at any given tape velocity, will be much higher—250 kc, for example, at 60 ips. This, likewise, is directly proportional to tape velocity, and thus also to tape cost per minute. The lowest effectively recoverable frequency in the direct mode will not be below 50 cps, in any case, and will be higher at the higher tape velocities—100 cps at 30 ips, 200 cps at 60 ips. This is tabulated below:

Tape velocity (inches/sec)	FM (kc)	Direct (kc)
60	0–20	0.2 –250
30	0–10	0.1 –125
15	0– 5	0.05– 60
7½	0– 2.5	0.05– 30
3¾	0– 1.25	0.05– 15
1⅞	0– 0.6	0.05– 7.5

Direct recording is accomplished by directly impressing the analog data signal (with the requisite bias) through the recording head onto the magnetic tape.

FM recording is accomplished by choosing some suitable carrier frequency in the mid-range of the instrument's direct response capability, the information then being impressed by frequency-modulating the carrier. Playback is through an appropriate FM demodulator. Data may be handled in a range from dc to some fraction of the carrier frequency.

A pair of channels, one direct and one FM, can record a single signal of bandwidth from dc to the highest directly recordable frequency.

Standards for many tape speeds have been set by large users of the method, so tapes may be interchanged readily. The table above reflects the frequency-response standards set by the U.S. standardizing body, IRIG, the Inter-Range Instrumentation Group of the Department of Defense. Sanborn 7- and 14-channel magnetic recording instruments conform entirely to IRIG standards.

Among the most valuable of the magnetic recording methods' capabilities is that of *time expansion and time compression:* the equipment can replay data either slower or faster than it was recorded. This makes it possible to slow down high-speed phenomena for detailed examination. Data much too fast to be recorded on visible media may be gathered and recorded accurately by magnetic means; by playing back the tape at some slower speed, the signals may be brought within the bandpass of a direct-writing recorder, and an accurate chart of the data then obtained. Slow-speed data may be gathered over a long period of time, perhaps automatically or by telemetering, then replayed rapidly for quick examination.

Sanborn magnetic recorder product line

Sanborn magnetic recorders comprise two series of tape-transport mechanisms and one series of electronics.

Model 2004, a 4-channel recorder of extremely low cost, is a basic instrument capable of operation at 4 speeds (1⅞, 3¾, 7½ and 15 ips). Recording channels may be direct or FM. Inexpensive quarter-inch tape is used. Maximum effectively recoverable signal frequency, in the direct mode at the 15 ips speed, is 30 kc, and in the FM mode 2.5 kc. At this speed, in FM, the signal-to-noise ratio is 40 db without electronic flutter compensation, which is optionally available. The instrument uses the same plug-in, solid-state electronics as the maximum-performance 3900 series. The full Sanborn line of specialized signal amplifiers and signal conditioners is available to suit the output of a wide variety of basic transducers to drive the Model 2004 electronics.

The recorders of Sanborn's Series 3900 conform throughout to IRIG standards. The new tape transport mechanism, designed and built by Hewlett-Packard, achieves a degree of tape motion smoothness which is matched otherwise only at very much greater cost. In this key aspect of tape recorder performance, described by flutter and FM S/N ratio specifications, it is outstanding. It also sets a new high standard of ruggedness and reliability among high-performance recorders. This is the result not only of unusual mechanical design, but also of all solid-state plug-in electronic circuitry. All versions have six pushbutton-selected operating speeds and an accurate built-in footage indicator.

3500A RECORDER, 3501A RANGE UNIT, 3510A AUXILIARY UNIT

Versatile strip-chart recorder

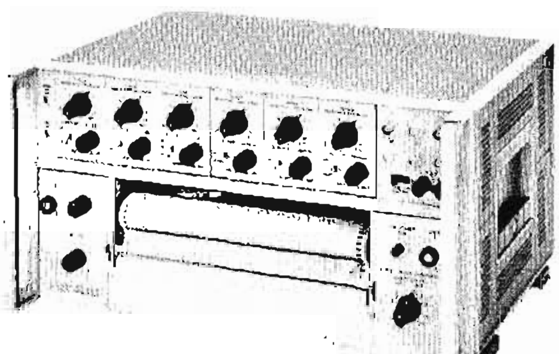
The Hewlett-Packard/Sintef 3500A Recorder is a new concept in multi-channel strip-chart recorders. A single recording mechanism, using the sampling technique, plots the input data from all channels. The result is a high-performance recorder at a low cost per channel. The input channels are in the form of plug-in units, so the system can be expanded up to the maximum of 12 channels, simply and inexpensively. Up to 6 channels can be installed in the 3500A itself, the remaining 6 in the 3510A Auxiliary Unit.

The recorder has high accuracy and resolution, plus low drift, features which make it ideal for long-term monitoring of critical phenomena. Its high resolution results from the fact that all channels can deflect the full 20 cm width of the chart paper. In addition, the recorder has a fast response, 20 msec maximum, enabling it to follow discontinuities.

Utilizing the sampling technique, the hp 3500A samples the input data at the rate of 100 samples per second per channel and plots the information as a series of points on the chart paper. Identification of a particular trace with its input channel is easy. Individual traces can be broadened manually or automatically in synchronism with channel numbers along the edge of the chart paper.

The hp 3501A Range Units are the plug-in input channels for the recorder. They provide calibrated sensitivities from 0.05 to 20 v/cm at a high input impedance and have extremely low drift. The operation of each unit is independent of channel position, and the dc zero reference of each channel can be set anywhere on the chart.

NEW



3500A with six 3501A Range Units

Specifications, 3500A

Active data channels: 1 to 6; additional 1 to 6 channels can be added using the 3510A.

Input: one independent input (with common ground) for each channel.

Response time: 20 msec maximum for full-scale change.

Recording accuracy: ±0.2% of selected full scale.

Sampling density: 100 samples per sec per channel.

Trace width: adjustable from approximately 0.2 to 0.6 mm.

Chart speed: nine speeds from 0.1 to 50 mm/sec in a 1, 2, 5 sequence.

Recording medium: electro-sensitive paper 7-13/16" wide, 120' long (20 x 3658 cm).

Internal reference: 1 volt (accuracy ±0.05%) for calibration of sensitivity.

Power: 115 or 230 volts ±10%, 60 cps ±2% (50 cps optional), approximately 90 watts maximum with six active channels.

Dimensions: 16¾" wide, 9" high, 13¼" deep (425 x 229 x 337 mm); hardware furnished for conversion to rack mount 19" wide, 8¾" high, 11¼" deep behind panel (483 x 221 x 286 mm).

Weight: net 36 lbs (16,2 kg); shipping 40 lbs (18 kg).

Accessories furnished: 03500-0042 plug-in extender; 03500-6018 extender cable assembly.

Price: hp 3500A, $1600.

Option 01.: modified for operation from 50 cps ±2% power line, add $25.

Specifications, 3501A

(installed in 3500A Recorder)

Response time: 20 msec maximum for full-scale change.

Sensitivity: 9 calibrated sensitivities from 0.05 to 20v/cm in a 1, 2, 5 sequence; vernier control provides continuous adjustment between ranges and increases max. sensitivity to 0.02 v/cm.

Accuracy: ±0.2% of selected full scale.

Linearity: less than 0.1% deviation from absolute linearity.

Input resistance: 1 megohm.

Zero drift: less than ±0.1% per 10°C.

Weight: net 11 oz (310 g).

Power: approximately 1.2 watts, supplied by Model 3500A.

Price: hp 3501A, $225.

Specifications, 3510A

Active data channels: 1 to 6.

Power: approx. 1.2 watts per channel, supplied by 3500A.

Dimensions: 16¾" wide, 3¾" high, 13¼" deep (425 x 95 x 337 mm); hardware furnished for conversion to rack mount 19" wide, 3-15/32" high, 11¼" deep behind panel (483 x 88 x 286 mm).

Weight: net 9 lbs (4,1 kg); shipping 12 lbs (5,4 kg).

Accessories furnished: 03510-6002 interconnecting cable assembly; 5060-0215 joining bracket kit.

Price: hp 3510A, $200.

680 TO 683 SERIES STRIP-CHART RECORDERS, 6"

Compact, module-type, multi-speed servo recorders with a variety of options

Advantages:

- All solid-state circuitry
- One-half second maximum balance time
- Continuous electronic reference
- Electric pen lift with remote control
- Synchronous motor driven chart
- Three-position tilting chart table

Uses:

- General-purpose strip-chart recording
- Single span voltage (681) or current (683) recording
- Temperature recording (682) with cold junction thermocouple

The Moseley 680 to 683 Series of 6" strip-chart recorders provide a wide choice of servo-type instruments for general or specialized use. The 680 is fully equipped with multi-range input, multi-speed chart transport, full-range zero set, and electric pen lift, features essential for general-purpose applications. The 682 has a single span compensated for a temperature measuring cold-junction thermocouple in a choice of commonly used ranges (Figure 1). The 681 has a single voltage span, customer-selected within a range from 5 mv to 120 v; the 683 has a single current span in a selected value up to a maximum full-scale sensitivity of 5 μa. All standard 681, 682 and 683 models have a two-speed (60-to-1 ratio) chart transport with choice of almost any maximum speed up to 8 in/min, and extra-cost option of a 16-to-1 instead of 60-to-1 speed ratio.

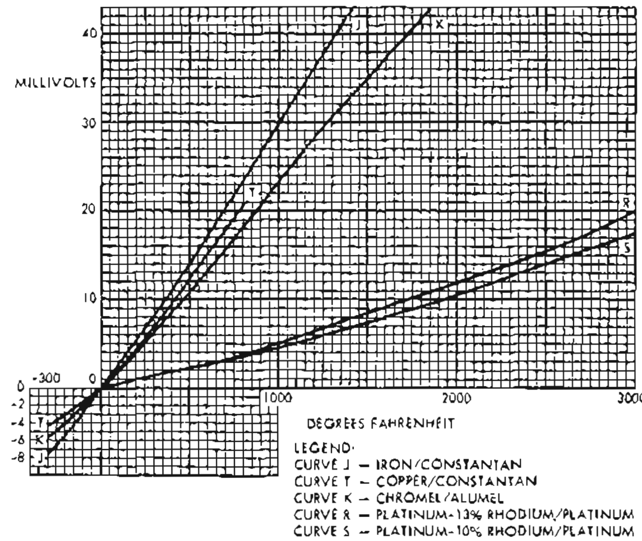
Span limits for commonly used cold junctions

Type	Thermocouple element	Temperature range: Centigrade min.	Centigrade max.	Fahrenheit min.	Fahrenheit max.	Minimum span*	Use module
J	Iron-Constantan	−200°	760°	−320°	1400°	100°C 200°F	Type R-2-J
T	Copper-Constantan	−200°	400°	−310°	1800°	100°C 200°F	Type R-2-T
K	Chromel-Alumel	−200°	1370°	−310°	2500°	100°C 200°F	Type R-2-K
R	Platinum-Platinum (13% Rhodium)	0°	1770°	32°	3100°	500°C 1000°F	Type R-2-R
S	Platinum-Platinum (10% Rhodium)	0°	1770°	32°	3215°	500°C 1000°F	Type R-2-S

*Due to the non-linear response of thermocouples the minimum span may be smaller than the value shown. The limiting factor is not the temperature span but the difference between the thermocouple output voltages at each end of the selected span. This difference voltage must be approximately 5 millivolts, or more.

Figure 1. Maximum operating ranges for available cold junction modules.

All recorders in the series feature module construction with all transistor circuitry, high accuracy, fast response, synchronous motor chart drive and full view tilting chart magazine. Of a total of six, four modules are identical in all models. In specialized instruments the input module and control plate module are designed for a particular function and are not interchangeable to other models. Standard facilities in all models include instant chart speed transfer, local and remote pen lift control, tear-off or chart roll storage, and a choice of cartridge-fed ink pen or pressure stylus.



TEMPERATURE — MILLIVOLT RELATIONSHIPS FOR COMMONLY USED COLD JUNCTIONS
(32° Reference Junction, See Chart for Correct Input Module)

Figure 2. Temperature-millivolt relationships for commonly used cold junctions.

Specifications

Recording mechanism: servo-actuated ink pen drive; electrical isolation from ground; local/remote electric pen lift; full-scale zero adjustment; stylus in place of pen (Option 12.) at no extra cost.

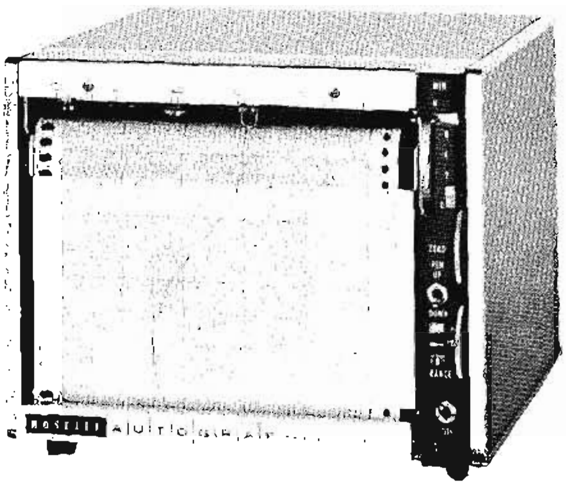
Chart size: 6" x 100' roll charts, 5" writing width; pressure-sensitive rolls are 80' in length; metric paper has 12 cm writing width; visible chart area during operation, approx. 4" x 6".

Balance speed: 0.5 sec max. for full scale.

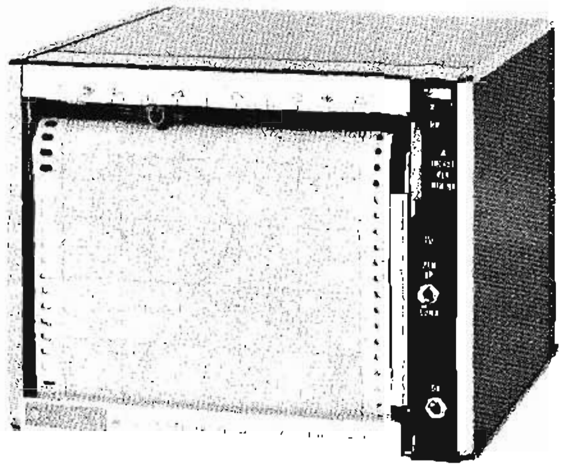
Chart speeds: 680: 8 speeds at 1, 2, 4, 8 in/min; 1, 2, 4, 8 in/hr; 680M (metric): 2.5, 5, 10, 20 cm/min; 2.5, 5, 10, 20 cm/hr; 681, 682, 683: 2 speeds in 60-to-1 ratio provided selected maximum speed is not greater than 8 in/min (20 cm/min metric); 16-to-1 instead of 60-to-1 speed ratio available at extra cost on any model under Option 08.; speeds up to 60 in/min available at extra cost on special order.

Spans: 680: 10 calibrated spans, 5, 10, 50, 100, 500 mv; 1, 5, 10, 50, 100 v, full scale; 680M (metric) 6, 12, 60, 120, 600 mv; 1.2, 6, 12, 60, 120 v, full scale; extra span of 1 mv full scale available at extra cost; 681: customer selection of any single span between 5 mv and 120 v full scale; extra cost option of any span between 1 mv and 5 mv; 682: customer-selected single temperature span specified from chart of available modules; 683: customer-selected single current span up to full scale sensitivity of 5 μa.

Input resistance: 680, 681: 200,000 ohms/volt (166,666 ohms/volt on metric) full scale through 10 v span; 2 megohms on all others; potentiometric operation on most



680



681

sensitive span draws zero current at null; constant 100,000 ohms on all spans available at extra cost; 682: true potentiometric input draws zero current at null; 683: dependent on current span selected; basic sensitivity of standard model is 5 μa at 1000 ohms full scale (6 μa on metric).

Accuracy and resolution: better than 0.2% of full scale, with 0.1% of full scale resettability.

Standardization: continuous zener-controlled electronic reference; calibration of 682 in accordance with NBS circular 561 (1955), "Standard Reference Tables for Thermocouples".

Interference rejection: better than 100,000 to 1 on 5 mv dc span.

Zero Set: 680: continuously adjustable over full-scale span; 681-683: adjustable by internal control, factory set for zero-left operation.

Power: 115 or 230 volts, 60 cps, approx. 22 volt-amperes; available at extra cost for 50 cps under Option 10.

Dimensions: 7¾" wide, 6-3/32" high, 8" deep (197 x 155 x 203 mm).

Weight: net approx. 11 lbs (5 kg); shipping 17 lbs (7,6 kg).

Accessory kit supplied: spare fuse, pen cleaning wire, slide-wire cleaner, 2 ink cartridges (red and blue), set of bristol wrenches and a roll of appropriate chart paper.

Prices

Moseley 680 (standard) or 680M (metric), $750; *H01-680(s) (Moseley 680 with added 1 mv full-scale span) or *H01-680M(s) (Moseley 680M with added 1.2 mv full-scale span), $800; *H02-680(s) or *H02-680M(s) (Moseley 680 or 680M with 100,000 ohms input resistance on all spans), $825; Moseley 681, 681M, 683, 683M (standard spans), $625; Moseley 681 or 681M with span between 1 and 5 mv, $675; Moseley 682 or 682M with selected available module, $675.

Options

01. With installed 5000-ohm, 0.1% linearity retransmitting potentiometer, add $50.
02. With installed event marker, add $25.
03. With installed limit switches, add $90.
04. With installed digital encoder, add $25 plus cost of selected encoder.
06. With dual rack mounting adapter, add $35.
07. With dual rack adapter and latching glass door, add $100.
08. With 16-to-1 instead of 60-to-1 speed ratio, add $25.
09. With remote chart drive switch, add $25.
10. For 115 or 230 volt, 50 cps operation, add $25.
11. With special scale markings, add $10.
12. With stylus for pressure-sensitive paper instead of ink pen, no charge.
13. For operation with Moseley 60D Logarithmic Converter, add $25.
14. With locking glass door, add $45.

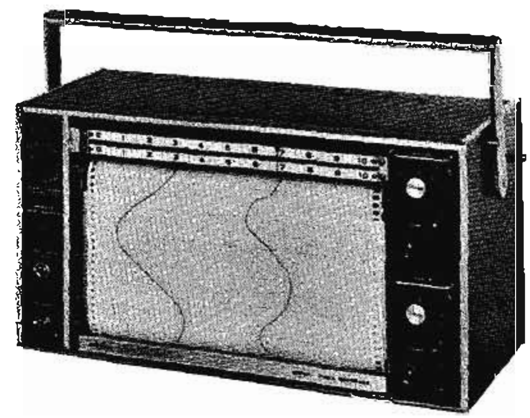
* Only one feature available per instrument, factory installed.

7100A, 7101A 10" STRIP-CHART RECORDERS

Multi-speed, multi-span, one- or two-pen models

A rugged, compact, servo potentiometer type 10" strip-chart recorder with high accuracy and fast response, the 7100A Series combines unique Moseley-pioneered features in a versatile instrument with a choice of models tailored for specific applications or general laboratory use. Two basic models are offered, the 7100A, with two independent pen channels, and the 7101A, with a single pen channel. Other features of each model are identical and include 12 instantly selectable chart speeds, 10 calibrated spans with full-scale zero suppression, 1-megohm input resistance, continuous electronic reference and advanced solid-state circuitry.

Moderately priced options provide a variety of built-in operational features, increasing the versatility of any model. Event markers installed on either or both channels conveniently identify key recording areas; high-low limit switches provide automatic alarm and chart drive control; retransmitting potentiometers on either or both channels will produce a proportional readout for monitoring or process control; and the standard manual pen lift may be replaced by an electromagnetic control for local or remote operation. For accurate recordings of signals as low as one-thousandth of a volt a plug-in module with spans from one millivolt through 100 volts, full scale, is available. Another option provides an *external* 10-to-1 chart speed reducer unit which doubles the selectable number of chart speeds. All models in the series may be ordered with metric calibration and scaling at no extra cost.



7100A

Specifications

Recording mechanism: 7100A series have two servo-actuated ink pen drives, independent and free of ground; 7101A series have a single ink pen drive, manual pen lift.

Balance time: 0.5 second or less for full scale.

Chart size: standard rolls with 10" (25 cm) writing width; 120 foot length.

Chart speeds: 12 synchronous motor driven speeds: 1, 2 in/hr; 0.1, 0.2, 0.5, 1, 2 in/min; 0.1, 0.2, 0.5, 1, 2 in/sec; metric unit: 2.5, 5, 15, 30 cm/hr; 1.25, 2.5, 5, 15, 30 cm/min; 1.25, 2.5, 5 cm/sec; remote controlled 10-to-1 speed reducer available at extra cost.

Spans: 10 calibrated spans (each channel of 7100): 5, 10, 50, 100, 500 mv; 1, 5, 10, 50, 100 v, full scale; variable span control mode allows continuous arbitrary full-scale span setting; removal of internal linkage permits potentiometric operation on 4 most sensitive spans.

Input resistance: one megohm at null on all fixed calibrated spans; when in variable mode, 100,000 ohms on four most sensitive steps and one megohm on all others; potentiometric operation draws essentially zero current at null.

Standardization: continuous electronic reference from zener-diode-controlled power supply.

Zero set: continuously adjustable over full scale, plus one full scale of suppression; extended zero suppression available at extra cost.

Accuracy: better than 0.2% of full scale; resettability better than 0.1% of full scale.

Interference rejection: 120 db dc common mode; line frequency common mode rejection is 100 db on 5 mv span.

Power: 115 or 230 volts ±10%, 60 cps, approximately 65 volt-amperes for 7100A, 42 volt-amperes for 7101A; 50 cps models available on special order.

Dimensions: 7100A or 7101A bench: 16¾" long, 8-11/16" wide, 7¼" deep (425 x 220 x 184 mm); 7100AR or 7101AR rack: 16¾" inside rack clearance, 8¾" panel width, 7¼" maximum depth (426 x 222 x 184 mm).

Weight: 7100A, net 30 lbs (13,5 kg), shipping 38 lbs (17,1 kg); 7101A, net 25 lbs (11,3 kg), shipping 32 lbs (14,4 kg).

Accessory kit supplied: spare fuse, pen cleaning wire, slidewire cleaner, 2 ink cartridges (red and blue), set of bristol wrenches and a roll of appropriate chart paper.

Prices:

dual channel:	Moseley 7100A (standard) Moseley 7100AR (standard, rack) Moseley 7100AM (metric) Moseley 7100AMR (metric, rack)	$1800
single channel:	Moseley 7101A (standard) Moseley 7101AR (standard, rack) Moseley 7101AM (metric) Moseley 7101AMR (metric, rack)	$1390

Options

01. With 1 mv to 100 v full-scale spans, add $50.
02. With 10-to-1 chart speed reducer, add $85.
03L. With left side event marker, add $35.
03R. With right side event marker, add $35.
03B. With both left and right event markers, add $70.
04. Installed retransmitting pots, each, add $50.
05. High-low limit switch (one channel only), add $90.
06. Remote electric pen lift, add $50.
07. Remote on-off chart control, add $25.
08. Extended (5-scale) zero suppression, per axis, add $150.
09. With cold junction temperature module instead of standard span module, no charge.
10. For 50-cycle operation, no charge.
11. With hinged glass chart door and lock, add $50.

TYPE Q ROLL CHART ADAPTERS

Convert selected Moseley 11" x 17" x-y recorders for strip-chart recording

Advantages:

- Increase versatility of x-y recorder
- Fast paper change, easy chart storage
- Easily installed by user (Q-1, Q-2)
- Normal recorder functions unimpaired

Moseley Type Q roll chart adapters are designed especially for use with Moseley bench-type Model 2D (pages 347, 348) and 7000A (page 346) Series X-Y Recorders. They permit use of 10" x 120' continuous roll chart paper in a variety of operating modes. Types Q-1 and Q-2 are manually operated and are supplied in a single kit for user installation, using existing pre-tapped mounting holes in compatible recorders.

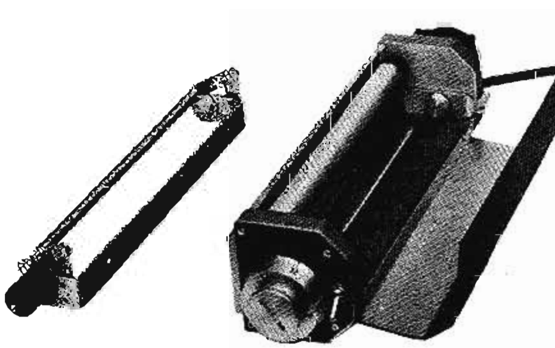
Type Q-1, Q-2

This version permits manual chart advance by operating a hand crank. A crank handle also is provided on the supply reel for rewind purposes. Included in the kit is a tear-off wire attachment for chart "pull-through, tear-off." Both the Q-1 and Q-2 are supplied in a single kit and cannot be purchased separately.

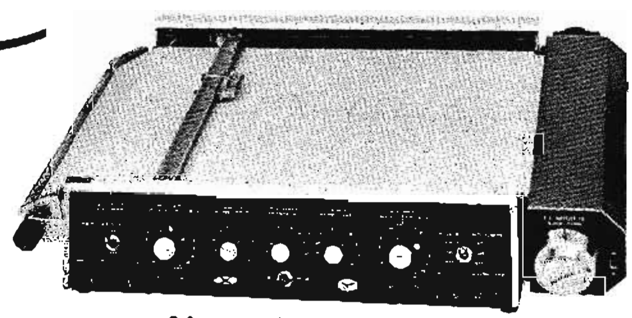
Type Q-3

The Type Q-3 adapter consists of a synchronous motor and gear-train assembly which attaches to the right side of the recorder; six roll speeds may be selected by rotating a knob on the end of the take-up spool housing. Standard speeds furnished for operation on 60-cycle current are 2, 4, 8, 16, 24 and 32 inches per minute. For the same frequency, metrically scaled and calibrated units are available at no extra cost to operate at speeds of 5, 10, 20, 40, 60 and 80 centimeters per minute. At slightly extra cost, both standard and metric models are available for operation on 50-cycle current. When installed on a Moseley 2D Series X-Y Recorder which employs either vacuum or AUTOGRIP® electric paper holddown, a factory modification of the recorder is required to provide chart advance operating power.

Installation of the Q-3 on a Moseley 2D or 7000A series recorder converts to operation as a strip-chart recorder of high accuracy and sensitivity. When also equipped with a Moseley F-3B Optical Line Follower (page 353), the resulting system may be used for process control. In this use a pre-recorded curve is followed optically by a pick-up device which generates an electrical output proportional to the y coordinate of the recorded curve. This signal is suitable for the control of processes, machines or other laboratory and industrial functions.



Q-3 component parts



Q-3 mounted on Moseley 7000A

Specifications, Type Q Accessories

Recorder compatibility: all Moseley bench-type 2D and 7000A series X-Y Recorders; not useable on rack mounted models; Q-1 and Q-2 furnished as a single kit for user installation; Q-3 must be factory installed.

Paper requirements: roll chart, continuous grid, 10" x 120', light-weight, Moseley Part No. 228-0010; heavy-weight, 228-0011.

Controls: Q-1, Q-2, none; Q-3, rotating turret speed selector providing chart speeds of 0, 2, 4, 8, 16, 24, 32 in/min (standard); metric unit: 0, 5, 10, 20, 40, 60, 80 cm/min; extra-cost option provides speeds one-tenth of standard.

Power: Q-1, Q-2, none (manually operated); Q-3, 115 v, 60 cps, approximately 12 watts (normally supplied from recorder on which installed); 50 cps units in both standard and metric models available at extra cost.

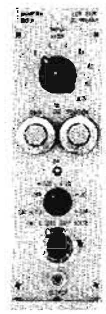
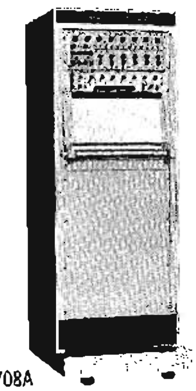
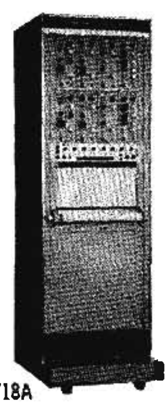
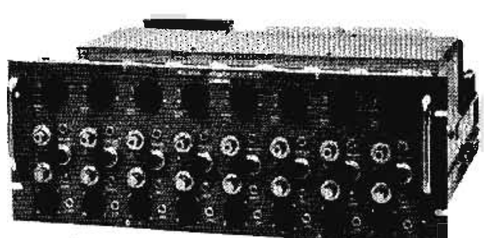
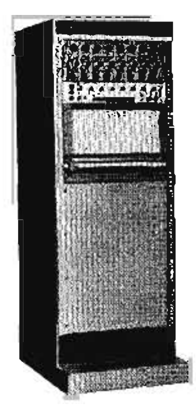
Prices: Moseley Q-1 and Q-2 (supplied as a single kit), $85; Moseley Q-3 or Q-3M (metric) for 115 v 60 cps operation (includes factory installation), $650.

Options:

01. Q-3 or Q-3M with all speeds reduced by 10-to-1 ratio, add $65.
02. Q-3 or Q3M for 50 cps operation, add $25.

THERMAL WRITING OSCILLOGRAPHIC RECORDING SYSTEMS

Summary of Sanborn systems for permanent, graphic records of measurements

Application	Signal conditioners	System basic assemblies 6 and 8 channels vertical flush-front chart 9 electrical mm/sec speeds 50 mm wide, 6-channel 40 mm wide, 8-channel
Intermediate, miniature, low-power dissipating plug-ins; preamps may be intermixed in system	 8800 Series 7 different types of compact, solid-state plug-in preamplifiers can be used in any combination in these systems. Signal coupler; low-, medium-, high-gain dc; carrier; phase sensitive demodulator; max. sensitivities, 1μv/div to 20 μv/div. System performance specifications pages 374, 375	 7706A, 7708A Basic assembly description pages 366, 367
Most versatile highly reliable plug-ins; wide choice of preamps which may be intermixed in system	 350 Series Eleven different types of tube and solid-state plug-in preamplifiers can be used in these systems. Low-, medium-, high-gain dc; carrier; phase sensitive demodulator; logarithmic; ac wattmeter; rms volt/ammeter; 400-cycle frequency deviation; frequency meter; accelerometer; maximum sensitivities 2 μv/div to 5 mv/div. System performance specifications pages 376 to 379	 7716A, 7718A Basic assembly description pages 366, 367
Most economical multichannel plug-ins; for systems that do not require channel interchangeability	 950 Series A choice of 4 different economical 8-channel units having identical amplifier channels on a common chassis are available for 7728A. Low-, medium-, high-gain dc; maximum sensitivities 10 μv/div to 50 mv/div. System performance specifications page 380	 7728A Basic assembly description pages 366, 367

System basic assemblies

4 channels
horizontal pull-out chart
9 manual mm/sec speeds
50 mm wide

System basic assemblies

2 channels
flush-front chart
4 mm/sec speeds
50 mm wide

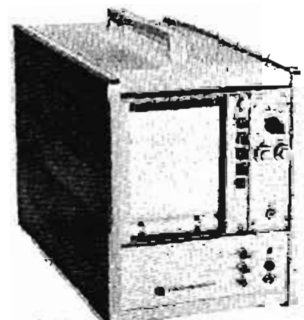
System basic assemblies

1 channel
vertical flush-front chart
4 mm/sec speeds
100 mm wide

AVAILABLE
MID-1966

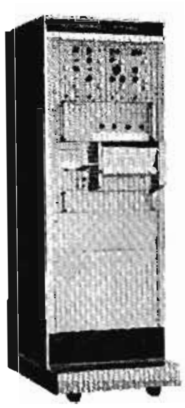
7702A

Basic assembly description page 369



7701A

Basic assembly description page 370



7714A

Basic assembly description page 368

7712A

Basic assembly description page 369

320, 321, 322

Portable, fixed amplifier recorders with plug-in card electronics.

System description page 372

295, 301

Portable, fixed amplifier recorders with plug-in card electronics.

System description page 371

6- AND 8-CHANNEL RECORDING SYSTEM BASIC ASSEMBLIES

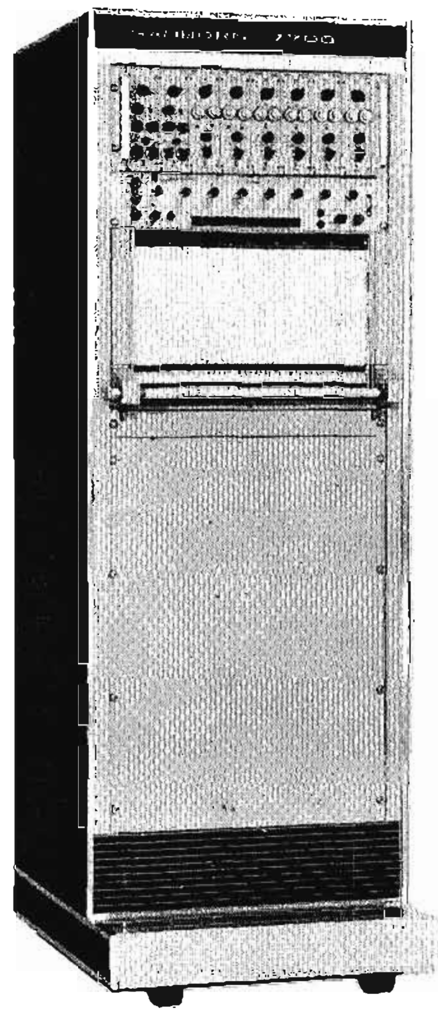
Models 7706A, 7716A, 7708A, 7718A, 7728A

Advantages:

Extremely versatile input capacity
Completely integrated: signal input to galvanometer
Field-proved electronics, recorder
True rectilinear inkless recording
Clear resolution to 4 cps/mm, 0.25 div non-linearity

Uses:

Record 6 or 8 variables simultaneously
Select the signal conditioners and system packaging best suited to the application



7708A

Sanborn 6- and 8-channel basic assemblies offer complete versatility for making accurate, permanent records of multiple variables simultaneously. These basic assemblies accept 6 or 8 channels of interchangeable preamplifiers designed to condition and control simple or complex signals. Variables appear as sharp, clean, permanent traces on Permapaper® charts (opaque, or translucent for copying). They can be analyzed independently, compared immediately with accurate timer pulses, or marked for identification, and stored for later use. Frequency response of the recorder is 0 to 125 cps on 50 mm wide (6-channel) assemblies; 0 to 150 cps on 40 mm wide (8-channel) assemblies. Rise time is 4 msec on 8-channel systems, 5 msec on 6-channel. The basic assemblies all use the same flush-front recorder with fully solid-state power amplifiers, which have built-in electrical limiting to protect recorder styli accuracy and feedback circuits to virtually eliminate drift. These systems also can be purchased in optional rack mounts and portable cases.

Compact all solid-state 8800 Preamplifiers

For Models 7706A, 7708A basic assemblies, the eight channels of 8800 Preamplifiers occupy only 7" x 19" of panel space and, while slightly less versatile than 350 Series, offer greater economy in space and cost, plus comparable reliability and performance (see pages 374-375).

11 versatile 350 Preamplifiers

For Models 7716A, 7718A basic assemblies, the 350's are the most versatile and highly developed of Sanborn interchangeable plug-in signal conditioners. They are available in many types, from sensitive dc with plug-in zero suppression to specialized logarithmic and frequency deviation types. This series employs tube and solid-state circuitry, and each plug-in has its own power supply module (see page 376 to 379).

Economical, all-channels-alike 950 Amplifiers

For Model 7728A (7726A) basic assembly the 950 Series is ideal for applications where many channels of similar real-time or stored data must be monitored simultaneously and there is no need to change individual channels. Four classes of dc 8-channel amplifiers are available in this series (see page 380). Each amplifier channel is complete from signal input to galvanometer output and all channels receive power from a single power supply. Complete system performance for 6- and 8-channel systems are tabulated on page 380.

Specifications, (all models)

(The complete system performance specifications of these basic assemblies with the three classes of preamplifiers (amplifier) are on Pages 374 to 380.)

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 optional 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; optional second event marker (608-100-C11) 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 (188AP, + dc input and 188APM, ±dc input) and require 1.5 v at 0.5 ma at input to produce slightly over 1 mm deflection.

Front-panel controls: individual stylus heat controls; push-button 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 length: standard roll 200 feet long; adapter (462-184) allows the use of special 1000 foot rolls: adapter requires 8¾" (222 mm) of panel space.

Paper takeup: standard paper takeup on front panel; concealed takeup (358-800) is available on special order occupies additional 8¾" (222 mm) of panel space.

Power: recorder: 115 volts ±10%, 60 cps, 230 watts; 115 or 230 volts, 50 cps available on special order; systems: 7708A, 390 watts; 7718A, 970 watts; 7728A, 515 watts.

Dimensions

7706A, 7708A: mobile cabinet mount: 65⅛" high, 22" wide, 30" deep (1654 x 559 x 762 mm); rack mount Option 1: (recorder) 17½" high, 19" wide, 24⅛" deep (445 x 483 x 613 mm); (amplifier) 7" high, 19" wide, 20½" deep (178 x 483 x 621 mm); portable cases Option 2: (recorder) 19¾" high, 20" wide, 21½" deep (502 x 508 x 546 mm); (amplifier) 7-9/16" high, 22" wide, 21½" deep (193 x 559 x 546 mm).

7716A, 7718A: mobile cabinet mount: same as 7706A, 7708A with allowance for additional 7" (178 mm) of panel height; rack mount Option 1: (recorder) same as 7706A, 7708A; (amplifier, 2 required) 10½" high, 19" wide, 19½" deep (267 x 483 x 495 mm); master power panel requires 1¾" high, 19" wide (45 x 483 mm) panel space; portable cases Option 2: (recorder) same as 7706A, 7708A; (amplifier, 2 required) 11-1/16" high, 20" wide, 21½" deep (281 x 508 x 546 mm).

7728A: mobile cabinet mount: same as 7706A, 7708A; rack mount Option 1: (recorder) same as 7708A; (amplifier) 7" high, 19" wide, 18" deep (178 x 483 x 457 mm).

Weight, typical (for all systems in cabinet): 8-channel recorder with 8 amplifiers in cabinet mount, viz. 7708A: net 590 lbs (265,5 kg), shipping 755 lbs (339,8); rack mount Option 1: recorder, all systems: net 210 lbs (94,5), shipping 250 lbs (112,5 kg); 8800 Preamplifiers (8): net 100 lbs (45 kg), shipping 120 lbs (54 kg), subtract 12 lbs (5,4 kg) for 6-channels; 350 Preamplifiers (2 racks of four) viz. 7718A: net 200 (90 kg), shipping 240 lbs (108 kg) (subtract 20 lbs, 9 kg, for 6 channels); 950 Amplifier, viz. 7728A: net 85 lbs (38,3 kg), shipping 95 lbs (42,8 kg); 950 Amplifier, viz. 7726A: no change for 6 channels; portable cases Option 2: recorder, all systems: net 300 lbs (125 kg), shipping 340 lbs (153 kg); 8800, 950 Amplifiers viz. 7708A, 7728A: net 120 lbs (54 kg), shipping 140 lbs (63 kg); 350 Amplifiers viz. 7718A: two cases, each case, net 125 lbs (56 kg), shipping 140 lbs (63 kg); subtract 20 lbs (9 kg) to determine weight of 6-channel systems, viz. 7716A.

Accessories: 8-channel, 40 mm (50 div), 200 ft Permapaper roll (651-58), $16.50; 6-channel, 50 mm (50 div) 651-57, $16.25 (consult hp sales office for 1000 ft rolls and price for quantity purchases of 200 ft rolls); 399 Analog Writing Arm (8-channel), $6.50; 398 Analog Writing Arm (6-channel), $7; 411-3 Marker Arms (8-channel), $6.50; 401 Marker Arms (6-channel), $6.50.

Optional accessory equipment: 358-800 Concealed Paper Take-up, $145; 462-184 1000 ft Roll Adapter, $175; 608-100-C11 Extra Event Marker, $70; 188AP Marker Driver Amplifier (+1.5 v dc input), $75; 188APM Marker Driver Amplifier (±1.5 v dc input), $105; 358-1400 Recorder Carrying Case, $250; 858-1400 (7706A, 7708A, 7728A) Amplifier Carrying Case, $150; two 354-1100-C? and -C5, $200 ea.

Prices (Note 1): Sanborn 7706A (6-channel cabinet assembly, less 8800 Amplifiers), $4750; Sanborn 7708A (8-channel cabinet assembly, less 8800 Amplifiers), $5425; Sanborn 7716A (6-channel cabinet assembly, less 350 Amplifiers), $5,225; Sanborn 7718A (8-channel cabinet assembly, less 350 Amplifiers), $6,250; cabinet consists of master control panel, blower system preamplifier rack(s), recorder assembly with power amplifiers and power supply, and preamplifier power supplies; Sanborn 7728A (8-channel cabinet assembly, less 950 Amplifiers), $3300; cabinet assembly consists of master control panel and cabling, blower system, transfer chassis and 8-channel recorder; Sanborn 7726A is quoted on request.

Option 1 (Note 1) all models: (same as 6- or 8-channel assemblies less cabinet includes: blower, master power panel cabling and slides for rack mounting): Sanborn 7706A Option 1, $4430; Sanborn 7708A Option 1, $5105; Sanborn 7716A Option 1, $5035; Sanborn 7718A Option 1, $6,060; Sanborn 7728A Option 1, $2955; 950 Amplifiers used with this recording system under Option 1 have a muffin fan installed on the rear for cooling purposes; when ordering, add a -3 after the amplifier model number, and add $100 to the price of the 950 Amplifiers; also add 1⅝" to the depth dimension of the amplifier.

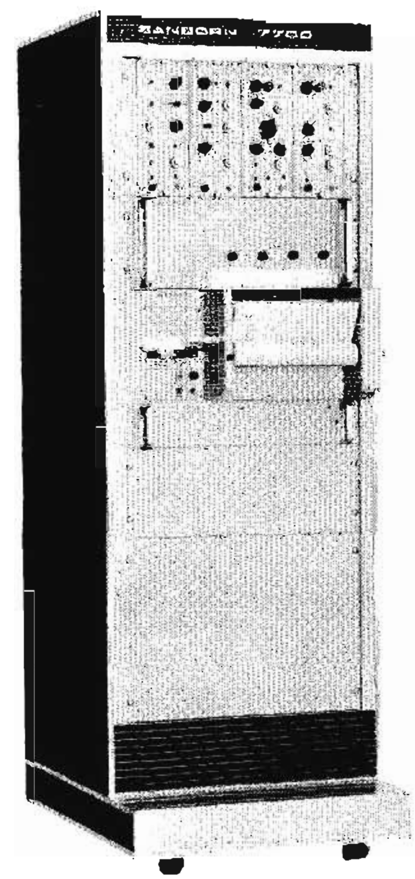
Option 2 (Note 1) all models: Sanborn 7706A Option 2, $4650; Sanborn 7708A Option 2, $5350; Sanborn 7716A Option 2, $5,340; Sanborn 7718A Option 2, $6,365; Sanborn 7728A Option 2, $3250 (recorder and amplifier assemblies supplied in portable cases).

Note 1: Add price (times number of channels) of signal conditioners (see pages 374 to 380) required to the above basic assembly prices for complete system cost. "D" version recorders have 9 mm/min, in addition to standard 9 mm/sec speeds; adds $250 to system cost; order by requesting "D" recorder.

7714A 4-CHANNEL RECORDING SYSTEM BASIC ASSEMBLY

Horizontal, pullout table-top simplifies chart noting; accepts 350 preamps

This Sanborn recorder provides the convenience of horizontal table-top chart marking, the flexibility and high performance of the interchangeable, individual-channel preamplifiers (used in 6- and 8-channel assemblies) and the economy of a 4-channel system. Individual power amplifiers have built-in electrical limiting to protect recording stylus and current feedback circuits which virtually eliminate drift. Variables appear as sharp, clear, true rectangular coordinates on 50 mm wide Permapaper.® Frequency response is 0 to 125 cps, −3 db at 10 div peak-to-peak; rise time is 5 msec to 90% of final amplitude with less than 4% overshoot.



Specifications

(For complete performance specifications with signal conditioners available for these basic assemblies, see pages 376, 379.)

Paper speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 mm/sec, mechanically changed manually; paper drive motor may be turned on or off remotely by 115 v ac.

Timer marker: right margin, provides 1 sec timing marks from built-in timer, manual and remote marking possible; second event marker (608-100-C11) can be installed between channels 3 and 4 for remote marking; also solid-state marker driver amplifiers for dc event marking are available (188AP, + dc input and 188APM, ± dc input); they require 1.5 v at 0.5 ma at input to produce slightly over 1 mm deflection.

Front-panel controls: individual stylus heat controls, speed selector handle motor starting switch, timer-off-marker switch, remote control plug.

Paper length: 200 ft rolls of standard 4-channel Permapaper (651-54), 50 mm channel width, easily loaded from top of recorder; transparent Permapaper (651-184) for making multiple copies of recording on contact copier (Ozalid, etc.) is available.

Paper take-up: automatic paper take-up standard equipment.

Paper footage indicator: located on recorder right side, indicates paper footage remaining on the supply roll.

Power: 115 volts ±10%, 60 cps, 350 watts; 115 volts, 50 cps available at no extra cost; 115 or 230 volts, 50 cps cost slightly higher (consult your hp sales office).

Cooling: 20 cfm is minimum required airflow to keep recorder assembly operating at rated temperature; when recorder assemblies or systems are purchased without a Sanborn cabinet with air-cooling blower system, the user should provide the specified cooling for proper equipment operation.

Dimensions: 7714A mobile cabinet mount: 65⅛" high, 22" wide, 30" deep (1654 x 559 x 762 mm); rack mount Option 1: (recorder) 12¼" high, 19" wide, 17" deep (318 x 483 x 432 mm); (amplifier) 10½" high, 19" wide, 19½" deep (267 x 483 x 495 mm); power and styli heat control panel requires additional space 7" high, 19" wide, 11⅞" deep (178 x 483 x 304 mm).

Weight: (typical) 4-channel recorder with 4 amplifiers in cabinet mount, viz. 7714A: net 340 lbs (153 kg), shipping 480 lbs (216 kg); rack mount Option 1: (recorder) net 101 lbs (45,5 kg), shipping 126 lbs (56,7 kg); with four 350 Preamplifiers: net 100 lbs (45 kg), shipping 120 lbs (54 kg).

Accessories: 4-channel, 50 mm (50 div), 200 ft Permapaper roll (651-54), $12.60 (consult local hp sales office for quantity prices of 200 ft rolls); 398 Analog Writing Arm (4-channel), $7.15; 411-7 Event Marker Arm (4-channel), $6.65.

Optional accessory equipment: 608-100-C11 Extra Event Marker, $70; 188AP Marker Driver Amplifier (+1.5 v dc input), $75; 188APM Marker Driver Amplifier (±1.5 v dc input), $105.

Prices (Note 1): Sanborn 7714A (4-channel cabinet assembly less 350 Preamplifiers), $3985; cabinet assembly includes master control panel, blower systems, stylus heat controls, preamplifier rack, recorder assembly with power amplifiers and power supply and preamplifier power supplies.

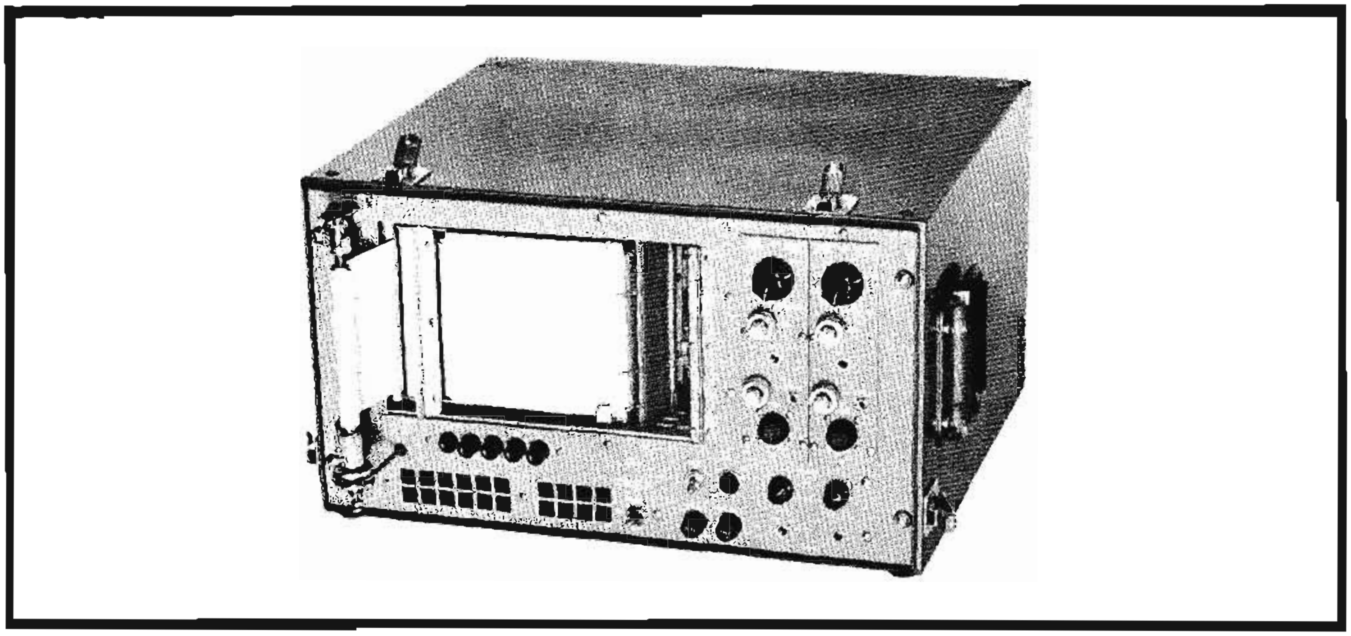
Option 1 (Note 1): same as 4-channel assembly above, less cabinet; includes: blower, master power panel, stylus heat panel, cabling and guide supports for rack mounting (note cooling requirements for operating temperature); Sanborn 7714A Option 1, $3735.

Note 1: Add price of signal conditioners for each channel required to the above basic assembly price for complete system cost.

7702A, 7712A DUAL-CHANNEL RECORDING SYSTEMS BASIC ASSEMBLIES

Mobile cart, portable or rack mounted systems with versatile plug-in preamplifiers

These handy Sanborn dual-channel recorders can be mounted in a cabinet, mobile cart or portable carrying case. They use the same plug-in preamps as 6- and 8-channel assemblies. The recorder chart paper runs horizontally in 7702A (8800 preamps, Note 2) and vertically in 7712A (350 preamps). Each assembly consists of fully solid-state individual current feedback power amplifiers and single power supply. Frequency response is dc to 125 cps, —3 db at 10 div peak-to-peak; and rise time is 5 msec to 90% of final amplitude with less than 4% overshoot.



Specifications

(For complete performance specifications with Sanborn's versatile plug-in 8800 (Note 2) and 350 series signal conditioners see pages 374 to 379.)

Paper speeds: standard recorders are supplied with 4 speeds (1, 5, 20 and 100 mm/sec) mechanically shifted and selected by front-panel pushbuttons; other speed combinations are available on special order; provision is made for optional remote operation of paper speeds and drive from suitable 115 v ac source.

Timer-off-marker: separate stylus marks edge of chart (paper) 1 sec pulses in "time" position (timer motor) or with 60 cps signal operator can use as a reference mark in "mark" position; remote marking provision at rear connector by simple contact closure (115 v ac); an extra marker is available on special order.

Panel controls: individual stylus heat controls, power switch, timer-off-marker switch, pushbutton speed selectors and individual galvanometer damping adjustments (screwdriver).

Paper: standard 200 ft rolls of 50 mm wide 2-channel Permapaper® (651-52), easily loaded from the top of recorder; one channel only may be used with 1-channel Permapaper (651-51); transparent Permapaper (651-182) is available for making multiple copies of recording on contact copier (Ozalid, etc.).

Paper take-up: automatic paper take-up standard equipment.

Power: 115 volts ±10%, 60 cps, 200 watts; 115 or 230 volts ±10%, 50 cps on special order.

Dimensions: 7702A, 7712A, mobile cart: 36¼" high, 14½" wide, 28¼" deep (921 x 368 x 718 mm); rack mount Option 1: 7702A—10½" high, 19" wide, 16¼" deep (267 x 483 x 406 mm); 7712A—14" high, 19" wide, 17¼ deep (356 x 483 x 438 mm); portable case Option 2: 7702A—11" high, 19¼" wide, 17½" deep (279 x 489 x 445 mm); 7712A—14½" high, 19¼" wide, 17½" deep (368 x 489 x 445 mm).

Weight (approx): typical for either 7702A or 7712A with 2 preamplifiers in mobile cart: net 125 lbs (56,3 kg), shipping 176 lbs (79,2 kg); rack mount Option 1: net 90 lbs (40,5 kg), shipping 114 lbs (51,4 kg); portable case Option 2: net 110 lbs (49,5 kg), shipping 140 lbs (63 kg).

Accessories: 2-channel, 50 mm (50 div) 200 ft Permapaper roll (651-52), green coordinates on opaque white paper, $7.30: 1-channel, 50 mm (50 div) 200 ft Permapaper roll (651-51), green lines on white, $4.25 (consult local hp sales office for quantity prices); 398 Analog Writing Arm, $7; 411-10 Event Writing Arm, $6.65 ea.

Optional accessory equipment: 462-189 Extra Marker (center margin), $75; 297-1400 Portable Case (7702A recorder) (Note 2); 296-1400 Portable Case (7712A recorder), $155.

Prices (Note 1): Sanborn 7702A (2-channel mobile cart recorder assembly less 8800 Series Preamplifiers) (Note 2); Sanborn 7712A (2-channel mobile cart recorder assembly less 350 Series Preamplifiers), $1715; mobile cart assembly includes 2-channel recorder, dual-channel power amplifier and power supply, paper take-up and preamplifier power supply.

Option 1 (both models): same as 2-channel assembly above less mobile cart (includes guide supports for rack mounting): 7702A Option 1 (Note 2); 7712A Option 1, $1575.

Option 2 (both models): same as 2-channel assembly above but recorder and preamplifiers are mounted in portable case: 7702A Option 2 (Note 2); 7712A Option 2, $1730.

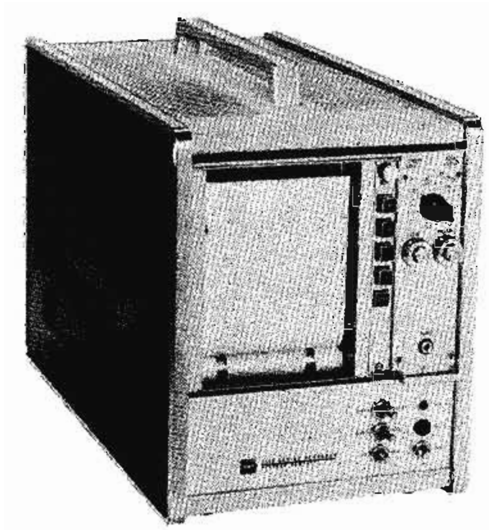
Note 1: Add price of signal conditioners (see pages 374 to 379), times the number of channels you desire to use, to the above basic assemblies prices for complete system cost.

Note 2: 7702A available early 1966, specifications tentative, price on request.

7701A,AX 1-CHANNEL RECORDING SYSTEM BASIC ASSEMBLIES

100 mm wide channel increases resolution 100 to 200%

The Sanborn 7701A provides two to three times the signal resolution of a standard width recorder and can be used with any of the versatile solid-state 8800 interchangeable plug-in signal conditioners. Frequency response is dc to 30 cps, —3 db full scale. The low-impedance ruggedly constructed galvanometer employs velocity feedback for damping and the power amplifier has electrical limiting to protect recording stylus. Up to 2000 hours of continuous unattended recording at 0.5 mm/min (optional plug-in 1 minute timer) is possible without changing chart roll.


7701A

Specifications

(For complete performance specifications with Sanborn's versatile plug-in 8800 Signal Conditioners see pages 374, 375.)

Paper speeds: 4 mm/sec speed 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 in the field or purchased as option.

Event marker: right margin, manually operated from front panel; 1 sec or 1 min plug-in timer and second event marker optional.

Front-panel controls: stylus heat control, pushbutton paper speed selectors, remote-local switch, timer-off-marker switch, power switch and galvanometer damping adjustment.

Paper: 200 ft roll of 100 mm wide-channel standard 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 volts ±10%, 60 cps, 100 watts; 115 or 230 volts ±10%, 50 cps, 100 watts (Model 7701AX).

Dimensions: 7701A, in carrying case: 12-5/16" high, 9-31/32" wide, 18⅛" deep (312 x 253 x 460 mm); without case: 10-7/16" high, 8-11/16" wide, 17-7/16" deep (265 x 221 x 444 mm); rack mounting adapter (mounts 2 wide-channel recorders): 14" high, 19" wide, 17½" deep (356 x 483 x 445 mm).

Weight: 7701A in carrying case, includes typical 8800 Series Preamplifier: net 46½ lb (20,9 kg), shipping 62 lbs (27,9 kg); without carrying case: net 40½ lbs (18,2 kg), shipping 52 lbs (23,4 kg); rack mount adapter: net 16 lbs (7,3 kg), shipping 20 lbs (9,1 kg).

Accessories: 1-channel, 100 mm (50 div) 200 ft roll Permapaper (651-217), $8.45 (consult local hp sales office for quantity prices); 412-4 Analog Stylus, $15; 411-9 Event Marker Stylus, $9.

Optional accessory equipment: left edge event marker 07701-60140, $45; 60 cps timer (operates right edge event marker) 358-1300H-C2 1 sec timer, $20; 07701-60150, 1 min timer, $20; mm/min speed reduction kit for adding 0.5, 2.5, 10 and 50 mm/min speeds to recorder, 07701-60130, $110.

Prices (Note 1): Sanborn 7701A with carrying case (less 8800 Preamps), $1150; Sanborn 7701AX with carrying case (less preamps) 115 or 230 volts, 50 cps, $1250; Sanborn 7701A, Option 1, recorder less carrying case but including (1) 7701-06A Rack Module, $1145; Sanborn 7701A, Option 2, recorder less carrying case and rack module, $1075; Sanborn 7701-06A (rack module for 1 or 2 recorders), $70; Sanborn 7701-04A (carrying case), $75.

Note 1: Prices for the wide choice of 8800 Series Preamplifiers available for this recording system are listed on pages 374, 375; add $35 to the price of the recorder when ordering either High-Gain DC 8803A or Carrier 8805A Preamplifier in the 7701A or 7701AX; a 440 cps regulator card, 07701-60110, must be mounted in the recorder if the 8803A Preamplifier is used, and 321-100-C10 (2400 cps regulator card) if 8805A is used; when the 440 cps card is in the recorder any preamplifier but 8805A can be used; with the 2400 cps card, any preamp but 8803A can be used.

299, 301 ONE-CHANNEL PORTABLE THERMAL WRITING RECORDERS

Two briefcase-size systems for medium-gain dc and ac, or carrier measurements

These single-channel, 25 lb recorders are widely used by engineers and technicians for measuring and recording the results of equipment checkout and servicing, in the field and in the laboratory. They possess most of the features found in larger systems and produce high resolution traces on a 32 mm (40 div) wide channel. Four inches of chart are displayed at all times for study and marking. Model 299 is very useful for medium-gain broad dc and ac measurements; 301 (with built-in excitation source) for carrier inputs from resistance bridges, variable reluctance devices, differential transformers and other ac transducers.

299

Specifications

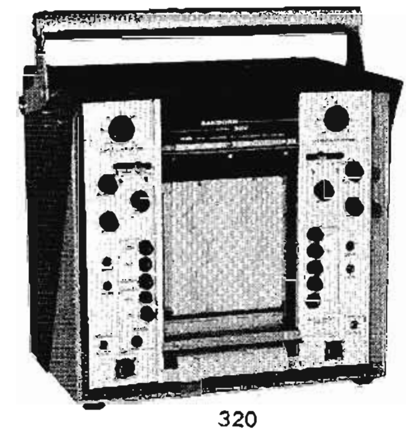
Recorder model	Sanborn 299	Sanborn 301†
Sensitivity (maximum)	10 mv/div (each div = 1/32")	10 μv/div (each div = 1/32")
Sensitivity range (attenuation)	10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div; attenuator error ±2% max.	X1, 2, 5, 10, 20, 50, 100 and 200 attenuation factors; attenuator error ±2% max.
Input circuit	5 megohms each side, balanced to ground	6000 ohms min. resistance, 13 K min. reactance—measured with full zero suppression and R & C balance; 7000 ohms resistance, 13 K reactance—with R & C balance control centered and zero suppression out; transducer impedance, 100 ohms min.
Common mode or quadrature rejection ratio	50:1 on most sensitive ranges; 25:1 on other ranges	quadrature rejection ratio is greater than 100 to 1
Common mode or quadrature voltage tolerance	±2.5 v max. on most sensitive range, higher on other ranges to ±500 v max.	quadrature tolerance: from centerline twice amplitude of equivalent full-scale in-phase signal; from chart edge, up to the equivalent of full-scale in-phase signal, where full scale is defined as centerline to either chart edge
Zero suppression	±2 v max., from mercury cells, in series with output of input attenuator, and used for both single-ended and balanced inputs; corresponds to max. suppression of 10 times center of chart to either edge	5-step switch, center out, two positions for both positive and negative signal, each step equivalent to approx. 5 turns of R-Bal control
Frequency response		
(−3 db max. at 10 div p-p)	dc to 100 cps	dc to 100 cps
(−3 db max. at full scale)	dc to 50 cps	dc to 50 cps
Zero drift		
Temperature, 0 to 50°C	0.5 div/10°C	0.25 div/10°C
Line voltage variation, 103 to 127 volts	0.25 div	0.1 div
Time	0.5 div/hr, 2 div/24 hrs	——
Noise (peak-to-peak max.)	0.1 div	0.25 div
Calibration (internal)	0.2 v, ±1%	40 μv/excitation volt, ±1% (200 μv/20 div deflection)

†Carrier frequency 2400 cps, internally supplied; carrier voltage 4.5 to 5.5 v rms, not adjustable.

320, 321, 322 TWO-CHANNEL PORTABLE THERMAL WRITING RECORDERS

Fixed-amplifier systems for simultaneously measuring two broad-range precision dc or carrier variables

These complete recording systems are extremely useful in the field when two similar variables must be simultaneously analyzed and permanently recorded. They operate in any position, record signals on two 50-mm wide channels, have electrical limiting to protect recording styli and current feedback circuits to reduce drift. Model 320 has guarded and floating inputs designed for broad dc and ac signals even though complicated by excessive noise due to ground loops. Model 322 has two general-purpose direct-coupled amplifier channels, each with calibrated zero suppression, which can be used for single-ended and balanced inputs. Model 321, with built-in 2400 cps carrier excitation source, is designed to measure signals from resistance bridges, variable reluctance devices, differential transformers and other ac transducers.


320

Recorder model	Sanborn 320	Sanborn 321†	Sanborn 322, 322A
Maximum sensitivity	0.5 mv/div (each div = 1 mm)	10 μv/div (each div = 1 mm)	10 mv/div (each div = 1 mm)
Attenuation range	0.5, 1, 2, 5, 10, 20 mv/div and v/10 div; attenuator error ±2% max.	X1, 2, 5, 10, 20, 50, 100 and 200 attenuation factors; attenuator error ±2% max.	10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div; attenuator error ±2% max.
Input circuit	0.5 megohm on mv/div and 1 megohm on v/10 div; floating and guarded with channel-to-channel isolation; dc source resistance should be below 10 K on mv	6000 ohms min. resistance, 13 K min. reactance, measured with full zero suppression and R & C balance; 7000 ohms resistance, 13 K reactance, with R & C balance control centered and zero suppression out; transducer impedance, 100 ohms min.	5 megohms each side balanced to ground
Common mode or quadrature rejection ratio	140 db max. at dc; 120 db min. at 60 cps with no input unbalance; 100 db min. at 60 cps with 5000 ohms unbalance	Quadrature rejection ratio is greater than 100 to 1	50:1 on most sensitive range, 25:1 on other ranges
Common mode or quadrature voltage tolerance	±500 volts max.	Quadrature tolerance: from centerline twice amplitude of equivalent full-scale in-phase signal; from chart edge, up to the equivalent of full-scale in-phase signal, where full scale is defined as centerline to either chart edge	±2.5 volts max. on most sensitive ranges; higher on other attenuator positions to ±500 volts max.
Zero suppression	None	5-step switch, center out, two positions for both positive and negative signal, each step equivalent to approx. five turns of R-Bal controls	±2.5 v max. from mercury cells, in series with output of input attenuator, and used for single-ended and balanced inputs; corresponds to max. suppression of ten times center of chart to either edge (322A has no zero suppression)
Frequency response (—3 db max. at 10 div p-p)	dc to 125 cps	dc to 125 cps	dc to 125 cps
(—3 db max. at full scale)	dc to 50 cps	dc to 50 cps	dc to 50 cps
Zero drift Temp., 0 to 50°C;	0.25 div/10°C	0.25 div/10°C	0.5 div/10°C
Line voltage variation, 103 to 127 v	0.1 div	0.1 div	0.25 div
Time	——	——	0.5 div/hr, 2 div/24 hrs
Noise (p-p max.)	0.25 div	0.25 div	0.1 div
Internal calibration	10 mv, ±2%	40 μv excitation volt, ±1% (200 μv 20 div deflection)	0.2 v ±1%

†Carrier frequency 2400 cps, internally supplied; carrier voltage 4.5 to 5.5 v rms, not adjustable.

Specifications (1, 2-channel portables)

Gain stability: better than 1% to 50°C on all models; better than 1% for line voltage variations 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.

Response time: 5 msec, 10% to 90% with 4% or less overshoot over center ten divisions.

Paper speeds: single-channel 299,301: two speeds (5 and 50 mm/sec); dual-channel 320, 321, 322: four speeds (1, 5, 20 and 100 mm/sec); other speeds are available on any model on special order.

Channel width: single-channel models, 1.25" divided into 40 div, 1/32" apart; dual-channel models, 2" divided into 50 div, 1 mm apart.

Timer-marker: single-channel models have separate stylus for edge marking (60 cps excitation); on dual-channel models, 1 second timers are internal and extra event marker (462-189) 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, 5 pin AN type on front panel; dual-channel models in portable cases have 3-pin AN type front-panel connectors, rear connectors when rack mounted (optional binding post adapters available).

Monitor output connectors: miniature phone jack on front panels provide approx. 40 mv/div across min. external load of 100 K.

Electrical limiting: single-channel, approx. 125% of full scale; dual-channel, approx. 115% of full scale.

Power requirements: single-channel, 115 volts ±10% 60 cps, 45 watts; dual-channel, 115 volts ±10% 60 cps, 100 watts; 115-230 volts 50 cps available in all models on special order.

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 (models ending in R): 14" high, 19" wide x 16" deep (356 x 483 x 406 mm); paper takeup 320-300 for dual-channel portable is 4¾" high, 14½" wide, 9½" deep (121 x 370 x 241 mm) and 320R-300 on rack mount adds only 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).

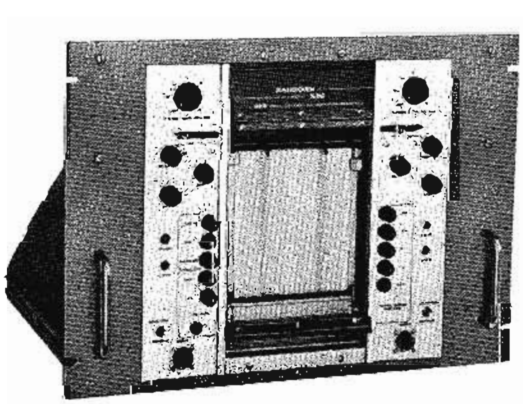
Accessories: 1-channel: Permapaper®, 1¼" wide (40 div), 125 ft roll (651-202), $3.40 ea (consult hp sales office for quantity prices); 403A Analog Writing Stylus, $7.50; 411-1 Marker Stylus, $6.65; dual-channel: Permapaper (651-52) 50 mm (50 div), 200 ft roll, $7.50; 398 Analog Writing Stylus, $7; 411-10 Marker Stylus, $6.65.

Optional accessory equipment: paper takeup 299-300 for single-channel 299,301; $40; paper takeup 320-300 for dual-channel 320, 321, 322 (in portable cases) $125; 320R-300 for dual-channel 320R, 321R, 322R (rack mounts), $150; binding post adapter (to make it easier to connect banana plugs, spade lugs, clip leads, bare wires, etc.): 299-200-C10 for 299 and 322, $7; 301-200-C11 for 301, $8; 320-100-C31 for 320 and 321, $10; extra marker 462-189 (center-margin) for dual-channel models, $75.

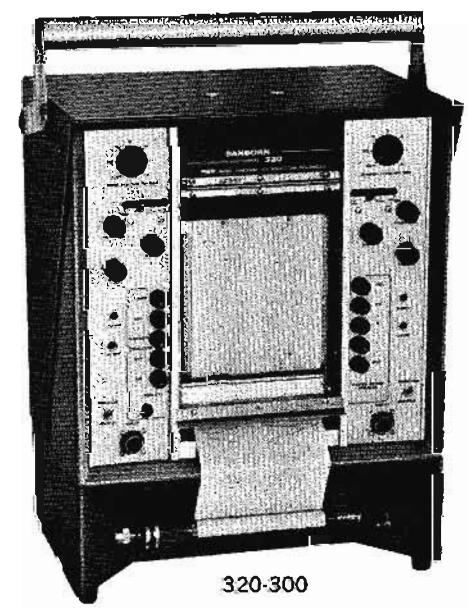
Prices: single-channel: Sanborn 299, $800; Sanborn 301, $850; dual-channel: portable case: Sanborn 320, $1650; Sanborn 321, $1650; Sanborn 322, $1395; Sanborn 322A (without zero suppression) $1295; rack mount: Sanborn 320R, $1800; Sanborn 321R, $1800; Sanborn 322R, $1545; Sanborn 322AR, $1445.

Model 53 Battery Converter

This handy accessory is a portable, stable source of ac power that will operate Sanborn single- and dual-channel recorders in most field applications. It will supply 128 volts, 60 cps at 125 watts continuously for 2 hours, and with a 35 watt load, battery life between charges is 7 hours. Model 53 is a combination charger/converter/storage battery packed in a flameproof carrying case 9" high, 14" wide, 5" deep (246 x 372 x 137 mm). Weight 30 lbs (6,7 kg). Sanborn 53 (including 12-volt storage battery), $171; without battery, $160.


320R


Model 53


320-300

SYSTEM PERFORMANCE: 8800 PREAMPS IN 7708A, 7706A, 7702A†, 7701A

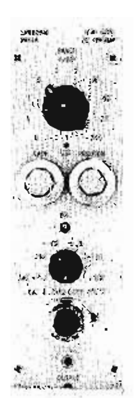
Compact, solid-state interchangeable plug-ins, 2-1/16" x 7"

Model	Sanborn 8801A	Sanborn 8802A	Sanborn 8803A	Sanborn 8809A*
Preamplifier type	low-gain dc	medium-gain dc	high-gain dc	special-purpose dc
Max. sensitivity	5 mv/div	1 mv/div	1 μv/div	20 mv/div
Attenuation range	0.005, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2 and 5 v/div, attenuator error ±1% max.	1, 2, 5, 10, 20, 50, 100, 200, 500 and 1000 mv/div, attenuator error ±1% max.	1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000 and 5000 μv/div and 10, 20, 50, 100, 200, 500, 1000, 2000 and 5000 mv/div; attenuator error ±1% max.	continuously adjustable over the range of 20 to 50 mv/div
Input circuit	500 K ±1% resistive, each side, all ranges; approx. 100 pf input capacitance: input balanced to ground	180 K ±1% resistive, each side, all ranges, approx. 100 pf input capacitance; input balanced to ground	1 megohm min. on μv ranges, 5 megohms on mv ranges; input is floating and guarded from chassis	two inputs: high impedance: $\Delta V/\Delta I$ higher than 100 K; low impedance. 1500 ohms ±2%; both single-ended with respect to common terminal on power supply; chassis terminal to chassis isolation on 7701A up to ±50 v dc
Zero suppression	precedes signal attenuation and gain control, may be used with single-ended and balanced inputs; ranges referred to input are ±10 and ±100 v; on three most sensitive ranges suppression cannot be used above ±50 v	precedes signal attenuation and gain control, may be used with single-ended and balanced inputs; ranges referred to input are ±2 and ±20 v; on three most sensitive ranges suppression cannot be used above ±12.5 v	precedes 1, 2, 5 attenuator switch and gain control; ranges referred to input are ±1, ±10, ±100 mv or v for μv or mv signal ranges respectively	none
Common mode or quadrature rejection ratio	typically 60 db (dc to 150 cps) but can be a minimum of 48 db (250:1)	typically 60 db (dc to 150 cps) but can be a minimum of 48 db (250:1)	on μv ranges: 160 db at dc and 120 db at 60 cps; on mv ranges 100 db at dc and 60 db at 60 cps	100 db min. at dc
Common mode or quadrature voltage	±50 v max. on three most sensitive ranges; ±500 v max. on all other ranges	±12.5 v max. on three most sensitive ranges; ±125 v max. on next three ranges; ±500 v max. on all other ranges	±300 v dc on all ranges; at 60 cps: 10 v rms at 1 μv/div, 20 v rms at 2 μv, 50 v rms at 5 μv, 100 v rms at 10 μv, 220 v rms at 20 μv through 5000 μv; 100 v rms at 10 mv, 220 v rms on all other ranges	±50 v max. with respect to chassis
Zero drift (temp. and volt variations)	1 div/10°C max. from 0 to 40°C; 0.15 div max. from 103 to 127 volts	1 div/10°C max. from 0 to 40°C; 0.15 div max. from 103 to 127 volts	(20 to 40°C) 2 div at 1 μv/div, decreasing to 0.1 div max. on least sensitive ranges; 0.1 div from 103 to 127 volts	0.25 div/10°C max from 0 to 40°C; 0.4 div max. from 103 to 127 volts
Gain stability (temp. and line volt variations)	0.2%/10°C max. from 0 to 40°C; 0.25%/10°C max. from 103 to 127 volts	0.2%/10°C max. from 0 to 40°C; 0.25% from 103 to 127 volts	(20 to 40°C) 0.4% for sensitivities 1 to 10 μv/div, 0.2% above 10 μv/div, from 103 to 127 volts	1%/10°C max. from 0 to 40°C; 1% max. from 103 to 127 volts
Noise (max. p-p at calibrated gain)	0.1 div	0.1 div	1 div at 1 μv/div, 0.5 div at 2 μv/div, 0.2 div at 5 μv/div and 10 mv/div, 0.1 div or less on all other ranges	0.1 div
Max. non-linearity	0.25 div	0.25 div	0.25 div	0.25 div
Internal calibration	100 mv ±1%	20 mv ±1%	200 μv ±1% in μv position; 20 mv ±1% in mv position	+600 mv ±2%
Price	Sanborn 8801A, $275	Sanborn 8802A, $325	Sanborn 8803A, $600	Sanborn 8809A, $75

Frequency response for 7708A, 7706A, 7702A: dc to 150 cps (40 mm channels), dc to 125 cps (50 mm channels), −3 db, 10 div p-p; 7701A, dc to 30 cps, −3 db at any amplitude; except where limited by response of the preamplifier.

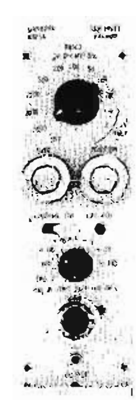
*Designed primarily for 7701A basic assembly (page 370). † Available early 1966.

NEW

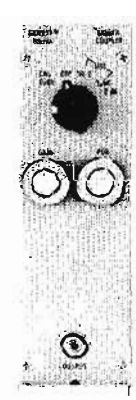


8801A

8802A



8803A



8809A

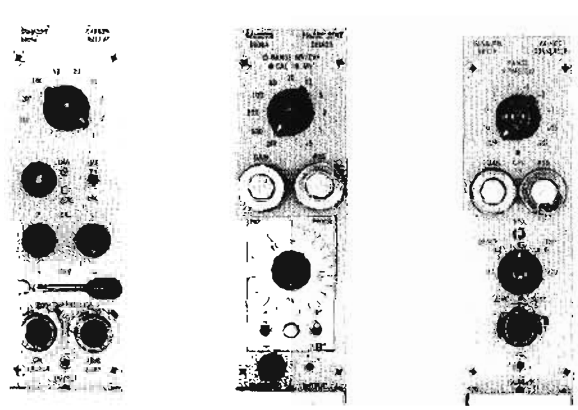
LOW-GAIN, MEDIUM-GAIN, HIGH-GAIN DC; SPECIAL-PURPOSE DC, PHASE-SENSITIVE DEMODULATOR, CARRIER, AC-DC CONVERTER

Measure variables 1 microvolt to 250 volts, even in the presence of high (or quadrature) voltages with 0.25 division non-linearity

Model	Sanborn 8806A	Sanborn 8805A	Sanborn 8807A
Preamplifier type	phase-sensitive demodulator	carrier	converter ac-dc
Max. sensitivity	0.5 mv/div	10 μv/div	1 mv/div (scale exp.), 20 mv/div (without scale exp.)
Attenuation range	signal: 0.5, 1, 2, 5, 10, 20, 50, 100, 200 and 500 mv/div; error ±1% max.; reference voltage: 3 to 20 v rms and 20 to 125 v rms	signal attenuation of X1, 2, 5, 10, 20, 50, 100 and 200; attenuation error ±2%	0.02, 0.05, 0.1, 0.2, 0.5, 1, 2 and 5 v rms/div, without scale expansion; attenuator error ±2%; frequency range 50 cps to 100 kc
Input circuit	1 megohm signal and ref. inputs transf. isolated; 0 to 360° plug-in phase shifter (front panel) provides either calibrated single-freq. or uncal. poly-freq. ref. signal; ref. freq. can be 60 cps to 40 kc uncalibrated, any single freq. 60 cps to 40 kc calibrated; std. freq. 60, 400, 5 kc and 20 kc	approx. 10 K; transducer impedance 5 K max., 100 ohms min.; std. carrier freq. 2400 cps from power supply; provision made to accept 440 to 4800 cps with component substitution; carrier excitation 4.5 to 5 v rms	1 megohm; input is floating and guarded from chassis
Zero suppression	none	signal inserted in series with external transducer output can suppress 0 to 100% of full-scale transducer load, either phase, 0 or 180°, by lever switch	any 5, 10, 20 or 50% section of any range can be expanded to full scale; since zero suppression follows detector section, zero position can be any amplitude between zero and full scale if "scale expansion" is used
Common mode or quadrature rejection ratio	quadrature rejection ratio with cal. phase shifter is 100:1 min. for 2X full-scale (center-to-edge) quadrature signal; uncal. phase shifter*; common mode rejection 40 db min.	quadrature rejection is 100:1 min.	40 db min., 400 cps
Common mode or quadrature voltage	quadrature voltage tolerance equals 2X the amplitude of a full-scale (center-to-edge) in-phase signal; common mode tolerance, 500 v rms max.	quadrature voltage tolerance, in the presence of full-scale in-phase voltage, equals 2X the in-phase voltage required for full-scale (center-to-edge) output	±500 volts peak
Zero drift (time, temp. and volt variations)	0.3 div/10°C max. from 0 to 40°C; 0.25 div max. from 103 to 127 v	0.3 div/10°C max. from 0 to 40°C; 0.1 div max. from 103 to 127 v	0.7 div/10°C max., 0 to 40°C, with X20 scale expansion, decreasing to 0.1 div/10°C max. without scale expansion
Gain stability (temp. and line volt variations)	0.35%/10°C max. from 0 to 40°C; 1.15% max. from 103 to 127 v	0.3%/10°C max. from 0 to 40°C; 0.4% max. from 103 to 127 v	0.3%/10°C max., 0 to 40°C, without scale expansion; 0.25%, 103 to 127 v
Noise (max. p-p at calibrated gain)	0.5 div	0.25 div	1 div (at X20 scale expansion)
Max. non-linearity	0.25 div	0.25 div	0.25 div
Internal calibration	10 mv ±1%	2% of rated full-scale output of transducer ±1%	1 v rms, 500 cps, ±0.5%
Price	Sanborn 8806A, $575 (with uncal. phase control); $550 (with cal. phase control)	Sanborn 8805A, $400	Sanborn 8807A, $600

*Infinite quadrature rejection may be obtained for a particular reference signal level, frequency and (uncal.) phase control setting.

NEW



8805A 8806A 8807A

SYSTEM PERFORMANCE WITH STANDARD 350 PREAMPS IN 7718A, 7716A, 7714A, 7712A

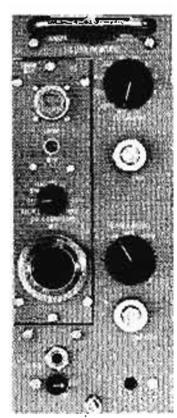
Extremely versatile, high performance, tube and solid-state, interchangeable plug-ins 4-3/16" x 10½"

Model	Sanborn 350-1300C	Sanborn 350-1000B	Sanborn 350-1500A
Preamplifier type	low-gain dc	medium-gain dc	high-gain dc
Max. sensitivity	5 mv/div	1 mv/div	2 μv/div
Attenuation range	0.005, 0.01, 0.025, 0.05, 0.1, 0.25, 0.5, 1, 2.5 and 5 v/div; attenuator error ±2%	1, 2, 5, 10, 20, 50, 100, 200, 500 and 1000; mv/div attenuator error ±2%	attenuation of X1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000; attenuator error ±1%
Input circuit	5 megohms ±1% each side to ground shunted by approx. 300 pf on 0.005 v/div position and 200 pf on all other positions; input balanced to ground	5 megohms ±1% each side to ground shunted by approx. 250 pf on 1, 2 and 5 mv/div; 200 pf on all other ranges; input balanced to ground	100 K min., independent of gain; input is floating and guarded from chassis
Zero suppression	follows attenuator switch and precedes gain control, can be used with single-ended input only; suppresses ±5 v on most sensitive range, corresponding to max. suppression of 40 times center of chart to either edge on any range	can be used with single-ended or balanced inputs; suppresses up to ±2.5 v referred to input on 1, 2 and 5 mv/div; ±2.5 v times 0.2 of mv/div range on all other ranges	350-2B plug-in provides amplifier with suppression voltage ranges of ±2 mv, ±10 mv and ±100 mv
Common mode or quadrature rejection ratio	>60 db on 0.005 v/div; normally better than 34 db on all other ranges; can be min. of 28 db (25:1)	>60 db on 1, 2 and 5 mv/div normally better than 34 db on all other ranges; can be min. of 28 db (25:1)	160 db at dc, 120 db at 60 cps for up to 5000 ohms unbalance in input
Common mode or quadrature voltage	±5 v on 0.005 v/div; ±5 volts times 100 times v/div range on other positions with upper limit of 500 v	±5 v on 1, 2 and 5; ±5 v times 0.2 of mv/div range on all other ranges, with an upper limit of ±500 v	20 v rms at X1, 40 v rms at X2, 100 v rms at X5, 200 v rms at X10, 220 v rms all other positions
Zero drift (time, temp. and volt variations)	0.4 div/hr max., 2 div/24 hr max.; 0.3 div/10°C from 0 to 40°C; 0.8 div max. from 103 to 115 v, and from 115 to 127 v	2 div/hr on 1, 1 div/hr on 2, 0.4 div/hr and 2 div/24 hr max. on all other ranges; 1.3 div/10°C for 1, 0.7 div/10°C for 2, 0.3 div/10°C on all other ranges from 0 to 40°C; 2.5 div for 1, 1.25 div for 2, 0.5 div for all other ranges from 103 to 127 v	1 div/24 hr max. on X1 range, decreasing with range setting, from 20 to 40°C; 0.2 div/°C max., decreasing with range setting to 0.1 div/20°C max., 0.1 div max. from 103 to 127 v
Gain stability (temp. and line volt variations)	0.6%/10°C max. from 0 to 40°C; 0.25% max. from 103 to 127 v	0.6%/10°C max. for 1; for 2, 0.35%/10°C; 0.2%/10°C max. on all other ranges from 0 to 40°C; 0.25% max. from 103 to 127 v	0.1%/24 hr max.; 0.2%/10°C max., 20 to 40°C; 0.25% max. from 103 to 127 v
Noise (max. p-p at calibrated gain)	0.1 div	0.1 div	1 div on X1 range with high frequency cutoff, decreasing to 0.1 div with range and cutoff
Max. non-linearity	0.25 div	0.25 div	0.25 div
Internal calibration	100 mv ±1%	20 mv ±1%	0.2 mv ±0.5%
Price	Sanborn 350-1300C, $250	Sanborn 350-1000B, $325	Sanborn 350-1500A, $525; (350-2A, $75; 350-2B, $165; 350-4A, $130)

Frequency response for all systems: dc to 150 cps (40 mm channels); dc to 125 cps (50 mm channels); —3 db, 10 div p-p; except where limited by response of the preamplifier.

350-1300C

350-1000B



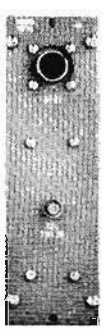
350-1500A
(350-2B plug-in)

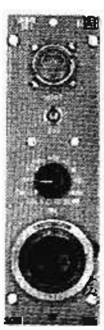
LOW-GAIN, MEDIUM-GAIN, HIGH-GAIN DC, PHASE-SENSITIVE DEMODULATOR, CARRIER

Measure variables with precision even in the presence of high (or quadrature) voltages with 0.25 division non-linearity

Model	Sanborn 350-1200E,ET*	Sanborn 350-1100C
Preamplifier type	Phase sensitive demodulator	carrier
Max. sensitivity	0.5 mv/div	10 μv/div
Attenuation range	Signal: 0.5, 1, 2.5, 5, 10, 25, 50, 100, 250, 500 mv/div; attenuator error ±2%; reference voltage: 10 to 125 v rms; reference frequencies from 60 cps to 5 kc	Attenuation of X1, 2, 5, 10, 20, 50, 100, 200; attenuator error ±1%
Input circuit	Signal and reference: single-ended 100 K; 350-1200ET 85 to 90 K (floating input, either side may be grounded)	Approx. 2.5 K, including zero suppression circuit; transducer impedance 1 K max.; 100 ohms min.; standard carrier frequency is 2400 cps, internally provided; 600, 1200 and 4800 cps optional; carrier excitation is 4.5 to 5 volts
Zero suppression	None	Signal inserted in series with external transducer output which can suppress 0 to 100% of full-scale transducer load (either phase, 0° or 180°, by lever switch)
Common mode or quadrature rejection ratio		
Common mode or quadrature voltage	Quadrature voltage tolerance is twice the amplitude of a full-scale (edge-to-edge) in-phase signal	Quadrature voltage tolerance, in presence of full-scale in-phase voltage, is twice the in-phase voltage amplitude required for full-scale (center-to-edge) output
Zero drift (time temp., and volt variations)	0.1 div/hr max.; 0.3 div/10°C max. from 0 to 40°C; 0.15 div max. from 103 to 127 volts	
Gain stability (temp. and line volt variations)	0.8% max./10°C from 0 to 40°C; 1.15% max. from 103 to 127 volts	
Noise (max. p-p at calibrated gain)	0.25 div	0.1 div
Max. non-linearity	0.5 div	0.25 div
Internal calibration	10 mv ±1%	2% of rated full-scale output of transducer ±1%
Price	Sanborn 350-1200E, $400; Sanborn 350-1200ET, $470	Sanborn 350-1100C, $425

*350-1200ET has isolation transformers for floating signal and reference inputs.

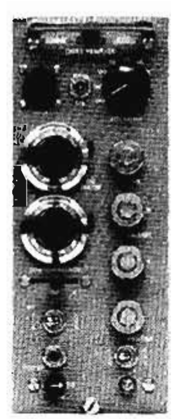

350-2A


350-2B


350-4A

The 350-1500A is a basic chopper preamplifier with three interchangeable plug-in front ends. When 350-2B is inserted, the preamplifier is a high-performance dc amplifier with zero suppression; 350-2A can be used when zero suppression is unnecessary; 350-4A is the plug-in to use for excitation and balancing dc strain gage bridges (100- to 1000-ohm impedance).


350-1200E

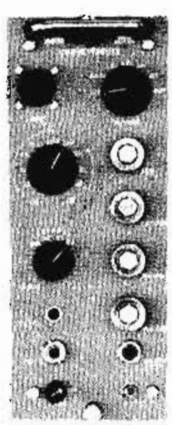

350-1100C

SYSTEM PERFORMANCE WITH SPECIAL 350 PREAMPS IN 7718A, 7716A, 7714A, 7712A

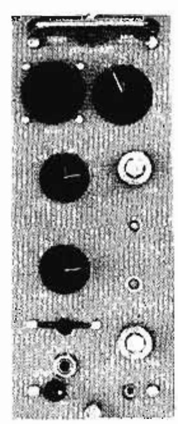
Record complex audio, noise, pulse rates, doppler shifts, rpm, ac transducer outputs, etc.

Model	Sanborn 350-1400A	Sanborn 350-2300*	Sanborn 350-2500*
Preamplifier type	logarithmic (level detecting on ac ranges)	ac wattmeter (average power)	rms volt/ammeter (true rms)
Max. sensitivity	logarithmic: 1 db/div, 50 db full scale; linear ac: 2 mv/div; dc: 200 mv/div	voltage: 1 v rms normal full scale; current: 2 ma rms normal full scale	voltage: 0.5 v rms/div; current: 1 ma rms/div
Attenuation range	ac ranges: 100 mv to 100 v rms, 7 ranges in 10 db steps: 0.1, 0.32, 1, 3.2, 10, 32 and 100 v full scale logarithmic or linear; total range is −70 db to +40 db in 50 db ranges in logarithmic mode; reference is 1 v for 0 db; frequency range 5 cps to 100 kc; dc ranges: logarithmic, one 50 db range (−10 to +40 db) with reference of 0 db for +0.6 v; linear, +10 v full scale	power range: equals normal full-scale voltage setting times normal full-scale current range setting; voltage ranges: 1, 2.5, 5, 10, 25, 50, 100, 250 v rms full scale; current ranges: 0.002, 0.005, 0.01, 0.02, 0.5, 1, 2, 5 amps rms full scale; voltage and current range errors are ±1%, frequency range: 40 cps to 10 kc	voltage ranges: 25, 100, 150, 250 and 300 v rms full scale; other position, line, provides direct connection to power line for line check; current ranges: 0.05, 0.1, 0.25, 0.5, 1, 2.5 and 5 amps rms full scale; frequency ranges: voltage, 30 to 2500 cps ±3%, 20 to 5000 cps ±10%; current, 50 ma range 50 to 1000 cps ±3%, all other ranges 50 to 2000 ±3%
Input circuit	10 megohms, single-ended, ac and dc, all ranges	voltage: 25 K/full-scale v, up to 25 v normal range; constant at 625 K on all other ranges; current: from 20 to 400 mv max. drop for front inputs depending on range; both inputs floating and may be grounded	voltage: 1000 ohms/full-scale v; current: from 200 to 300 mv max. drop for front input, depending on ranges; both inputs floating and may be grounded
Zero drift (time, temp. and volt variations)	1 div/hr max.; 1 div/10°C max., 0 to 40°C; 2 div max. from 103 to 127 volts	1 div/10°C from 0 to 40°C; 1 div from 103 to 127 volts	0.5 div/hr max.; 0.3 div/10°C max. from 0 to 40°C; 1 div max. from 103 to 127 volts
Noise (max. p-p at calibrated gain)	0.1 div	0.33 div	0.1 div
Max. non-linearity	Linear, ±0.5 div; log, ±1 div	1.5 div	1.5 div
Internal calibration	dc corresponding to full-scale (edge-to-edge) output	2 mw full-scale power	dc corresponding to full-scale (edge-to-edge) rms alternating voltage or current
Price	Sanborn 350-1400A, $475	Sanborn 350-2300, $850	Sanborn 350-2500, $600

Frequency response for all systems: dc to 150 cps (40 mm channels); dc to 125 cps (50 mm channels); −3 db, 10 div p-p; except where limited by response of the preamplifier.
*To be deleted from series after inventory depletion.


350-1400 A


350-2300

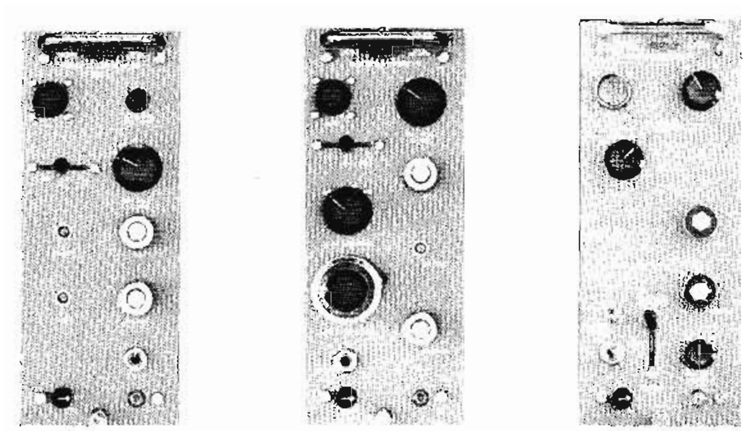

350-2500

SPECIAL-PURPOSE SIGNAL CONDITIONERS

Accurately condition and control "special" variables with exact plug-in

Model	Sanborn 350-2600*	Sanborn 350-2800A	Sanborn 350-3900A
Preamplifier type	400 cycle frequency deviation	frequency meter	accelerometer (level detecting)
Max. sensitivity	0.1 cps/div	———	0.5 mv/div: mv may be peak to peak, zero to peak, or average.
Attenuation range	±2.5 cps, ±5 cps, ±12.5 cps and ±25 cps full scale; input voltage range 0.5 to 225 v (zero to peak)	frequency ranges. 0–100 cps (30 cps min operating frequency), 0–500 cps, 0–2.5 kc, 0–10 kc and 0–50 kc for full-scale deflection without zero supression or scale expansion; scale expansion allows full-scale measurement of any 10, 20 or 50% section of any range; zero suppression provides selection of zero output position to be any frequency between zero and full scale when scale expansion is used; input voltage range: 30 mv to 450 v on all ranges except 50 kc which is 150 mv to 450 v peak to peak	attenuation: X1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, and 5000 (error ±1%); frequency range 2 cps to 100 kc
Input circuit	100 K min., single-ended to ground	100 K min., single-ended to ground	single-ended, higher than 1000 megohms; input capacitance 30 pf
Zero drift (time, temp. and line volt variations)	0.75 div/hr max. on most sensitive ranges, decreasing to 0.25 div/hr max.; 1 div from 103 to 127 v	without scale expansion, 0.1 div/hr max.; 0.25 div/10°C max., 0 to 40°C; 0.5 div from 103 to 127 v	0.5 div/hr max.; 0.3 div/10°C max. from 0 to 40°C; ±0.5 div from 103 to 127 v
Noise (max. p-p at calibrated gain)	1 div	1 div for 30 cps input, decreasing to 0.1 div	0.1 div
Max. non-linearity	1 div	without scale expansion, 0.75 div	0.5 div
Internal calibration	dc voltage which corresponds to +20 cps frequency deviation	power line frequency applied to input	25 mv ±0.5%
Price	Sanborn 350-2600, $550	Sanborn 350-2800A, $415	Sanborn 350-3900A, $600

*To be deleted when inventory is depleted.



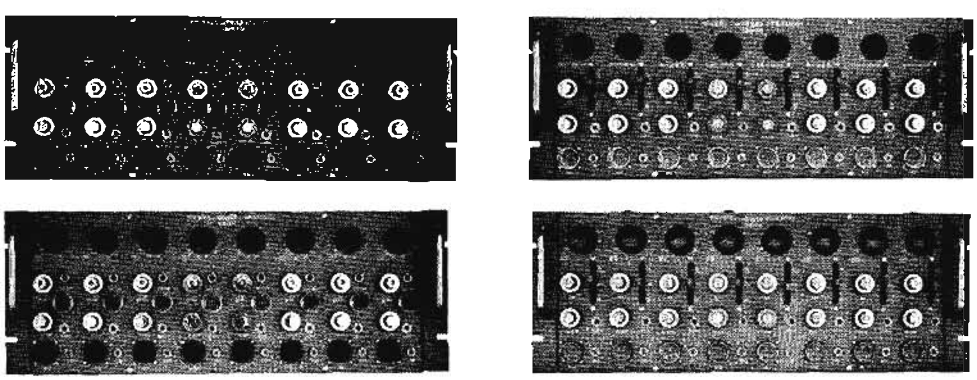
350-2600 350-2800A 350-3900A

SYSTEM PERFORMANCE WITH 950 AMPLIFIERS IN 7728A, 7726A

Economical, low-gain, medium-low gain, medium-gain, high-gain dc

Model	Sanborn 958-3600	Sanborn 958-2900	Sanborn 958-3400	Sanborn 958-1500
Amplifier type	low-gain dc	medium-low gain dc	medium-gain dc	high-gain dc
Max. sensitivity	50 mv/div	10 mv/div	0.5 mv/div	10 μv/div
Attenuation range	0.05, 0.1, 0.2, 0.5, 1 and 2 v/div, attenuator error ±2% max.	10, 20, 50, 100, 200 and 500 mv/div; 1, 2, 5 and 10 v/div; attenuator error ±2%	0.5, 1, 2, 5, 10 and 20 mv/div; 0.5, 1, 2, 5, 10 and 20 v/10 div; attenuator error ±2%	10, 20, 50, 100, 200, 500, 1000 and 2000 μv/div; attenuator error ±2%
Input circuit	550 K each side balanced to ground, except 500 K on negative input side on three most sensitive ranges	5 megohms each side balanced to ground	0.5 megohm on mv ranges, 1 megohm on volt ranges, input is floating and guarded from chassis	100 K all ranges, floating and guarded from chassis
Zero suppression	precedes signal attenuation and gain control, may be used with single-ended and balanced inputs; ±40 v max. suppression referred to input	follows attenuator switch and precedes gain control, may be used with single-end and balanced inputs; suppresses ±2.5 v max. on most sensitive range, corresponding to max. suppression of 10 times center of chart to either edge on any range	none	none
Common mode or quadrature rejection ratio	typically more than 40 db, but may be as low as 28 db (25:1)	34 db min. on most sensitive ranges, 28 db min. on all other ranges	140 db min. at dc; 120 db min. at 60 cps with no unbalance; 100 db min. at 60 cps with 5000 ohms unbalance	140 db min. at dc; 120 db min. at 60 cps with no input unbalance; 100 db min. at 60 cps with 5000 ohms unbalance
Common mode or quadrature voltage	±40 v max. on 3 most sensitive ranges; ±400 v max. on all other ranges	±2.5 v max. on most sensitive ranges; for other ranges max. voltage is increased in proportion to the full-scale voltage to a max. of ±500 v	±500 v max.	±200 v max.
Zero drift (time, temp., and volt variations)	0.5 div/10°C max. from 0 to 50°C; 0.1 div max. from 103 to 127 v	0.5 div/hr max., 2 div/24 hr max.; 0.5 div/10°C max. from 0 to 50°/C; 0.1 div max. from 103 to 127 v	0.25 div/10°C max. from 0 to 50°C; 0.1 div max. from 103 to 127 v	0.25 div/10°C max. from 0 to 50°C; 0.1 div max. from 103 to 127 v
Gain stability (temp. and line volt variations)	1% max. from 0 to 50°C; 1% max. from 103 to 127 v	1% max. from 0 to 50°C; 1% max. from 103 to 127 v	1% max. from 0 to 50°C; 1% max. from 103 to 127 v	1% max. from 0 to 50°C; 1% max. from 103 to 127 v
Noise (max. p-p at calibrated gain)	0.1 div	0.1 div	0.25 div	0.5 div
Max. non-linearity	0.25 div	0.25 div	0.25 div	0.25 div
Internal calibration	1 v ±1%	0.2 v ±1%	10 mv ±2%	0.2 mv ±2%
Price	Sanborn 958-3600, $2500	Sanborn 958-2900, $2500	Sanborn 958-3400, $3500	Sanborn 958-1500, $3800

Frequency response for all systems: dc to 150 cps (40 mm channels); dc to 125 cps (50 mm channels); -3 db, 10 div p-p; except 958-1500, which is dc to 100 cps.

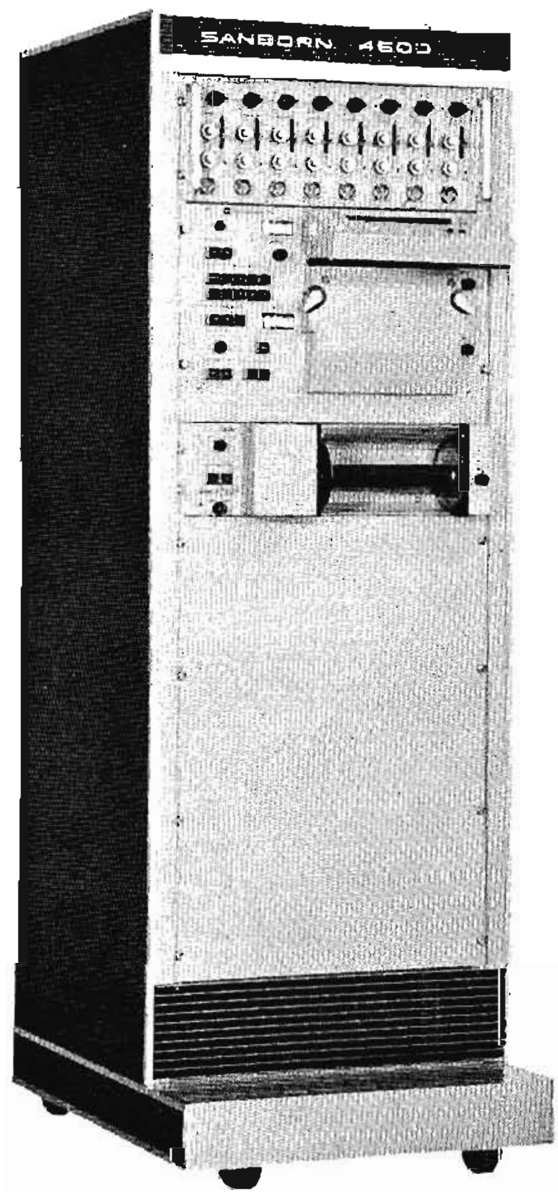


958-3600 958-3400 958-2900 958-1500

4500 MULTI-CHANNEL OPTICAL RECORDING SYSTEM

Record high-frequency, high-speed test data on integrated amplifier-to-galvanometer system

NEW



Advantages:

- Up to 25 channels
- One basic galvanometer for 0 to 5 kc response
- Sensitivities: 2.5 mv/in to 625 mv/in
- Record up to 4" (p-p) amplitudes at 0 to 5 kc; 8" (p-p) at 0 to 3 kc
- Trace positioned electrically anywhere on chart

Uses:

- Telemetry recording
- 400-cycle power measurements
- Transients measurements
- Measuring data sampled at high pulse rates

The Sanborn Model 4500 Optical Recorder is a completely integrated system that can provide high-speed, permanent recordings of many variables, without annoying time delay errors between channels, in the 0 to 5000 cycle range. Per-channel cost is low, and the system is convenient to operate. Signals are connected directly to either front or rear panel of system multi-channel amplifiers and immediately recorded on 8-inch wide chart. Front-panel position controls make it easy to move each channel's trace to any position on chart.

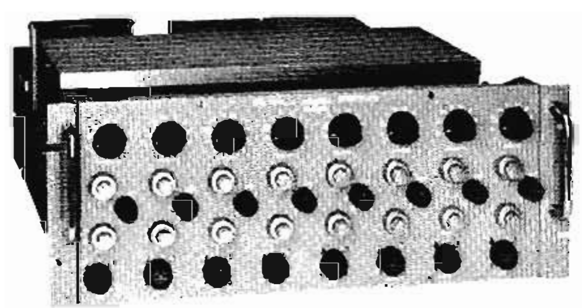
Amplifiers are available with maximum sensitivities of 2.5, 50 and 625 mv/in; with and without zero suppression and common mode voltages, and have zero drift, gain stability and noise ratings for high-quality amplification. Each amplifier assembly consists of eight identical, solid-state modular channels of electronics and a common power supply. This same assembly is offered with 6 channels of electronics for 6-, 14- and 18-channel optical recording systems. Twenty-four channel systems are driven by three 8-channel amplifiers; the 25th channel galvanometer can be driven directly or by an external amplifier.

Special frequency boost and compensation circuits extend frequency response of 2 kc galvanometers to 5 kc range (−3 db). Current feedback in matching network between amplifier and galvanometer stabilizes frequency response of galvanometers over broad temperature range. Galvanometers of other natural frequencies are available for applications when the signal is to be applied directly to the recorder. Recordings can be made at any of nine speeds (0.25 to 100 in/sec) on ultraviolet-sensitive paper and immediately developed under attached post-development lamp. Traces may overlap at amplitudes up to eight inches. Additional features include: full-width (0.01 and 0.1 sec) timing lines, amplitude lines (removable over part or all of paper), sequential light beam interruption for trace identification, event marker, a lamp power control and meter and a meter for indicating remaining paper footage. As in most Sanborn recording systems, the 4500 has provision for complete remote operation.

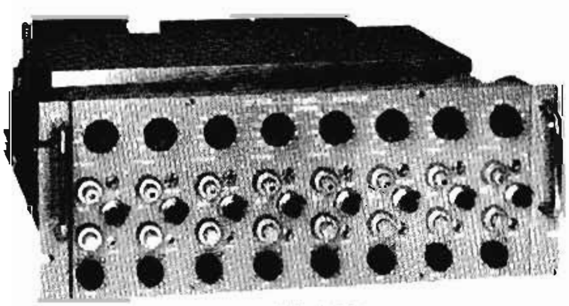
PERFORMANCE SPECIFICATIONS WITH 650 AMPLIFIERS IN 4500 BASIC ASSEMBLIES

Low-cost, solid-state, multi- (alike)-channel amplifiers: galvanometer driver; low-gain, medium-gain

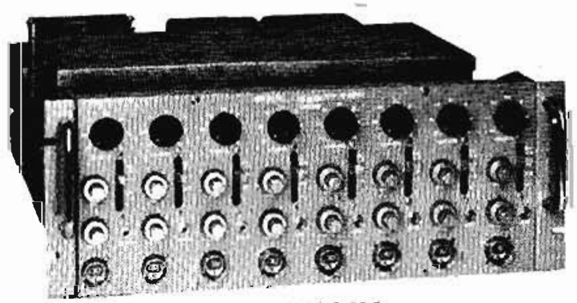
Model	Sanborn 658-2000	Sanborn 658-2900	Sanborn 658-3400
Amplifier type	galvanometer driver, general-purpose	low-gain, general-purpose	medium-gain, general-purpose
Max. sensitivity	625 mv/in (5 v for 8" trace)	50 mv/in (400 mv for 8" trace)	2.5 mv/in (20 mv for 8" trace)
Attenuation range	X1, 2, 4, 10, 20, 40; smooth gain 2.5-to-1 adj.; up scale and down scale output switch; attenuation error ±2% max.	X1, 2, 5, 10, 20, 50, 100, 200, 500, 1000; smooth gain 2.5-to-1 adj.; attenuation error ±2% max.	X1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000; smooth gain 2.5-to-1 adj.; attenuation error ±3% max.
Input circuit	single ended, 100 K	bal. to gnd.; 1 megohm each side	floating and guarded, 100 K
[illegible]	[illegible]		N/A
Common mode or quadrature rejection ratio	N/A		140 db at dc, 120 db at 60 cps bal., 110 db at 60 cps 1000 ohms unbal.
Common mode or quadrature voltage	N/A	±2.5 v on X1 range, multiply att. range X2.5 to max. of ±500 v	±500 volts
Frequency response (within 3 db point)	0 to 5 kc (4" p-p), 0 to 3 kc (8" p-p)	0 to 5 kc (4" p-p), 0 to 3 kc (8" p-p)	0 to 5 kc (4" p-p), 0 to 3 kc (8" p-p)
Response time (10% to 90%)	80 μsec 4% or less overshoot	80 μsec 4% or less overshoot	80 μsec 4% or less overshoot
Zero drift (time, temp. and line voltage variations)	0.025"/10°C max., 0 to 50°C; 0.02" max., 103 to 127 volts	0.1"/10°C max., 0 to 50°C; 0.02" max., 103 to 127 v; 0.1"/hr.	0.05"/10°C max., 0 to 50°C; 0.02" max., 103 to 127 volts
Gain stability (temp. and line volt variations)	better than 1%, 0 to 50°C; better than 1%, 103 to 127 volts	better than 1%, 0 to 50°C; better than 1%, 103 to 127 volts	better than 1%, 0 to 50°C; better than 1%, 103 to 127 volts
Noise (max. p-p at calibrated gain)	0.02" p-p max.	0.02" p-p max.	0.02" p-p max.
Max. non-linearity	±1.5% full scale (8")	±1.5% full scale (8")	±1.5% full scale (8")
Internal calibration	2.5 volts ±1%	0.2 volt ±1%	10 mv ±2%
Price	Sanborn 658-2000, $2200	Sanborn 658-2900, $2895	Sanborn 658-3400, $3780
Price (with cooling fan)	(658-2000-3) $2345	(658-2900-3) $3040	(658-3400-3) $3925



658-2000



658-2900



658-3400

Specifications

Channel capacity: up to 25.

Paper speeds: standard recorders are supplied with 9 speeds: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50 and 100 in/sec, electrically shifted and selected by front-panel pushbuttons; a connector and control panel are available for remote control of paper drive and speeds.

Timing lines: 0.01 or 0.1 sec interval lines can be recorded across the full chart width (8"); control can be from the remote control panel.

Amplitude lines: 0.1" interval amplitude lines can be superimposed on total chart or eliminated over 0.25 or 0.5 of full chart width; millimeter lines are available on special order.

Galvanometer: 9B-1A (standard); undamped natural frequency is 2000 cps; frequency response is flat within ±5% to 1200 cps; sensitivity is 17.5 ma/in; nominal coil resistance is 17 ohms; maximum safe current is 150 ma; the following list of additional galvanometers are available from Sanborn for applications where the signal is to be fed directly to the recorder: 200 cps (9B-1B), 500 cps (9B-1C), 3400 cps (9B-1D), 10,000 cps (9B-1E), 40 cps (9B-1F), 60 cps (9B-1G), 100 cps (9B-1H), 150 cps (9B-1J), 300 cps (9B-1K), 900 cps (9B-1L), 1500 cps (9B-1N), 3000 cps (9B-1P), 5000 cps (9B-1S), 8000 cps (9B-1T), 1000 cps (9B-1V); for further information contact your hp sales office.

Controls: Power On-Off, Timing Interval selector, Lamp Power Adjust, Lamp Off/Start, Paper Footage indicator, Event Marker, Paper Drive On/Off Jog pushbutton; all controls are on the front panel.

Viewing: calibrated periscope on front panel allows viewing the traces when recording or calibrating.

Input connectors (all amplifiers): each channel has both front and rear connector panels; 658-3400 has guard circuit connections, all mating connectors supplied.

Output (all amplifiers): ±72 ma to drive standard 2000 cps galvanometers, 17-ohm nominal load, ungrounded, approx. 10,000 ohms source impedance; current is limited to ±150 ma.

Output monitor (amplifiers): front-panel jack provides ±1 v full scale across 100 K ohms min. load (658-2900 and 658-3400 only).

Paper take-up: optional 650-900 mounted below recorder; front-panel pushbutton automatically controls paper and take-up speed; clutch keeps paper taut; relay stops take-up at end of roll.

Amplifier cooling: 20 cfm min. air flow required at rear of amplifiers for proper cooling, when the amplifier or system is purchased without a Sanborn cabinet and air-cooling blower, proper operational ambient temperature becomes the responsibility of the user; in such instances, and where the cabinet being used has sufficient depth (23") a blower can be installed on the rear of the amplifier for $145; to order an amplifier with this blower assembled, simply add a "-3" after the amplifier model number (i.e., 658-2900-3).

Power: 103 to 127 volts, 60 cps, 450 watts (recorder); 103 to 127 volts, 50 to 400 cps, 125 watts (amplifiers) (115 or 230 volts on special order); 105 to 125 volts, 60 cps, 195 watts (paper take-up) (115 or 230 volt, 50 cps on special order).

Dimensions: 650-1400 16-channel cabinet: 57⅝" high, 22" wide, 22" deep (1464 x 559 x 559 mm); 658-2400, 24-channel cabinet; 68¼" high (1734 mm) other dimensions same as 650-1400; rack mounts: recorder, 12½" high, 18" wide, 16½" deep (318 x 483 x 419 mm); paper take up, 5½" high, 19" wide, 12" deep (140 x 483 x 305 mm); amplifiers, 6-61/64" high, 18⅛" wide, 20⅛" deep (177 x 467 x 511 mm); portable cases: recorder, 13-5/16" high, 20-3/16" wide, 17¾" deep (338 x 513 x 451 mm); amplifiers, 7-9/16" high, 22" wide, 21½" deep (193 x 559 x 546 mm).

Weights: 650-1400, 16-channel cabinet: net 400 lbs (181,6 kg), shipping 450 lbs (204,3 kg); 650-2400, 25-channel cabinet: net 450 lbs (204,3 kg), shipping 500 lbs (227-7 kg); recorder: net 95 lbs (40,5 kg), shipping 150 lbs (67,5 kg); paper take-up: net 28 lbs (12,6 kg), shipping 35 lbs (15,8 kg); amplifiers: net 80 lbs (36 kg), shipping 90 lbs (40,5 kg); portable cases: (650-1400, recorder): net 45 lbs (20,4 kg), shipping 50 lbs (22,7 kg); (858-1400, amplifier): net 40 lbs (18,2 kg), shipping 45 lbs (20,4) kg.

Accessories: 8" wide ultraviolet sensitive paper: 200-ft roll, std. base (3A-26), $22.50; 350 ft roll, thin base (3A-27), $33.75; 9B-1R Dummy Galvanometer with mirror, $33; 9B-1W (w/o mirror), $9; 650-900 Paper Take-Up, $570.

Prices

Complete 8-channel system includes: Sanborn 4508-01A, 8-Galvanometer Block Recorder, $3200; eight Sanborn 9B-1A Galvanometers, $1000 ($125 each); 8-channel amplifier, $2200, $2895 or $3780 (see page 382); and Sanborn 658-1400 cabinet, $550.

Complete 24- or 25-channel systems include: Sanborn 4524-01A 25-Galvanometer Block Recorder, $3400; 24 or 25 9B-1A Galvanometers, $125 each; three 8-channel amplifiers priced above and on page 382); and Sanborn 658-2400 cabinet, $600.

Portable carrying cases: Sanborn 650-1400 (recorder), $150; Sanborn 858-1400(amplifier), $150; paper take-up (special order), $200; one additional case required for 14-channel systems, two for 18, 24 or 25 channels.

Optional systems: (require 6-channel amplifier): six-channel systems include: Sanborn 4508A-01A 8-Galvanometer Block Recorder, $3200; (six) Sanborn 9B-1A Galvanometers, $750 ($125 each); (one) 8-channel amplifier with 6 channels only of electronics, $2060 (658-2000), $2635 (658-2900), or $3540 (658-3400); and 658-1400 Cabinet, $550.

Fourteen-channel systems include: Sanborn 4514-01A, 14-Galvanometer Block Recorder, $3300; (14) Sanborn 9B-1A Galvanometer, $1750 ($125 each); (one) 8-channel amplifier chassis with full 8 channels of electronics (priced above and on page 382), (one) 8-channel amplifier chassis with 6 channels only of electronics and 658-1400 Cabinet (see optional 6-channel system above).

Eighteen-channel systems include: Sanborn 4518A-01A 18-Galvanometer Block Recorder, $3300; (18) Sanborn 9B-1A Galvanometers, $2250 ($125 each); (three) 8-channel amplifier chassis each with 6 channels only of electronics (see prices above); and 658-2400 Upright Cabinet, $600.

3907A, 3914A, 3917A, 3924A INSTRUMENTATION MAGNETIC TAPE RECORDERS

Accurate, low-cost standard and extended bandwidth data recording

Advantages:

- 50 to 100 kc, 50 to 250 kc direct bandwidths
- 0 to 10 kc, 0 to 20 kc FM bandwidths
- Six pushbutton speeds, 1⅞ to 60 ips, no capstan changes
- 40 db or better signal-to-noise ratios
- 0.2% flutter, 0 to 200 cps at 30 and 60 ips
- IRIG compatibility

Uses:

- Industrial: telemetry; flight, jet and missile engine, scientific laboratory tests; vibration studies, research; "back-up" or prime monitors in large process and test installations
- Medical: physiological, biological research; instruction

Standard bandwidth 3907A, 3914A

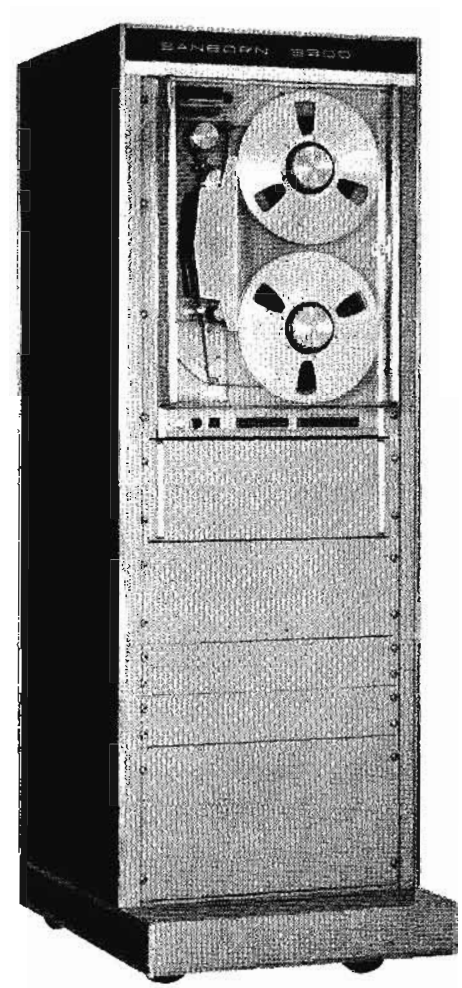
Sanborn 3907A, 3914A 7 and 14-channel magnetic tape recorders are excellent, accurate, low-cost systems for both industrial and medical applications. Complex recording requirements of IRIG telemetry and neuro-physiology can be handled easily with either system. Both systems are identical except for channel capacity. Seven-channel 3907A has a 7-track head assembly, uses ½" wide tape and 7 channels of record/reproduce electronics (FM, Direct, or Pulse modes), and for larger system requirements, the 3914A has a 14-track head assembly, uses 1" tape and two 7-channel racks of record/reproduce electronics.

Frequency response at 60 ips is 100 cps to 100 kc, Direct mode; 0 to 10 kc, FM mode. Their wide speed range 1⅞, 3¾, 7½, 15, 30 and 60 ips is particularly useful when time base expansion or contraction is needed, as it often is, for data analysis.

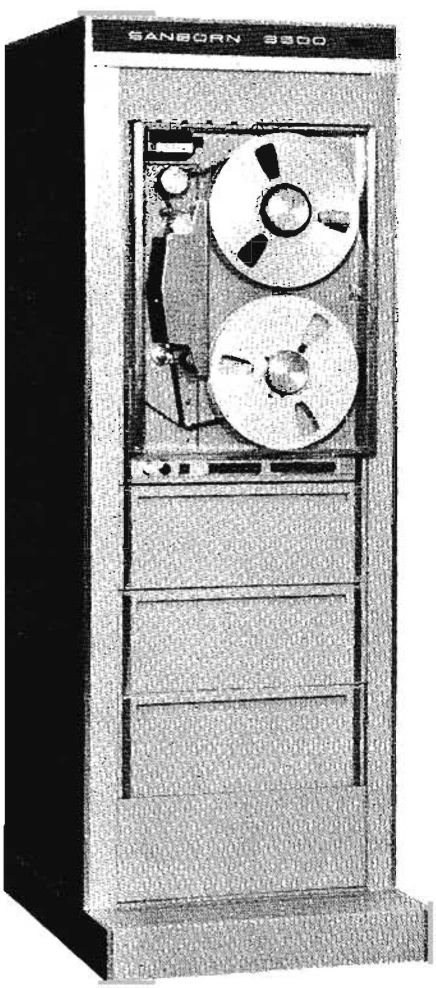
Low-flutter tape transport

The superior performance of these tape recorders is largely due to the unique tape transport that is rugged yet simple in design. They compete in basic characteristics (flutter, s/n ratio, etc.) with the better servo-controlled systems. The transport incorporates the most advanced, simple, direct damping techniques known to minimize flutter, providing as low as 0.2% p-p flutter over 0 to 200 cps bandwidth at 30 and 60 ips. The heads also provide extremely low cross-talk levels, which is highly desirable when Direct and FM channels are mixed on the same head stack, and the high output results in excellent Direct record signal-to-noise ratios. All models, except Option 3, have an additional edge track for voice commentaries, or pulsed or time-coded data. The tape guide system will accept any standard recording tape on 10½" reels. Other important elements of this carefully designed transport are a built-in footage counter accurate to 99.95%; a very simple snap-on reel holder mechanism, and single-side drive provides for

NEW



3907A Standard Bandwidth Recorder



NEW

3924A Extended Bandwidth Recorder

simple tape threading. All speeds selected electrically by front-panel pushbuttons, which apply voltage directly to the proper winding of one of three dual-winding drive motors, and the same capstan and idler serve all tape speeds.

Interchangeable electronics

Three modes of operation make 3907A, 3914A very versatile and flexible recording instruments. Interchangeable FM, Direct and Pulse record/reproduce inserts, with all solid-state electronics, plug into the insert rack and transfer chassis below the transport on the front panel (two racks are used in the 14-channel 3914A). The electronics can be all alike or mixed as required. Frequency compensation for any of the six speeds is available through small plug-in circuits that attach to the FM and Direct reproduce electronics in the inserts . . . frequency compensation is not required with Pulse record/reproduce inserts. (The individual reproduce preamplification for each channel is provided through a preamplifier card near the head assembly.)

Time scale expansion/reduction

In addition to their ability to cover accurately a broad range of frequency response requirements, 3900 recorders' wide speed range can be used to increase or decrease the record/reproduce time scale to a maximum of 32:1 to make data analysis more convenient. For instance: a 10 cps signal recorded at 1⅞ ips would appear as 320 cps played back at 60 ips increasing the scanning rate 32 times. Conversely, a 320 cps signal recorded at 60 ips could be played back as a 10 cps signal at 1⅞ ips into any Sanborn heated stylus recorder for a permanent record and immediate analysis (see pages 364-379). Fourteen channels of Direct mode taped data, as high in frequency as 100 kc, can be played back at reduced speeds and immediately read out by traces greater than 4" p-p on a Sanborn 4500 optical, multichannel recorder (see pages 381-383) which has 0 to 5 kc frequency response 3 db down. Other readout methods such as Sanborn 5601A multi-channel numerical display which is capable of driving hp 562A Digital Recorder (printout) can be used directly with Sanborn magnetic tape recorders.

Other combinations of input and readout equipment are compatible with Sanborn 3900 Series Instrumentation Tape Recorders; for more data call your local hp sales office.

Optional operating accessories

The versatile 3907A and 3914A may be operated at remote locations through Sanborn 3907-11A Remote Control Panel(s) that include all functions: stop, play, reverse, fast, forward and record; and Sanborn's 3907-06A Voice Channel Amplifier can be added to the cabinet when it is desireable to record commentaries at the same time that data is being recorded; edge tracks are standard in all transports except Option 3 recorder. Single-ended signals can be connected directly to these recorders, or Sanborn Input Signal Coupler 3907-07A may be used to adapt push-pull output to the signal-ended input to the 3900 systems. Sanborn Tape Adapters (3907-04A for ½" tape, 3914-04A for 1" tape) are capable of repetitive playback of tape loops up to 100 feet long.

A complete system

A complete system includes the multi-track tape transport, insert rack(s) and transfer chassis, preamplifier rack, power supply, 7 or 14 reproduce preamplifiers and the cabinet. Record/reproduce electronics can be purchased for FM, Direct or Pulse operation in any combination, with speed equalization plug-ins for the speeds at which you wish to record. In Pulse mode plug-ins are not required.

3917A/3924A Extended Bandwidth Recorders

New Sanborn 3917A, 3924A extended bandwidth 7- and 14-channel magnetic tape systems will record and store information with bandwidths to 250 kc maximum on Direct mode and to 20 kc max in FM mode. These broadband recorders permit the use of lower tape speeds for most data recording purposes or as much as 2.5 to 1 increase over narrow band systems in the quantity of data stored for the same operating speed. Sanborn 3900-12B Direct and 3900-13B FM Record/Reproduce broadband amplifier inserts and compatible speed equalization plug-ins (see page 389) are required—the reproduce preamplifier in these recorders has an additional stage for the higher gain/bandpass product requirements.

Direct mode

When 3900 Recorders are used in Direct mode, data can be recorded and reproduced, from 50 to 100 kc using narrow band 3907A, 3914A Systems; from 50 to 250 kc using extended bandwidth 3917A, 3924A Systems. Printed circuit Direct amplifier inserts with combined Direct record/reproduce circuits are available for all channels. The record section conditions the input signal to the record heads, applying signals proportional to the ac input signal to each track used on the tape. These signals can be played back through the reproduce section of the amplifier insert and displayed (on suitable equipment) as ac output voltages proportional to the input signal originally recorded. To provide ample gain and assure high signal-to-noise ratios each channel is supplied with a reproduce preamplifier card which precedes the reproduce circuit. Since bandwidth is primarily a function of tape velocity, that part of the reproduce amplifier having to do with bandwidth is made interchangeable for each speed by the use of speed equalization plug-ins (Sanborn 2000-1200-C2 to C7, for 3907A, 3914A; 3900-21A to -26A for 3917A, 3924A).

FM mode

FM record/reproduce amplifier inserts, 3900-13A, 3900-13B, convert input signal voltages into frequencies which are proportional to the reference carrier frequency. As such, this mode is ideal for recording data at dc levels, low ac

Direct record/reproduce

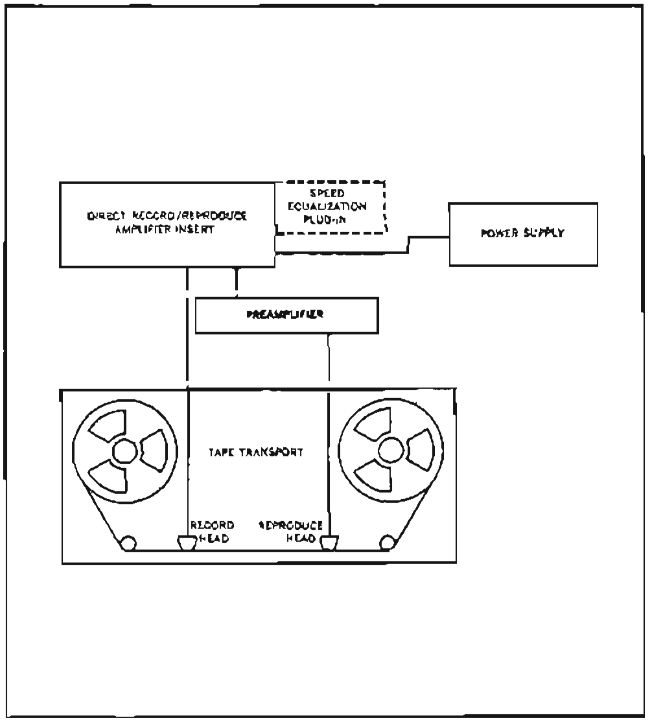


Figure 1.

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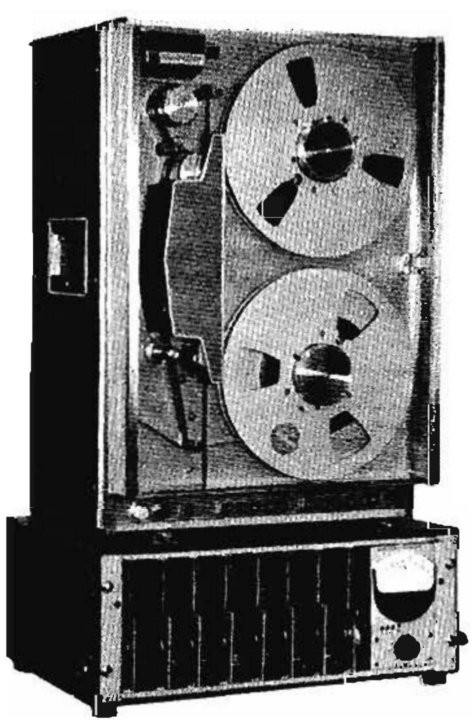
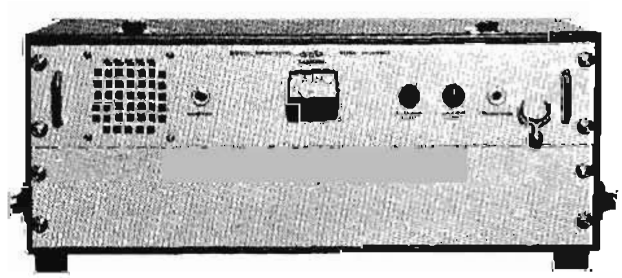


3907A, Option 2 Portable System



3907-06A Voice Channel Amplifier.

frequencies and where accurate preservation of waveshape is desired. The 3907A, 3914A narrow band system's bandpass is 0 to 10 kc and the extended bandwidth 3917A, 3924A bandpass extends from 0 to 20 kc. Full-scale output voltage in this mode produces ±40% deviation in carrier frequency sufficient to give perfect reproduction of the input at the output (a linear frequency-voltage relationship). Signals fed to the record head are square waves of current, sufficient in amplitude to cause the tape to saturate on alternate half cycles so that the output appears as alternate positive and negative pulses. On playback the pulses are picked up by the reproduce head, preamplified and then amplified, clipped and demodulated in the reproduce section of the FM inserts. And, as in the Direct mode, that part of the reproduce amplifier having to do with bandwidth is an attaching plug-in to the amplifier insert. There is an FM mode frequency-compensating plug-in for each of the six standard speeds which provides suitable modulation and demodulation frequency characteristics and output filtering to assure reproduction proportional to input.

FM record/reproduce

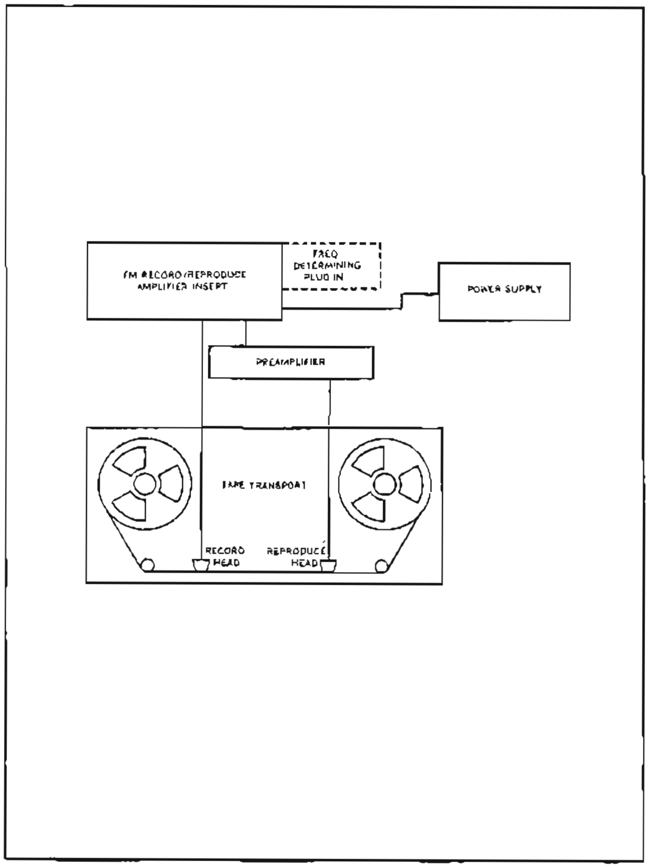


Figure 2.

Pulse mode

Standard 3907A, 3914A recorders also have electronics for recording rectangular pulses from digital output devices through Sanborn 2000-1400-1 Pulse Record/Reproduce Amplifier Inserts. Plug-ins are not required. Recording at one speed and playing back at another is possible; maximum rise time and minimum input pulse duration at the six tape speeds are tabulated in the specifications.

System features

The electronics in the 3900 Recorders can be conveniently and simply aligned, as well as interchanged between FM, and Direct or Pulse (3907A, 3914A only) modes of operation at the front panel. The insert rack and transfer chassis, located directly below the tape transport, contains the power supply and accommodates seven printed-circuit card record/reproduce amplifier inserts with plug-in speed equalization circuits. An eighth position is reserved for recording systems (all but Option 3) that have provision for voice commentaries through an edge track on the heads. Direct record/reproduce amplifier inserts (with speed equalization plug-ins) are required for voice channels. The reproduce amplifiers on the record/reproduce inserts for each channel are subdivided into three sections—preamplifier (fixed), main amplifier on record/reproduce inserts (interchangeable FM, Direct or Pulse), and plug-in bandpass circuits which equalize the system gain, (Direct) or frequency (FM) for all tape speeds. The preamplifiers provide high signal-to-noise ratios.

The all solid-state power supply on the insert rack and transfer chassis delivers regulated operating voltages to all of the electronics in the recorder. Supply voltages can be measured at test points on the front panel, and a built-in alignment meter and channel selector switch makes setting the center frequency and modulation sensitivity of each FM channel a simple procedure.

When it is desirable to cancel the small amount of noise introduced by transport flutter in FM operation (see specification on page 388) channel 3 and/or 10 in 14-channel systems can be reserved to record and play back an unmodulated carrier signal which helps to cancel noise in the output in any of the other channels. Placing the compensation switch on in the rear of the insert rack and transfer chassis applies a negative fed signal to the output of each of the other channels, effectively cancelling the flutter signal and increasing the signal-to-noise ratio over the bandwidth on all tape speeds.

Specifications, tape transport

(all models, unless otherwise specified)

The tape transport provides tape motion for all modes of operation and assures smooth, positive movement of the tape across the head assembly; operating controls are located on the front panel.

Number of tracks: 7 (3907A, 3917A); 14 (3914A, 3924A).

Track width: 0.05".

Track spacing: 0.07" center-to-center.

Max. interchannel time displacement error: ±1 μsec at 60 ips, between two adjacent tracks on same head.

Tape speeds: 60, 30, 15, 7½, 3¾, 1⅞ inches per sec.

Tape width: ½" (3907A, 3917A); 1" (3914A, 3924A).

Tape thickness: 1 mil.

Tape length: 3600 feet, 1 mil tape.

Reel size: 10½" phenolic hub type.

Start time: approx. 4 sec max.

Stop time: 1 second max.

Rewind time: approx. 150 seconds (3600 feet).

Operating controls: Line (Power), Stop, Play, Reverse, Forward (fast), Record, are pushbutton relays; receptacle at the rear of the transport is provided for remote control operation.

Drive speed accuracy: ±0.25% of nominal capstan speed with 60 cps line; speed is directly proportional to line frequency.

Speed	Bandwidth	Flutter (p-p)
60 ips	0 to 200 cps 0 to 1.5 kc 0 to 10 kc	0.2% 0.3% 0 6%
30 ips	0 to 200 cps 0 to 1.5 kc 0 to 5 kc	0.2% 0.5% 0.8%
15 ips	0 to 200 cps 0 to 1.5 kc 0 to 2.5 kc	0.25% 0.45% 0.6%
7½ ips	0 to 200 cps 0 to 1.25 kc	0.4% 0.65%
3¾ ips	0 to 200 cps 0 to 625 cps	0.5% 0.8%
1⅞ ips	0 to 200 cps 0 to 132 cps	0.8% 1.2%

Specifications, 3907A, 3914A
Direct Record/Reproduce mode

Record amplifier input: 20,000 ohms resistance, single-ended; 0.5 to 10 volts rms, adjustable.

Reproduce amplifier output: single-ended; 1 v rms to 2.1 v rms at ±3 ma, 100-ohm max. source impedance; dc level adjustable ±1.5 v.

Third harmonic distortion: typical, 1% at 1 kc, 60 ips.

Direct, standard bandwidth

Tape speed	Bandwidth	Frequency response	S/N ratio minimum rms*
60 ips	100-100,000 cps 300-70,000 cps	±3 db	40 db 45 db
30 ips	100-50,000 cps 300-35,000 cps	±3 db	42 db 47 db
15 ips	50-25,000 cps 300-16,000 cps	±3 db	40 db 47 db
7½ ips	50-12,000 cps 300-7,200 cps	±3 db	40 db 47 db
3¾ ips	50-6,250 cps 300-3,800 cps	±3 db	40 db 47 db
1⅞ ips	50-3,125 cps 300-2,200 cps	±3 db	40 db 45 db

* Measured with bandpass filter at output with an 18 db/octave rolloff.

FM Record/Reproduce mode

Record amplifier input: 20,000 ohms impedance, single-ended; ±2.5 volts dc (nominal), adjustable ±1.2 to ±3 volts dc.

Reproduce amplifier output: single-ended; ±2.5 volts dc (nominal) at ±3 ma max. adjustable ±1.2 to ±5 volts dc; 100 ohms max. source impedance; dc position adjustable ±2 volts dc.

Drift: ±0.25% max. for 10°C change, 15° to 35°C; ±0.25% max. for 10 volt change in line voltage.

FM, standard bandwidth

Tape speed	Bandwidth	Frequency response	FM center carrier frequency (nominal)	S/N ratio* without flutter comp.	S/N ratio* with flutter comp.**	Total harmonic distortion
60 ips	0–10 kc	+0, −1 db	54 kc	45 db	48 db	1.2%
30 ips	0–5 kc	+0, −1 db	27 kc	45 db	49 db	1.2%
15 ips	0–2500 cps	+0, −1 db	13.5 kc	45 db	49 db	1.2%
7½ ips	0–1250 cps	+0, −1 db	6.75 kc	42 db	47 db	1.5%
3¾ ips	0–625 cps	+0, −1 db	3.38 kc	42 db	47 db	1.5%
1⅞ ips	0–312 cps	+0, −1 db	1.69 kc	40 db	41 db	1.5%

* Over bandwidth, min. rms at zero frequency deviation measured with low-pass filter at output with an 18 db/octave rolloff.
** Channel 3 and/or 10 provide flutter compensators.

Specifications, 3917A, 3924A
Direct Record/Reproduce mode

Record amplifier input: 20,000 ohm resistance, single-ended; 0.5 to 10 volts rms, adjustable.

Record amplifier output: single-ended; 1 volt rms to 2.1 volts rms at ±3 ma; 100-ohms max. source impedance; dc level adjustable ±1.5 volts.

Third harmonic distortion: typical, 1% at 500 cps, 30 ips.

Direct, extended bandwidth

Tape speed	Bandwidth	Frequency response	S/N ratio filtered*	Minimum rms unfiltered
60 ips	300–250 kc 300–175 kc	±3 db	35 db 36 db	28 db
30 ips	150–125 kc 300–88 kc	±3 db	33 db 36 db	28 db
15 ips	100–62.5 kc 300–44 kc	±3 db	32 db 38 db	27 db
7½ ips	50–31.25 kc 300–22 kc	±3 db	30 db 39 db	26 db
3¾ ips	50–15.6 kc 300–11 kc	±3 db	30 db 39 db	26 db
1⅞ ips	50–7 kc 300–5 kc	±3 db	30 db 39 db	26 db

* Measured with bandpass filter at output with an 18 db/octave rolloff.

FM Record/Reproduce mode

Record amplifier input: 20,000 ohms impedance, single-ended; ±2.5 volts dc (nominal), adjustable ±1.2 to ±3 volts dc.

Reproduce amplifier output: single-ended; ±2.5 volts dc (nominal) at ±3 ma max., adjustable ±1.2 to 5 volts dc; 100-ohms max. source impedance; dc position adjustable ±2 volts dc for positioning optical or direct-writing galvanometers.

Drift: ±0.25% max. for 10°C change, 15° to 35°C; ±0.25% max. for 10 volt change in line voltage.

FM, extended bandwidth

Tape speed	Bandwidth	Frequency response	FM center carrier frequency (nominal)	S/N ratio* without flutter comp.	Total harmonic distortion
60 ips	0-20 kc	+0, −1 db	108 kc	45 db	1.5%
30 ips	0-10 kc	+0, −1 db	54 kc	45 db	1.5%
15 ips	0-5 kc	+0, −1 db	27 kc	45 db	1.5%
7½ ips	0-2500 cps	+0, −1 db	13.5 kc	44 db	1.5%
3¾ ips	0-1250 cps	+0, −1 db	6.75 kc	42 db	1.5%
1⅞ ips	0-625 cps	+0, −1 db	3.38 kc	40 db	1.8%

* Over bandwidth, min. rms at zero frequency deviation measured with low-pass filter at output with an 18 db/octave rolloff.

Specifications, 3907A, 3914A
Pulse Record/Reproduce mode

Record amplifier input: rectangular, zero-based negative-going pulse, −7.5 to −30 volts final amplitude; rise and fall times are not important except when they influence timing of recorded signal; no upper limit on pulse duration.

Reproduce amplifier output: rectangular zero-based negative-going pulse approximately −11.8 volts final amplitude across open circuit; output signal amplitudes, and rise and fall times are not related to input signals except as noted above; single-ended source resistance 1000 ohms max., may be loaded i.e., approximately 6 volts output with 1000-ohm load.

Pulse, standard bandwidths

Record and playback at	Max. rise time (micro-sec)	Min. input pulse for output pulse accuracy (duration) (μsec)	Accuracy of pulse reproduction (μsec)	Typ. min. input pulse for any output (μsec)
60 ips	4	50	±5	10
30 ips	4	100	±10	15
15 ips	5	200	±20	25
7½ ips	10	400	±40	35
3¾ ips	20	800	±80	50
1⅞ ips	40	1600	±160	70

Specifications, all models

Power: 115 volts ±10%, 60 cps ±2%; approximately 500 watts.

Dimensions: in mobile cabinet: 57¾" high, 22" wide, 26" deep (1368 x 559 x 660 mm); rack mount Option 1: 24-15/32" high, 19" wide, 14" deep (622 x 483 x 356 mm) transport; 7" high, 19" wide, 13⅞" deep (178 x 483 x 352 mm) insert rack and transfer chassis; portable cabinets Option 2: 25" high, 19⅝" wide, 15¾" deep (638 x 500 x 400 mm) transport; 7-9/16" high, 19⅝" wide, 14½" deep (192 x 500 x 368 mm) insert rack and transfer chassis; Sanborn 3907-04A, 3914-04A, ½" and 1" Tape Loop Adapters fit on left side of cabinet.

Weight (approx.)

Typical for 3907A, 3917A: net 310 lbs (140,7 kg), shipping 500 lbs (227 kg); rack mount Option 1: net 90 lbs (31,8 kg), shipping 95 lbs (43,1 kg) transport; net 30 lbs (13,6 kg), shipping 35 lbs (15,9 kg); insert rack and transfer chassis; portable carrying cases Option 2: net 80 lbs (36,3 kg), shipping 100 lbs (45,4 kg) transport; net 35 lbs (15,9 kg), shipping 40 lbs (18,2 kg) insert rack and transfer chassis.

Typical for 3914A, 3924A: net 340 lbs (154,3 kg), shipping 575 lbs (261,1 kg); rack mount Option 1: net 75 lbs (34,2 kg), shipping 100 lbs (45,4 kg) transport; net 60 lbs (27,2 kg), shipping 70 lbs (31,8 kg) insert racks and transfer chassis; portable carrying cases Option 2: net 85 lbs (38,6 kg), shipping 105 lbs (47,8 kg) transport; net 70 lbs (31,8 kg), shipping 80 lbs (36,4 kg) insert racks and transfer chassis.

Optional accessory equipment: 3907-07A Input Signal Coupler, less input cards, $395 (adapts equipment with push-pull output to single-ended input of 3900); 3907-11A Remote Control Panel (less cable), $100; 3907-06A Voice Channel Amplifier (includes microphone), $250; can be used on any channel with Option 3 Direct mode record/reproduce inserts and proper speed equalization plug-ins, or with Options 1 and 2 which have edge tracks in heads for voice commentaries but which require one 3900-10A Reproduce Preamplifier, $40, one 3900-12A Direct Record/Reproduce Insert, $155 or 3900-12B, $170; and one 3907-04A Direct Equalization Plug-in (see prices below) for the eighth channel, $600; 3914-04A Tape Loop Adapters for repetitive playback up to 100 feet of ½" and 1" tape respectively, $750.

Accessories

Heavy duty instrumentation tape: 37T-4, ½" (for 3907A) 1 mil, 3600' on phenolic hub reels; 1 to 9, $37.75 ea., 10 to 49, $35.80 ea., 50 or over, $33.80 ea.; 37T-9, 1" (for 3914A) 1 mil, 3600' on phenolic hub reels; 1 to 9, $68.75 ea., 10 to 49, $65.30 ea., 50 or over, $61.90 ea.

High performance instrumentation tape: (for 3917A and 3924A only) 37T-17, ½" 1 mil 3600' on phenolic hub reels; 1 to 9, $50.60 ea., 10 to 49, $49.35 ea., 50 or over, $48.18 ea.; 37T-16, 1" 1 mil 3600' on phenolic hub reels; 1 to 9, $91.30 ea., 10 to 49, $89 ea., 50 or over, $86.80 ea.

Empty reels: 37A-4, 10½" diam, phenolic hub for ½" tape, $6 ea.; 37T-15, 10½" diam, phenolic hub for 1" tape, $7.50 ea.

Optional accessories: 37T-7 splicing tape, ½" Mylar, 100 + feet, $1.55; 48A-13 bulk eraser, Cinema Type 9205A, $100; 48A-14, head demagnetizer, Robins Type HD-6, $11.50; 48A-15, ½" tape splicer, Robins Type TS-500, $75; 01060-69010 Cabinet Dust Cover, gabardine, $16.

Prices: Note 1: Sanborn 3907A (less 7-channels of record/reproduce amplifier inserts and associated equalization plug-ins), $6185; Sanborn 3917A (less 7-channels of record/reproduce amplifier inserts and associated equalization plug-ins), $6935; Sanborn 3914A (less amplifier inserts and plug-ins), $8415; Sanborn 3924A (less amplifier inserts and plug-ins), $9915.

Option 1: same as above, less cabinet but including all hardware for 19" rack mounting: 3907A Option 1, $5680; 3914A Option 1, $7910; 3917A Option 1, $6430; 3924A Option 1, $9410.

Option 2: same as above but mounted in portable cabinets: 3907A Option 2, $6185; 3914A Option 2, $8415; 3917A Option 2, $6935; 3924A Option 2, $9915.

Option 3: same as above but less monitoring track: deduct $135 from standard and optional models prices above.

Electronics standard bandwidth recorders: Sanborn 3900-12A (Direct record/reproduce insert less plug-in), $155 ea; plug-ins: Sanborn 2000-1200-C2 for 1⅞ ips, $35; 2000-1200-C3 for 3¾ ips, $30; 2000-1200-C4 for 7½ ips, $30; 2000-1200-C5 for 15 ips, $30; 2000-1200-C6 for 30 ips, $30; 2000-1200-C7 for 60 ips, $30; Sanborn 3900-13A (FM record/reproduce insert less plug-in), $180 ea; plug-ins: Sanborn 2000-1300-C2 for 1⅞ ips, $60; 2000-1300-C3 for 3¾ ips, $40; 2000-1300-C4 for 7½ ips, $40; 2000-1300-C5 for 15 ips, $40; 2000-1300-C6 for 30 ips, $40; 2000-1300-C7 for 60 ips, $40; Sanborn 2000-1400-1 (Pulse record/reproduce insert no plug-ins required), $60 ea.

Electronics extended bandwidth recorders: Sanborn 3900-12B (Direct record/reproduce insert less plug-in), $170 ea; plug-ins: Sanborn 3900-21A for 1⅞ ips; $35; 3900-22A for 3¾ ips, $30; 3900-23A for 7½ ips, $30; 3900-24A for 15 ips, $30; 3900-25A for 30 ips, $30; 3900-26A for 60 ips, $30; Sanborn 3900-13B (FM record/reproduce insert less plug-in), $190 ea; plug-ins: Sanborn 2000-1300-C3 for 1⅞ ips, $40; 2000-1300-C4 for 3¾ ips, $40; 2000-1300-C5 for 7½ ips, $40; 2000-1300-C6 for 15 ips, $40; 2000-1300-C7 for 30 ips, $40; 2000-1300-C11 for 60 ips, $40.

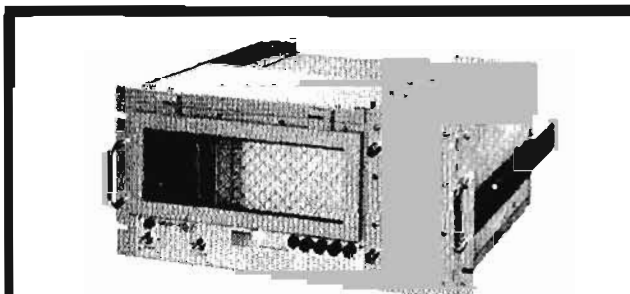
Note 1: add price of inserts and plug-ins times the number of channels and speeds you require to the basic assembly price above for complete system cost.

360, 361 EVENT RECORDING SYSTEMS

Record wide range of two-state events on 30, 60, 90 or 120 channels

Sanborn 360, 361 Recording Systems will monitor the on/off status of multiple events simultaneously, providing instantaneous, permanent, sharp traces on electro-sensitive paper. Pulsed writing provides constant trace density over the full paper speed range, reduces power consumption and extends the life of the writing styli. To serve a wide range of input signal modes, levels and applications, Sanborn offers 7 interchangeable 10-channel writing controls, each of which isolates the input signal from chassis.

Model 361 is a compact 30-channel recorder with built-in paper take up and front-panel access to plug in three plug-in writing control cards. Model 360 can monitor a maximum of 120 channels of data, but also is offered with one or two 30-channel modules removed for 60- or 90-channel applications. Up to 12 writing control cards fit into optional companion power supply and card rack, Model 360-500-1. Model 360 can be used without writing control or associated power supply by simple contact closure.



361

Specifications

Paper speeds: (selected by pushbuttons) 360: 0.5, 1, 2, 5, 10, 20, 50, 100, 200 mm/sec; (optional 360-1 Recorder has 9 additional mm/minute speeds); 361: 1, 5, 20, 100 mm/sec (other combinations on special order); provision for optional remote operation in all models.

Paper capacity: 360: 120-channel roll 16" (403 mm) wide, 450' (117 m) long; 361: 30-channel roll 4" (104 mm) wide, 275' (69.9 m) long; footage indicator included in 360.

Styli (both models): individually replaceable or reversible, mounted in plug-in module holding 30 styli.

Signal input capability: see table.

Timing (optional): 360, 361: 1 sec timer can be ordered or added in field; time marks can be made on one or more channels; 360-1 accommodates optional 1 sec and 1 min timers.

Time resolution: can respond to events as brief as 1.3 msec, with all Sanborn writing controls, at max. chart speed.

Time duration accuracy: combined error, chart drive and paper, does not exceed 1%; all other errors, ±0.5 mm combined.

Simultaneous events: error typically less than 0.25 mm; max. between any two channels 1.25 mm.

Operating environment: 0 to 40°C; 0 to 55°C when 360 is used with only 360-3100 writing control cards.

RF shielding: meet MIL-I-26600/2 Class 1B on conducted and radiated interference.

Power: 360, 360-1: 105 to 125 volts, 60 cps, 3.1 amp (230/115 volts, 50 cps special order); power supply for writing controls (360-500-1): 103 to 127 volts, 50 to 400 cps, 150 watts (230 to 115 volts ac special order); 361: 103 to 127 volts, 60 cps (230 to 115 volts, 50 cps special order).

Dimensions: rack mounts: 360, 360-1 recorders: 14" high, 19" wide, 21" deep (356 x 483 x 533 mm); 360-500-1 writing control power supply and rack module (for 360, 360-1): 7" high, 19" wide, 17-13/16" deep (178 x 483 x 453 mm); 361 recorder: 8¾" high, 19" wide, 14½" deep (222 x 483 x 368 mm); portables: 360: 15¾" high; 19" wide, 21" deep (400 x 483 x 533 mm); 360-500-1: 7-9/16" high, 22" wide, 21½" deep (193 x 559 x 456 mm); 361: 8¾" high, 19" wide, 15½" deep (248 x 483 x 394 mm).

Weight (approx.): 360, 360-1: net 130 lbs (58.5 kg), shipping 175 lbs (78.8 kg); 360-500-1: net 42 lbs (18.9 kg), shipping 60 lbs (27.0 kg); 361: net 50 lbs (22.5 kg), shipping 60 lbs (27 kg) (rack mount); portable cases, accessory weights on request.

Accessories available: 3E-2 30-channel, 275 ft. roll electro-sensitive paper, $12.20; 3E-1 120-channel, 450 ft. roll, $45; 412-2 electric writing styli, $4.50 each. 360-1100 Upright Cabinet for 360, 360-1, $350; carrying cases: 360-1400, $200 (360, 360-1 recorder); 858-1400, $150 (pwr supply and rack module, 360-500-1); 361-1400, $125 (361 recorder); regulator card for 360, 360-1. 361 power supplies for every three 360-2200, -2500 writing control cards, $125; timers, threshold calibrator, speed kits quoted on request.

Prices: Sanborn 360, $3900; Sanborn 360-1, $4150; Sanborn 360-500-1 (pwr supply and rack module for 360, 360-1), $950; Sanborn 361, $1575; writing control cards as required, see prices in chart.

Sanborn model	Positive input 360-2600	Negative input 360-2700	Stylus pair 360-2800	Jumper card 360-2900	Floating input 360-3100	Adjustable threshold 360-2200**	Balance input 360-2500**
Max./min. input signals to record events	trace: +6 v dc; no trace: less than +1 v dc or open ckt.; +40 and −15 v dc max.	trace: −6 v dc; no trace: more (+) than −1 v dc or open ckt.; −40 and +15 v dc max.	trace (+ inputs): on even channels when input is open or below +1 v dc; trace on odd channels when input is above +6 v dc; trace (− inputs): on odd channels when input is open or more (+) than −1 v dc; trace on even channels with −6 v dc or more (−)	---	trace: terminal B must be (+) with respect to A (+5 to +40 v dc); no trace: terminal B must be −15 to +1 v dc with respect to A	trace (− mode): voltage should be more (−) than threshold; trace (+ mode): voltage should be more (+) than threshold; 100 mv (typ.) change will switch trace on or off	trace: terminal A (+) with respect to B; 50 mv (typ.) differential required for trace or no trace when either terminal to signal gnd. is within ±25 v
Input resistance	15 K (nom.) to signal ground	15 K (nom.) to signal ground	8 K (nom.) to signal ground	---	27 K (nom.)	40 K (nom.) to signal ground	40 K (nom.) to signal ground
Notes*	self-testing switch permits "mark" test on installation	self-testing switch permits "mark" test on installation	adjacent channels monitor single event, 1 channel should always show trace; two traces or no trace shows failure; switch for (+), (−) input/self-testing	10-channel jumper for external contact closures to any group of 10 styli; max. external capacitance from each stylus lead to gnd. not > 1500 pf at 115 v ac	provides each channel with true floating two-wire input isolated from chassis; pwr supply not required in Model 360-500-1	indicates when channel voltage is above or below preset threshold (adj. ±20 v dc), ±100 mv (max.) drift for 25 to 60°C change inside rack	each channel has two input terminals
Price	$225	$225	$225	$25	$225	$575	$575

FUNCTION INDEX

NUMERICAL INDEX

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