1961

ELECTRONIC TEST INSTRUMENTS

HEWLETT-PACKARD COMPANY

FOUR EASY WAYS TO USE THIS CATALOG

1. Check headings on opposite page for general type of instrument you are seeking.

2. Turn the page opposite for four pages of "Short Form Catalog" listing hp instruments by type or function (example —"Signal Generators 50 KC to 40 GC").

3. Find equipment by its model number in the numerical index, back of this catalog (example —"hp 411A Voltmeter").

4. Find equipment sought by its name or title, alphabetical index, back of this catalog (example—"Digital Voltmeter").

OTHER IMPORTANT INFORMATION

PLACING YOUR ORDER OR RETURNING INSTRUMENTS. Page 6 contains time-saving suggestions for ordering. Pages 5 and 6 have information on service and repairs.

hp DIVISIONS, SUBSIDIARIES. Page 4 contains brief data about equipment available from, and communications with Dymec, a Division of Hewlett-Packard Co. *(see also pages 195-210),* and Palo Alto Engineering Company, a subsidiary.

OTHER INFORMATION ON hp INSTRUMENTS. In addition to data contained in this Catalog, information about application and operation of hp equipment is found in hp Data Sheets, Application Notes and the Hewlett-Packard Journal, monthly technical periodical from the hp Research and Development laboratories. These publications are offered without charge; see page 7 for details.

COMMUNICATING WITH HEWLETT-PACKARD

Mail: 1501 Page Mill Road, Palo Alto, California, U. S. A.
Telephone: DAvenport 6-7000, Palo Alto. Area Code 415.
TWX: PAL AL 02.
Cable: HEWPACK

COMMUNICATING WITH hp ENGINEER-SALESMEN

hp engineer-salesmen are located in most major manufacturing centers in the United States and Canada, and principal cities overseas. Names and complete addresses of Hewlett-Packard representatives are listed inside the back cover of this catalog.

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Mail: Rue du Vieux Billard No. 1, Geneva, Switzerland.
Telephone: No. (022) 26. 43. 36.
Telex: No. 2. 24. 86.
Cable: HEWPACKSA.

ⓗⓟ instruments in this catalog are grouped by type or function. Each group is generally preceded by "Applications Data" pages which summarize ⓗⓟ equipment offered in the group, and discuss latest measuring techniques.

QUICK-REFERENCE INDEX (See Also Indexes By Model Number and Instrument Name – Pages 212-217)

Oscilloscopes – DC to 1,000 MC

Instrument	Primary Uses	Characteristics	Price	Page
-hp- 120A	General laboratory and production measuring	DC to 200 KC	$ 450.00	16-18
-hp- 122A	General laboratory and production measuring	DC to 200 KC — Dual trace	675.00	16-18
-hp- 130B	General laboratory and production testing	DC to 300 KC — High sensitivity	650.00	20, 21
-hp- 150A	General laboratory high frequency and TV work	DC to 10 MC — Plug-in vertical amplifiers	1,300.00	22, 23
-hp- 151B/154A	Plug-ins for 150A	DC to 10 MC — High sensitivity	—	22, 23
-hp- 160B	Militarized general duty oscilloscope	DC to 15 MC, plug-in versatility	1,850.00	24-27
-hp- 162A	Dual trace plug-in for 160B, 170A	20 mv/cm, high stability	350.00	24-27
-hp- 162F	Fast rise amplifier for 160B, 170A	0.05 v/cm, dc to 30 MC	145.00	24-27
-hp- 166B	Marker generator plug-in for 160B, 170A	Time markers 0.1-10 µsec	130.00	24-27
-hp- 166C	Display scanner for 160B, 170A	Sampling unit for X-Y recording	300.00	24-27
-hp- 166D	Sweep delay generator for 160B, 170A	Main sweep, delaying sweep, main sweep, delayed or mixed	325.00	24-27
-hp- 170A	Militarized high frequency oscilloscope	DC to 30 MC; dual plug-in versatility	2,150.00	24-27
-hp- 185A	Sampling oscilloscope for very fast circuits	DC to 1,000 MC; 5" CRT	2,000.00	28-30
-hp- 187B	Dual trace plug-in for 185A	10 mv/cm to 200 mv/cm	1,000.00	28-30
-hp- 196A	Oscilloscope camera for all -hp- scopes	Prints, transparencies on Polaroid® films.	440.00	31

Oscillators – 0.008 cps to 10 MC

Instrument	Primary Uses	Frequency Range	Output	Price	Page
-hp- 200AB	Audio tests	20 cps to 40 KC	1 watt/24.5 v	$ 165.00*	36, 37
-hp- 200CD	Subsonic through Low rf tests	5 cps to 600 KC	160 mw or 10 v/600 ohms; 20 v open circuit	195.00*	36, 37
-hp- 200J	Interpolation, frequency measurements	6 cps to 6 KC	160 mw/10 v	350.00*	42
-hp- 200SR	Driving -hp- 739AR	5 cps to 600 KC	3 v rms into 50 ohms	230.00	83
-hp- 200T	Telemetry, carrier current tests	250 cps to 100 KC	160 mw or 10 v/600 ohms	500.00*	42
-hp- 201C	High quality audio tests	20 cps to 20 KC	3 w or 42.5 v/600 ohms	250.00*	36, 37
-hp- 202A	Low frequency measurements	0.008 to 1200 cps	28 mw or 30 v p-p/4000 ohms	550.00△	38, 39
-hp- 202C	Servo equipment tests, measurements	1 cps to 100 KC	160 mw or 10 v/600 ohms	300.00*	36, 37
-hp- 204B	Battery operated portable, floating output	5 cps to 500 KC	10 mw or 2.5 v/600 ohms	275.00	43
-hp- 205AG	High power audio tests, gain measurements	20 cps to 20 KC	5 watts	600.00△	48
-hp- 206A	High quality, high accuracy audio tests	20 cps to 20 KC	+ 15 dbm	800.00△	49
DY-207A	Audio sweep generation	20 cps to 20 KC	160 mw or 10 v/600 ohms	325.00	210
-hp- 233A	Carrier oscillator — current tests	50 cps to 500 KC	3 w/600 ohms	650.00	42
-hp- 650A	Wide range video tests	10 cps to 10 MC	15 mw or 3 v/600 ohms	550.00△	40, 41
DY-2200AR	Audio sweep generation	5 cps to 5 KC	10 v into 600 ohms	585.00	210

Voltmeters and Ammeters – DC to 1,000 MC

Instrument	Primary Uses	Frequency Range	Full Scale Range	Input Impedance	Price	Page
-hp- 400D	Wide range ac measurements High sensitivity	10 cps to 4 MC	1 mv to 300 v 12 ranges	10 megohms 15 pf shunt	$ 250.00*	70, 71
-hp- 400H	High accuracy wide range ac measurements	10 cps to 4 MC	1 mv to 300 v 12 ranges	10 megohms 15 pf shunt	325.00*	70, 71
-hp- 400L	High resolution, wide range ac measurements	10 cps to 4 MC	1 mv to 300 v 12 ranges	10 megohms 15 pf shunt	325.00*	70, 71
-hp- 403A	Battery operated portable; fast accurate, hum-free	1 cps to 1 MC	1 mv to 300 v 12 ranges	2 megohms 40, 20 pf shunt	275.00	69
-hp- 405BR/CR	Digital display of dc voltages	DC	3 digits to 999 v automatic range	11 megohms	850.00, 925.00	72
-hp- 410B	Audio, rf, VHF measurements; dc voltages; resistances	DC; ac—20 cps to 700 MC	1 to 300 v AC 1 to 1,000 v DC	DC — 122 megohms; ac—10 megohms/1.5 pf	245.00**	76
-hp- 411A	RF millivoltmeter	500 KC to 1 GC	10 mv to 10 v	—	450.00*	74, 75
-hp- 412A	DC voltage, dc current; ohms	DC	1 mv to 1,000 v 13 ranges	10 to 200 megohms depending on range	400.00*	78
-hp- 413A	DC null voltmeter	DC	1 mv to 1,000 v 13 ranges	10 to 200 megohms depending on range	350.00*	79
-hp- 425A	Low dc voltages and current	DC	10 µv to 1 v 11 ranges	1 megohm ± 3%	500.00*	77
-hp- 428A/B	DC current measurements	DC	3 ma to 1 amp 1 ma to 10 amp	—	500.00* 550.00*	80, 81
-hp- 456A	AC Current Probe	Converts amps to v for direct current readings on scope, VTVM			190.00	82
-hp- 457A	AC-to-DC converter	50 cps to 500 KC	1 to 300 v AC 0-1 v DC output	1 megohm, 30 pf shunt	—	73
-hp- 452A-470A	Voltmeter Accessories, including Dividers, Multipliers, Shunt Resistors and Connectors				—	84
-hp- 738AR	Voltmeter Calibrator	DC; 400 cps sine wave	300 µv to 300 v	Works into 3 to 10 megohms	875.00	83
-hp- 739AR	Frequency Response Test Set	5 cps to 10 MC (with 200SR)	3 v output	—	525.00	83
DY-2210/2211	Voltage-to-Frequency Converter	10 KC/100 KC	0.1 to 1,000 v	1 megohm 200 pf shunt	650.00 1,250.00	200
DY-2401	Integrating Digital Voltmeter	DC	0.1 to 1,000 v	1 megohm	3,750.00	201
DY-2410	Multiconverter	100 KC	0.1 to 1,000 v	1 megohm	1,975.00	201

Distortion, Wave Form Analyzers – 20 cps to 50 KC

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 302A	Waveform analyzer	20 cps to 50 KC	Measuring range 30 µv to 300 v oscillator-tuned voltmeter	$1,800.00△	60, 61
-hp- 330B/C/D	Audio distortion; AM, FM monitor	20 cps to 20 KC	Includes input amplifier, VTVM	—	62, 63

△Rack mounted instrument available for $15.00 less. *Rack mounted instrument available for $5.00 extra. **Rack mounted instrument available for $20.00 extra.

Frequency Measuring, Monitoring Equipment

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 100E Frequency Standard	Establish standard frequencies; calibrate, measure time	6 sine 10 cps to 1 MC; 4 pulse, 10 cps to 10 KC	Stability $5/10^8$ per week Timing comb	$ 925.00■	125
-hp- 101A Oscillator	1 MC time base	1 MC (fixed)	Stability $5/10^8$ per week	500.00	125
-hp- 103AR Quartz Oscillator	Frequency and time standards	1 MC and 100 KC (fixed)	Stability $5/10^{10}$ per day	2,500.00	121
-hp- 104AR Quartz Oscillator	Frequency and time standards	5 MC, 1 MC and 100 KC (fixed)	Stability $5/10^{10}$ per day	3,250.00	121
-hp- 113BR Frequency Divider and Clock	Adjust freq. standards; comparisons	——	100 KC input	2,750.00	122
-hp- 114BR Time Comparator	Time comparisons in time standard systems	——	Provides 0 to 999 msec delay in one msec steps	1,200.00	123
-hp- 500B/C Electronic Frequency Meter	Rapid frequency measurements	3 cps to 100 KC, 180 to 6,000,000 rpm	9 ranges ±2% accuracy. Input 0.2 to 250 volts	300.00*	96, 97
-hp- 506A Optical Tachometer Pickup	Rps and rpm measurement	180 to 300,000 rpm	Phototube and light source; output 1 v rms	150.00	98
-hp- 508A-D Tachometer Generators	Shaft speed measurement	30 to 40,000 rpm	Output 60, 100, 120, 360 cycles/rev.	125.00	98
-hp- 520A Nuclear Scaler	For counting high-rate pulses	Capacity 100 counts in 2 decades. 10,000,000 pps counting rate	100:1 divider for operation of low speed scalers	700.00△	101
-hp- 521A, C, D, E Industrial Electronic Counters	Measure frequency, speed, elapsed time	1 cps to 120 KC	Direct reading, good accuracy, 4 or 5 place in-line or columnar readout	475.00 to 950.00*	99
-hp- 521G Electronic Counter	Measure frequency, speed, elapsed time	1 cps to 1.2 MC	Direct reading, accuracy ± 1 count ±0.1%. 5-place registration	700.00*	99
-hp- 522B Electronic Counter	Frequency, period, time interval measurements	10 cps to 120 KC	5 digits, stability 10/million per week	915.00△	100, 101
-hp- 523C Electronic Counter	Frequency, period, time interval	10 cps to 1.2 MC	6 digit nixie stability $2/10^6$/week	1,575.00■	102, 103
-hp- 523D Electronic Counter	Frequency, period, time interval	10 cps to 1.2 MC	6 digit neon stability $2/10^6$/week	1,310.00■	102, 103
-hp- 5212/5512 Transistorized Counters	Measures frequency, period, ratio	2 cps to 300 KC	5 digit resolution, transistorized unit	975.00, 1,175.00	107 - 109
-hp- 5232/5532 Transistorized Counters	Measures frequency, period, ratio	2 cps to 1.2 MC	6 digit resolution, transistorized unit	1,300.00, 1,550.00	107 - 109
-hp- 5275 Time Interval Counter	Measures precise time interval	10 nanoseconds to 0.1 sec	7 digits, 10 ns resolution 3½" high	—	110
-hp- 524C Frequency Counter	Frequency, period, measurements	10 cps to 10.1 MC (Freq.) 0 cps to 100 KC (Period)	$5/10^8$ stability; digital display tube readout	2,400.00■	104 - 106
-hp- 524D Frequency Counter	Frequency, period, measurements	10 cps to 10.1 MC (Freq.) 0 cps to 100 KC (Period)	$5/10^8$ stability; decade counter readout	2,150.00■	104 - 106
-hp- 525, A, B, C Plug-ins for 524	Extend frequency range of -hp- 524	10 cps to 510 MC	Retains counter accuracy	—	105, 106
-hp- 526A, B, C, D Plug-ins for 524	Video, amplifier, time interval unit, period multiplier, phase unit	——	——	—	105, 106
-hp- 540B Transfer Oscillator	Frequency Measurements	10 MC to 12.4 GC	Extends range of 524 to 12.4 GC	850.00△	112, 113
-hp- 560A/561B Digital Recorders	Record counter measurements	Slave of counter	5 counts per second; 11 digit parallel entry	1,325.00△ 1,150.00△	114, 115
-hp- 562A Digital Recorder	Records 11 columns of digital information	Max. 5 prints per second	BCD input transistorized unit	—	116, 117
-hp- 565A Digital Printer	Digital printer for custom installation	Max. 5 prints per second	11 columns 11 characters/col.	640.00	116, 117
-hp- 570A/571B Digital Clocks	Adds time of day information to -hp- 560A or 561B	——	In-line, 6-place numeric readout; also can control measuring rate	—	114, 115
-hp- P932A Harmonic Mixer	Beat frequency mixer	Extends 540 range to 18.0 GC	100 mw max. input; 0.1 v min. output	250.00	112, 113
-hp- 934A Harmonic Mixer	Beat frequency mixer	2 to 12.4 GC	100 mw max. input; 0.5 mv min. output	150.00	112, 113
DY-2500 Computing Counter	Measures in desired engineering units	220 KC	Variable gate time	1,350.00, 1,425.00	202
DY-2504 Photoelectric Tachometer	Shaft speed measurement	0-10,000 rpm	Very low friction	—	203

Regulated Power Supplies

Instrument	Primary Uses	Range	Regulation no load to full load	Price	Page
-hp- 711A	General Purpose, metered output	0 to 500 v dc @ 100 ma	± 0.5% or 1 v	$ 250.00*	54
-hp- 712B	General Purpose, metered output	0 to 500 v dc @ 200 ma; bias, (fixed) —300 v @ 50 ma; (variable) 0 to —150 @ 5 ma	± 50 mv	390.00△	55
-hp- 715A	Low power klystron	—250 to —400 v dc 0 to —900 v dc	± 1%	325.00	58
-hp- 721A	Low power transistors	0 to 30 v dc @ 150 ma	± 0.3% or 30 mv	145.00	56
-hp- 722AR	High current transistors	0 to 60 v dc @ 2 amps	± 5 mv	525.00	57
-hp- 723A	Programmed voltages for systems	0 to 40 v dc @ 500 ma	± 20 mv	225.00	56
-hp- 724BR	Power frequency, time standards	24 ± 1 v dc @ 300 ma 48 hr standby capacity	——	850.00	124
-hp- 725AR	Power frequency, time standards	24 ± 1 v dc @ 300 ma 6 hr standby capacity	——	—	124

△ Rack mounted instrument available for $15.00 less. ■ Rack mounted instrument available for $25.00 less. *Rack mounted instrument available for $5.00 extra.

Square Wave, Pulse, and Digital Delay Generators

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 211A	Square wave generator	1 cps to 1 MC	Output —3.5 v p-p across 75 ohms and —27 v p-p across 600 ohms	$ 325.00*	50
-hp- 212A	Pulse generator	50 to 5,000 pps. 0.02 μsec rise time	Pulse length 0.07 to 10 μsec, output 50 v to 50 ohm load	600.00△	51
-hp- 218AR	Digital delay generator	——	Time interval 1 to 10,000 μsec; adjustable in 1 μsec steps	2,000.00	52, 53
-hp- 219A/B/C	Dual trigger, pulse, duration plug-ins for 218A	——	——	—	53

Signal Generators and Doublers — 50 KC to 40 GC (KMC)

Instrument	Frequency Range	Characteristics	Price	Page
-hp- 606A	50 KC to 65 MC	Output 0.1 μv to 3 v into 50 ohm load. Constant output impedance, versatile modulation.	$1,350.00△	132, 133
-hp- 608C	10 to 480 MC	Output 0.1 μv to 1 v into 50 ohm load. AM, pulse, or CW modulation. Direct calibration.	1,100.00**	134, 135
-hp- 608D	10 to 420 MC	Output 0.1 μv to 0.5 v crystal calibrator	1,200.00**	134, 135
-hp- 612A	450 to 1,230 MC	Output 0.1 μv to 0.5 v into 50 ohm load. AM, pulse, CW or square wave modulation. Direct calibration.	1,300.00**	136, 137
-hp- 614A	800 to 2,100 MC	Output 0.1 μv to 0.157 v into 50 ohm load. Pulse, CW or FM modulation. Direct calibration.	1,950.00**	138, 139
-hp- 616B	1,800 to 4,200 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, CW or FM modulation. Direct calibration.	1,950.00**	138, 139
-hp- 618B	3,800 to 7,600 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, CW, FM or square wave modulation. Direct calibration.	2,250.00**	140, 141
-hp -620A	7,000 to 11,000 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, FM or square wave modulation. Direct calibration.	2,250.00**	140, 141
DY-623B	5,925 to 7,725 MC	Output 70 μv to 0.223 v into 50 ohm load. FM or square wave modulation. Separate power meter and wave meter section.	1,900.00	209
DY-624C	8,500 to 10,000 MC	Output 3.0 μv to 0.223 v into 50 ohm load. Pulse, FM or square wave modulation. Separate power meter and wave meter section.	2,265.00△	209
-hp- 626A	10 to 15.5 GC	Output 10 dbm to—90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,400.00**	142, 143
-hp- 628A	15 to 21 GC	Output 10 dbm to —90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,400.00**	142, 143
-hp- 938A/940A	18-26.5; 26.5-40 GC	Frequency Doubler	1,500.00	146, 147
DY-5003	8.5 to 10 GC	Output +15 dbm to —85 dbm. FM, Pulse or square wave modulation.	3,600.00	209
DY-5381	8.5 to 10 GC	Output +24 dbm to —76 dbm. FM, Pulse or square wave modulation.	4,835.00	209
DY-5636	7125 to 8400 MC	Output +15 dbm to —85 dbm. FM, Pulse or square wave modulation.	4,475.00	209

Swept Frequency Oscillators — 1 to 18.0 GC

-hp- 682C	1 to 2 GC	Electronically swept; variable sweep width and rate. Pulse, square wave, FM and AM modulation.	$3,090.00△	144, 145
-hp- 683C	2 to 4 GC		3,000.00△	144, 145
-hp- 684C	4 to 8.1 GC		2,900.00△	144, 145
HO1 686C	7.0 to 11.0 GC		3,000.00△	144, 145
-hp- 686C	8.2 to 12.4 GC		2,900.00△	144, 145
-hp- 687C	12.4 to 18.0 GC		3,400.00△	144, 145

Other Instruments and Accessories

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
DY-335BR FM Monitor	Frequency monitor; modulation monitor	88 MC to 108 MC	Deviation ±3 KC; accuracy approx. ±1,000 cps	$1,550.00	210
DY-335ER TV Monitor	Carrier aural, visual monitoring. Color, black and white.	Channels 2 to 83	Aural, video deviation ±3 KC; accuracy approx. ± 500 cps	2,050.00	210
-hp- 350A/B Attenuator	Measurement of attenuation, gain	DC to 100 KC	110 db in 1 db steps. A—500 ohm level; B—600 ohm level	110.00*	64
-hp- 355A/B Precision Attenuator	Measurement of gain, attenuation	DC to 500 MC	Bilateral: 50 ohm impedance; 1 and 10 db steps	125.00	64
-hp- 360A-D Low Pass Filters	Eliminates harmonic voltages from uhf systems	Cutoff frequencies A- 700 MC B-1,200 MC C-2,200 MC D-4,100 MC	50 db rejection at 1.25 cutoff freq.	60.00, 50.00	186
-hp- 450A Amplifier, Stabilized	General purpose lab amplifier	5 cps to 1,000,000 cps	20 and 40 db gain, response ±½ db	160.00*	90
-hp- 460AR/BR Amplifier, Wide Band	Wide band or fast pulse amplification	100 KC to 120 MC	15 or 20 db gain, rise time 0.003μsec	225.00, 275.00	86, 87
-hp- 466A AC Amplifier	Transistorized general-purpose instrument	10 cps to 1 MC	20, 40 db gain; response ±0.5 db	150.00	90
-hp- AC-4 Decade Counters	——	——	——	——	111
-hp- AC-16 Cable Assemblies	——	——	——	——	193
-hp- AC-21 Probes	Voltage dividers, current, and low frequency probes			——	19
-hp- AC-60A/B Line Matching Transformers	Connect balanced system to VTVM, oscillators or 330B	5 to 600 KC, 20 cps to 45 KC	Max. level +22 dbm, +15 dbm	60.00, 80.00	192
-hp- AC-67B/C Terminations	100 ohm compensated and feed-through terminations			17.50 30.00	19
-hp- AC-97C Sweep Drive	Automatic frequency sweep	10° rotation to 50 revolutions	2 speeds, variable stops, x-axis output	275.00	61
-hp- AC-115B	Oscilloscope Testmobile			85.00	19

△ Rack mounted instrument available for $15.00 less. **Rack mounted instrument available for $20.00 extra. *Rack mounted instrument available for $5.00 extra.

Microwave Equipment to 40 GC (KMC)

Instrument	Coaxial Type N Conn.	"S" 3" x 1½" 2.6 - 3.95 GC	"G" 2" x 1" 3.95 - 5.85 GC	"J" 1½" x ¾" 5.3 - 8.2 GC	"H" 1¼" x ⅝" 7.05 - 10.0 GC	"X" 1" x ½" 8.2 - 12.4 GC	"M" .850 x .475" 10 - 15 GC	"P" .702 x .391" 12.4 - 18.0 GC	"K" .500 x .250" 18.0 - 26.5 GC	"R" .360 x .220" 26.5 - 40.0 GC	Page
Adapter, Waveguide to Coax		S281A $50	G281A $40	J281A $35	H281A $30	X281A $25					186
Cover to choke flange		S290A $65	G290A $55	J290A $40	H290A $35	X290A $20		P290A $30			186
Waveguide to waveguide						-hp- 292A Series $25.00 - $40.00					186
Waveguide Noise Source		S347A $300	G347A $285	J347A $250	H347A $225	X347A $200		P347A $250			179
Low Pass Filters						X362A $325	M362A $350**	P362A $350	K362A $385	R362A $385	186
Attenuators, Fixed 3, 6, 10, 20 db		S370A $100	G370A $85	J370A $75	H370A $75	X370A $65		P370A $80	K370A $115	R370A $115	181
Precision, Fixed		S372 $400	G372 $275	J372 $165	H372 $135	X372 $110		P372 $125	K372 $240	R372 $275	181
Variable	393A/394A	S375A $120	G375A $110	J375A $100	H375A $90	X375A $90	M375A $190	P375A $100	K375A $140	R375A $180	180, 181
Precision Variable		S380A $260	G382A $500	J382A $375	H382A $350	X382A $275	M382A $300	P382A $275	K382A $475	R382A $500	180, 181
Detector Mounts	420A $50				H421A $95	X421A $75	M421A $125	P421A $130	K422A $200	R422A $200	170, 171
	420B $75										170, 171
	440A† $85										170, 171
		S485D° $185	G485D $170	J485D° $170							161
		S485A‡ $165	G485B† $95	J485B† $90	H485B† $85	X485B† $75					161
Thermistor Mounts (Fixed tuned) ■	477B $75	S487B $105	G487B $95	J487B $90	H487B $80	X487B $75	M487B $110	P487B $110	K487C $225	R487B $225	160, 162
Thermistor Mounts (Temperature Compensated) ■	478A $145					X486A $145					157
Frequency Meters Direct Reading	536A $500		G532A $325	J532A $300	H532A $250	X532B $175	M532B $275	P532A $210	K532A $280	R532A $300	182
Directional Couplers, Cross Guide: 20, 30 db		S750 $150	G750 $120	J750 $85	H750 $75	X750 $60					184, 185
Directional Couplers, Multi Hole: 3, 10, 20 db		S752 $375	G752 $250	J752 $140	H752 $120	X752 $100	M752 $130	P752 $115	K752 $175	R752 $200	184, 185
Slotted Sections, Waveguide		S810A • $450	G810B§ $125	J810B§ $110	H810B§ $110	X810B§ $90	M810B§ $110	P810B§ $110			168, 169
Slotted Sections, Waveguide				(Mounts in 814B carriage)					K815B $265	R815B $265	169
Tuners, Slide Screw	872A $525	S870A $225	G870A $185	J870A $150	H870A $130	X870A $125	M870A $130	P870A $130	K870A $250	R870A $300	187
E - H						X880A $130		P880B $150			187
Waveguide Phase Shifter				J885A $550		X885A $425		P885A $600			188
Terminations, Low Power	908A $35	S910A $75	G910A $65	J910A $45	H910A $40	X910B $35		P910A $40			189
Terminations, High Power		S912A $200				X912A $75					189
Moving Load	906A	S914A $100	G914A $75	J914A $70	H914A $60	X914B $50	M914B $65	P914A $55	K914B $250	R914B $250	190
Standard Reflections						X916B-E $125					190
Adjustable Shorts		S920A $150	G920A $125	J920A $100	H920A $75	X920A $75	M920B $75	P920B $125	K920A $155	R920A $155	191
Waveguide Shorting Switch						X930 $160					191
Broad Band Probe	442B§ $40					All Frequencies					170, 171
Broad Band Probe, Untuned			444A $40 2.6 to 18.0 GC				446B $145 18.0 to 40 GC				170, 171

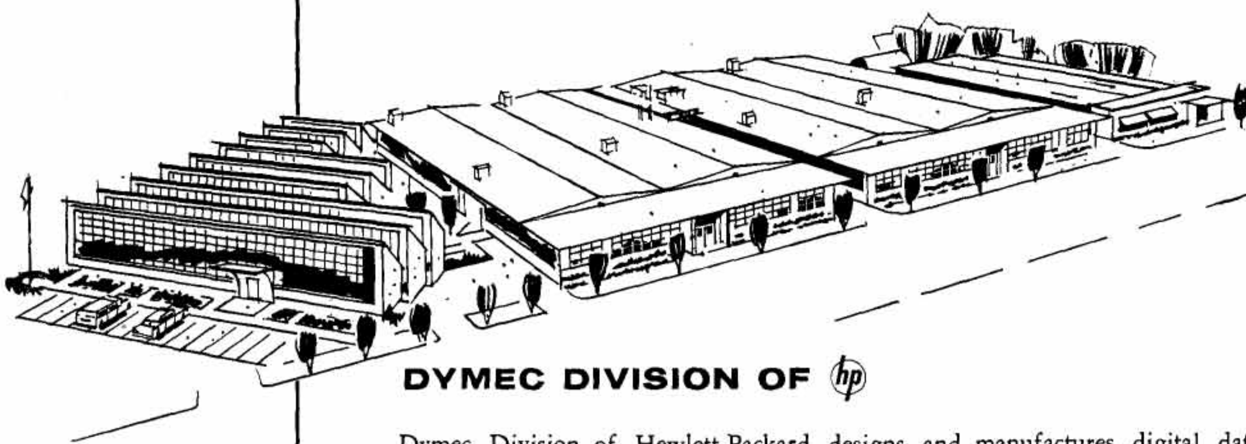
† For use with barretter or crystal.
■ Includes Thermistor, installed.
**Also available in N-Band, 15-21 GC, $350.00.
‡ For use with barretter only.
• Complete assembly including carriage.
§ Mounts in 809B Carriage.
° Includes barretter; checked for square law characteristics.

Microwave Test Instruments—for coaxial and waveguide systems

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 340B Noise Figure Meter	Noise figure measurement, alignment	30 and 60 MC	Fast, simple, adaptable to your specific equipment	$ 715.00△	178, 179
-hp- 342A Noise Figure Meter	Noise figure measurement, alignment	30 MC plus any 4 frequencies 38 to 200 MC	Versatile, accurate, new convenience	815.00△	178, 179
-hp- 343A, 345B, 349A Noise Sources	IF and rf amplifier measurement	10 to 600 MC, 30/60 MC, etc.	Broad band, 50 ohm impedance Selectable impedance 50, 100, 200 and 400 ohms	—	179
-hp- 344A Noise Figure Meter	Continuous Noise Figure Measurement in operating Radar Systems	25 or 30 MC	Remote modulator. Transistorized Rugged, compact.	1,600.00	177
-hp- 415B Standing Wave Indicator	SWR indicator or null indicator	315 to 2020 cps. Normal freq. 1,000 cps	0 to 70 db attn. Max. sensitivity 0.3 µv	200.00*	166
-hp- 416A Ratio Meter	Reflection coefficient measurements	1,000 cps ± 40 cps	Continuous swept frequency presentation; accuracy ± 3%	550.00△	172, 173
-hp- 417A VHF Detector	vhf bridge detector (for -hp- 803A)	10 to 500 MC	Approx. 5 µv sensitivity	400.00	175
-hp- 430C Microwave Power Meter	Measurement of rf power	Depends on bolometer mount	0.1 to 10 mw ± 5% accuracy	250.00*	158, 159
-hp- 431A Power Meter	Stabilized rf power measurements	Depends on bolometer mount	0.01 to 10 mw, extreme temperature stability	345.00	156, 157
-hp- 434A Calorimetric Power Meter	Measurement of rf power	DC to 12.4 GC	10 mw to 10 watts	1,600.00△	154, 155
-hp- 476A Universal Bolometer Mount	Measurement of rf power (with 430B/C)	10 to 1,000 MC	No tuning required SWR less than 1.25	85.00	160
-hp- 477B Coaxial Thermistor Mount	Measurement of rf power (with 430C)	10 MC to 10 GC	No tuning required SWR less than 1.5	75.00	160
-hp- 489A-495A Traveling-Wave Tube Amplifiers	Amplification throughout S, G, J or X bands	1 to 12.4 GC collectively	25, 30 db gain; nanosec rise time; variously 1 watt to 20 mw	—	88, 89
-hp- 760D, 761D Dual Directional Couplers	Reflectometer, power monitor or mixer	250 to 4,000 MC	26 to 30 db directivity	200.00, 185.00	183
-hp- 764D-767D Dual Directional Couplers	Reflectometer	216 to 4,000 MC	26 db directivity	150.00, 160.00	183
-hp- 803A VHF Bridge	Measurement of vhf impedance, SWR	50 to 500 MC	2 to 2,000 ohms impedance —90° to +90° phase angle	900.00	174, 175
-hp- 805C Coaxial Slotted Section	Measurement of SWR	500 to 4,000 MC	For Type N Connectors flexible cables	525.00	167
-hp- 805D Coaxial Slotted Section	Same as above	Same as above	For rigid ⅞" RG44/U line	600.00	167
-hp- 806B Coaxial Slotted Section	Same as above (mounts in 809B)	3,000 to 12,000 MC	For Type N Connectors flexible cables	200.00	169
-hp- 809B/814B Universal Probe Carriage	Supports 810, 815, 806B Waveguide Sections		Accepts 442B, 444A or 440B probes	175.00, 225.00	168, 169

△ Rack mounted instrument available for $15.00 less.
*Rack mounted instrument available for $5.00 extra.

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



DYMEC DIVISION OF hp

Dymec Division of Hewlett-Packard designs and manufactures digital data systems, rf systems and special-purpose instruments. Its products range from virtually standard catalog-type instruments to complex systems designed specifically to meet special customer requirements. A 16-page descriptive listing of Dymec systems and instrumentation appears on Pages 195-210 of this catalog. The complete list of Dymec Engineering Representatives appears on the inside back cover of this catalog.

Further information and ordering details may be obtained from these Representatives or by direct contact with

DYMEC
395 Page Mill Road, Palo Alto, California
DAvenport 6-1755, Area Code 415, TWX PAL AL 117-U.

PALO ALTO ENGINEERING COMPANY

PAECO, a subsidiary of Hewlett-Packard, designs and manufactures precision magnetic components for all types of electronic instrumentation. These include transformers (power, pulse, audio, miniature, toroidal), inductors, delay lines, magnetic amplifiers, filters, wirewound variable resistors and solid state power supplies. Construction may be commercial, MIL-T-27A, epoxy molded plug-in or encapsulated. The entire PAECO operation is keyed for rapid service in developing specialized components to customer specification. Further information on instrumentation components for special application may be obtained by contacting PAECO direct at:

PALO ALTO ENGINEERING COMPANY
620 Page Mill Road, Palo Alto, California
DAvenport 6-5360, Area Code 415.

WARRANTY

All our products are warranted against defects in materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.

SERVICE INSTRUCTIONS

(For Both Warranty and Non-Warranty Repairs)

If there is an authorized hp sales office convenient to you, please contact them for prompt, *factory-level* assistance. Of course, Hewlett-Packard also stands ready to help you; just contact us.

To speed action and handling, repair and service replacement parts inquiries directed to the Hewlett-Packard Company should be addressed to:

Customer Service
HEWLETT-PACKARD COMPANY
395 Page Mill Road, Palo Alto, California
Telephone: DAvenport 6-1755 — TWX No.: PAL AL 117-U
Area Code 415

Customers in Western Europe should address repair and service replacement parts inquiries to:

HEWLETT-PACKARD S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland
Telephone: No. (022) 26. 43. 36 — Telex: No. 2. 24. 86

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 special features such as special color, nonstandard power line voltage, etc.

Most Hewlett-Packard instruments are available in cabinets for bench use or with 19" panels for rack mounting. The letter "R" after the model number indicates a rack mounting instrument. For example, "400DR." Catalog listings indicate availability of cabinet or rack mounting arrangements. Please be sure your order indicates which you desire.

Where to Send Your Order

Your order should be made out to the Hewlett-Packard Company and sent to Palo Alto, California, through your local ⓗⓟ representative *(see inside of back cover)* or directly, if you prefer. 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 engineering representatives at authorized ⓗⓟ sales offices in the United States and in principal areas throughout the world *(see inside back cover for names and addresses.)* In addition, a staff of qualified engineers is maintained at ⓗⓟ offices in Palo Alto, California and Geneva, Switzerland, to supplement the services available from your local representatives.

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.

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 and Pro Forma Invoices

Upon request, quotations, or pro forma invoices, will be furnished to you by your local authorized ⓗⓟ sales office, the Hewlett-Packard Company or Hewlett-Packard S. A. Prices will be specified on an F.O.B. factory basis unless otherwise requested.

Repairs

An extensive service facility is maintained in Palo Alto, California, to repair and recalibrate any Hewlett-Packard instrument. In most cases repairs can also be made in the field, either by your own service technicians or by factory-trained personnel at one of the field repair facilities maintained by your local Hewlett-Packard representative or distributor *(see inside of back cover for locations and addresses)*.

Field servicing of instruments is normally faster since transportation time to the factory is eliminated. If, however, you wish to return an instrument to the factory for repairs, recalibration, or for any other reason, please contact Customer Service, Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, California, phone: DAvenport 6-1755, before shipment for instructions. Please give model number, name, serial number, and as much other information as possible concerning the reason for return. Non-warranty repairs are made at the cost of labor and materials, plus a small service charge. See page 5 for information on warranty repairs.

Repair Parts

Repair parts are ordered in the same way as instruments. Please identify parts by the ⓗⓟ stock number shown in the instruction manual, and if possible, by the schematic diagram circuit reference number. Model number and serial number of the instrument, and original purchase date should also be given, if known.

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 ⓗⓟ 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) and sent to the appropriate Hewlett-Packard office, either directly or through your local ⓗⓟ authorized sales offices.

If no ⓗⓟ representative or distributor has, as yet, been appointed for your area, your order should be placed directly on the Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, California, U. S. A.

Shipping Methods

Shipments to customers outside the United States or Western Europe are made from the appropriate ⓗⓟ facility by either surface or air, as requested. Sea shipments generally require special export packaging at a nominal surcharge of $5.00 per instrument.

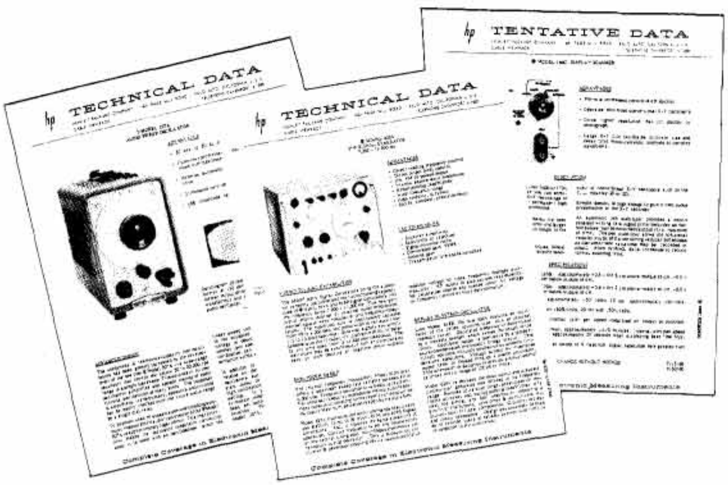
Terms

Terms for orders from countries outside the United States which are placed on the Hewlett-Packard Company, or Hewlett-Packard S. A. 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

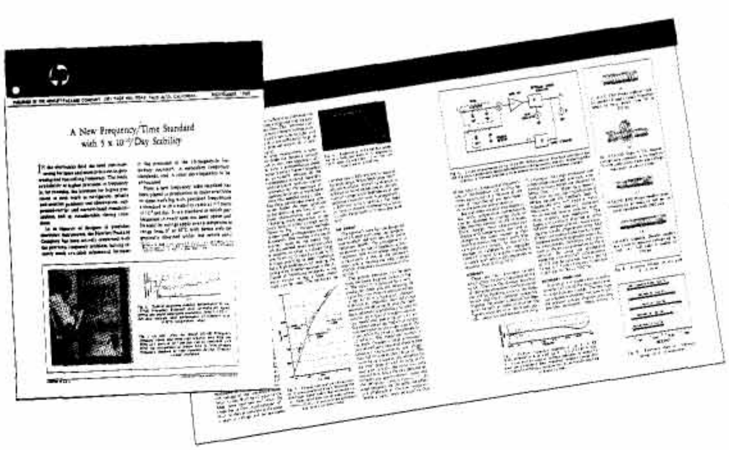
FAS, CIF, C & F, etc., quotations or pro forma invoices, as well as exportation assistance, are available on request from your local authorized ⓗⓟ sales office, the Hewlett-Packard Co., Palo Alto, California, or Hewlett-Packard S. A., Geneva, Switzerland.

OTHER HEWLETT-PACKARD PUBLICATIONS AVAILABLE TO YOU ON REQUEST



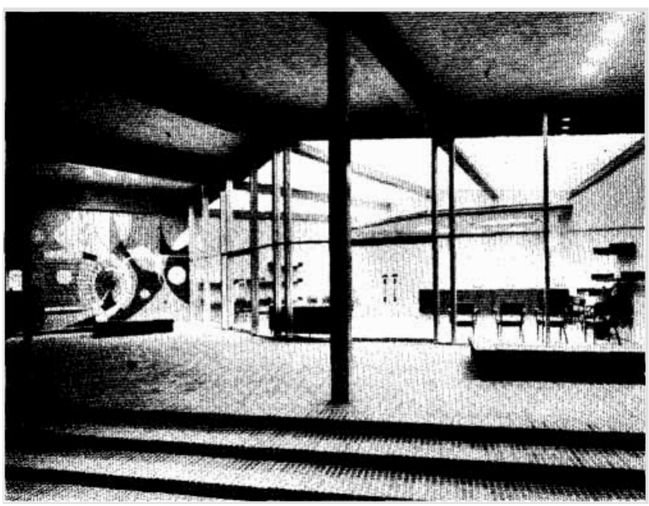
TECHNICAL DATA SHEETS. On standard hp instruments, these sheets contain essentially the same information as is given in this catalog. Where convenience indicates a single sheet, however, or for up-to-date data on instruments developed after publication of this catalog, TECHNICAL DATA SHEETS are useful. They may be obtained either from your local hp engineering representative, or by writing hp direct, attention Publications Section.

APPLICATION NOTES. One of the most popular series of publications in professional electronics. A series of over 50 APPLICATION NOTES describe measuring methods, techniques, efficient test instrument application. Many APPLICATION NOTES are referenced in this catalog; write the hp Publications Section for an index of all APPLICATION NOTES available, or for titles you desire; watch new literature announcements and hp advertising for announcements of other titles.



HEWLETT-PACKARD JOURNAL. Published monthly by the hp R & D laboratories, the Hewlett-Packard Journal is the most widely distributed publication in electronics. It is devoted to detailed, academic discussion of new measuring approaches, most productive methods of employing test instrumentation, latest instrumentation for complex as well as routine measurements. For your free subscription simply write on your letterhead to Hewlett-Packard Journal, Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, California.

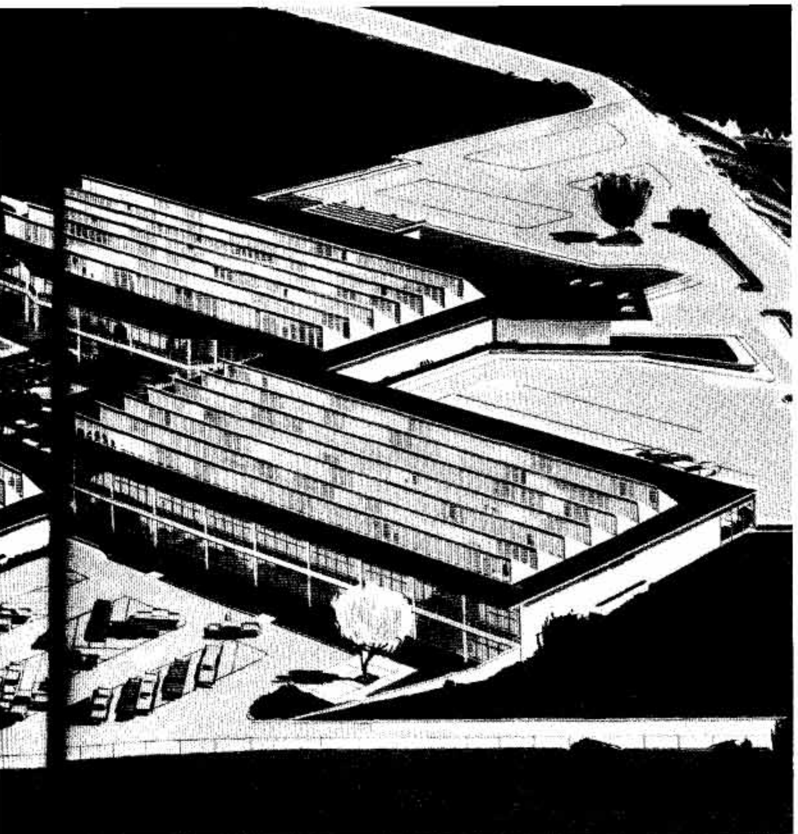
ABOUT HEWLETT-PACKARD



The Hewlett-Packard Company was founded in 1939 in Palo Alto, California. The first Hewlett-Packard product was a new kind of instrument — a resistance capacity audio oscillator. Hewlett-Packard pioneered the resistance capacity circuit which is now an accepted standard for test oscillator design.

During the past two decades, the Company has steadily broadened the instrument line, and now over 400 basic test instruments are manufactured. Among the more important types are oscilloscopes, audio oscillators, voltmeters, noise and distortion analyzers, signal generators, power meters, electronic counters and a complete array of waveguide and coaxial instrumentation for microwave work. Approximately 2600 men and women are now regularly employed, and almost 200 field representatives sell and service ⓗⓟ instruments in the United States, Canada and overseas.

Behind every ⓗⓟ instrument is a basic philosophy governing equipment design, manufacture, sales and service. This philosophy specifies that there shall be built into each ⓗⓟ instrument the greatest possible usefulness, accuracy, convenience, dependability and dollar value. Further, each instrument must make a contribution to the art of measurement, or it is not offered.

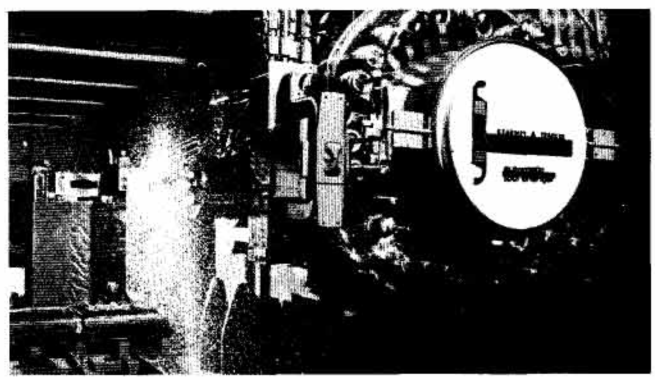


The new Hewlett-Packard plant at Stanford Industrial Park is engineered to be the most efficient yet thoroughly livable electronic manufacturing facility known. Housing Hewlett-Packard's engineering, manufacturing and administrative headquarters, it consists of four two-story buildings and a large underground storage area, totaling approximately 400,000 square feet. Additional ⓗⓟ manufacturing and service facilities are maintained at the "old" (1954) Palo Alto plant now principally occupied by Hewlett-Packard's Dymec systems division. Other ⓗⓟ manufacturing facilities are now in operation at Loveland, Colorado (near Denver) and at Böblingen, in Germany.

Consistently, Hewlett-Packard insures that these standards are met. Every effort is made to provide the best engineering staff possible, and to pursue the most up-to-date manufacturing methods.

This means not only modern techniques, but modern machinery. Hewlett-Packard's manufacturing departments are equipped with the newest and finest machinery obtainable for the job. Typical of this equipment is a highly efficient, tape-controlled milling machine which automatically performs several machining operations on complicated mechanical parts. Other examples include a vacuum die-caster for speeding production of precision die-cast parts, a specialized turret press punching many instrument chassis perforations with a single setup, a fully-equipped machine shop, and a complete plastic molding department to fabricate components.

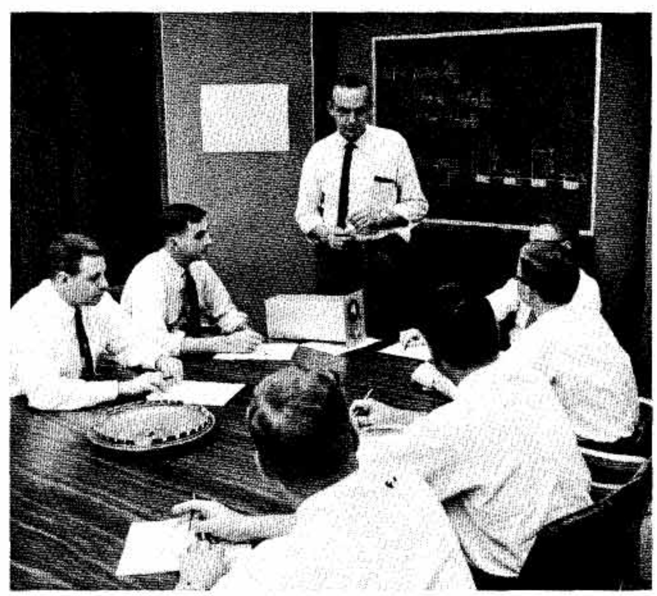
In addition to the different types of commercial machinery, a number of special devices developed by ⓗⓟ engineers are in daily use. Some of these were developed to meet unusual manufacturing problems; others were "imagineered" to make some special part better, faster, or at lower cost. They include such ingeniously simple units as the Lazy Susans shown at right, a semi-automatic device reducing reticule scribing time from 45 to 2 minutes, and a jumper-twister machine twisting up to 4 pre-cut wires at once.



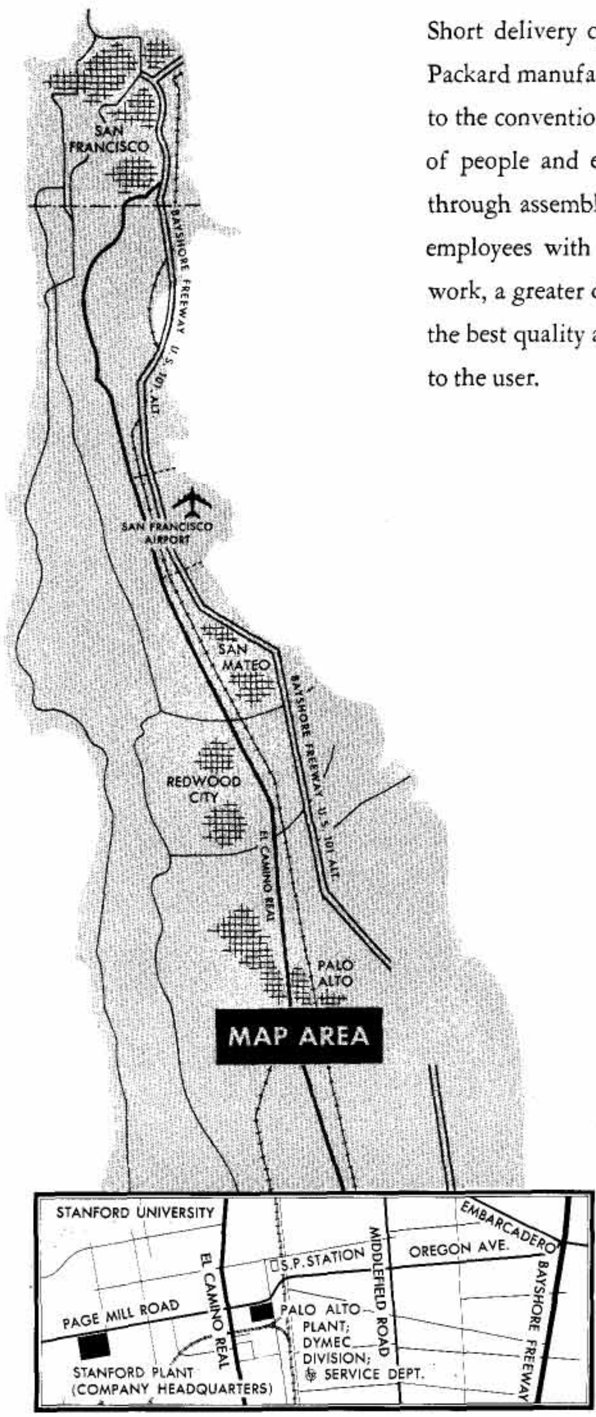
AUTOMATIC MILLING MACHINE, programmed on tape, mills, drills, reams, taps, bores with utmost precision—unattended except by complex electronic control system.

TWO ⓗⓟ INNOVATIONS. "Roller skate" conveyors expedite handling of assemblies between stations; rotating "Lazy Susans" mount quantities of resistor boards for rapid wiring.

The Hewlett-Packard production policy is also somewhat different from that employed elsewhere. Instruments are manufactured in "runs," and actual fabrication is preceded by careful planning to insure that all parts are available and supplied as needed to keep the runs progressing smoothly. As many as thirty runs are normally in progress simultaneously, yet production schedules are kept flexible to permit meeting special orders or unusual delivery requirements involving substantial numbers of instruments. Short delivery cycles are normally maintained. Another unique aspect of the Hewlett-Packard manufacturing process is the use of the "Product-Centered" approach as opposed to the conventional "Process-Centered" method. "Product-Centered" means that a group of people and equipment produces a given group of instruments from prefabrication through assembly, wiring and testing. This results in intimate familiarity on the part of employees with the finished instrument. It leads to a more critical self-inspection of work, a greater desire to excel, and makes possible a "hand-crafted" operation combining the best quality aspects of the "small company" approach with "big company" economies to the user.



To make sure you always receive latest data from hp representatives, hp development engineers take new equipment immediately to representatives' organizations, explain theory, operation and application to field engineers.



Location of the hp plants is Palo Alto, California. Administrative, engineering, manufacturing, purchasing and personnel headquarters are at the new Stanford plant. hp plants may be reached by Southern Pacific commuter train to California Avenue station (South Palo Alto), by Greyhound bus or by automobile via Bayshore Highway, U. S. 101 Alternate. Plant is approximately 25 minutes driving time from San Francisco airport, 40 minutes from downtown San Francisco.

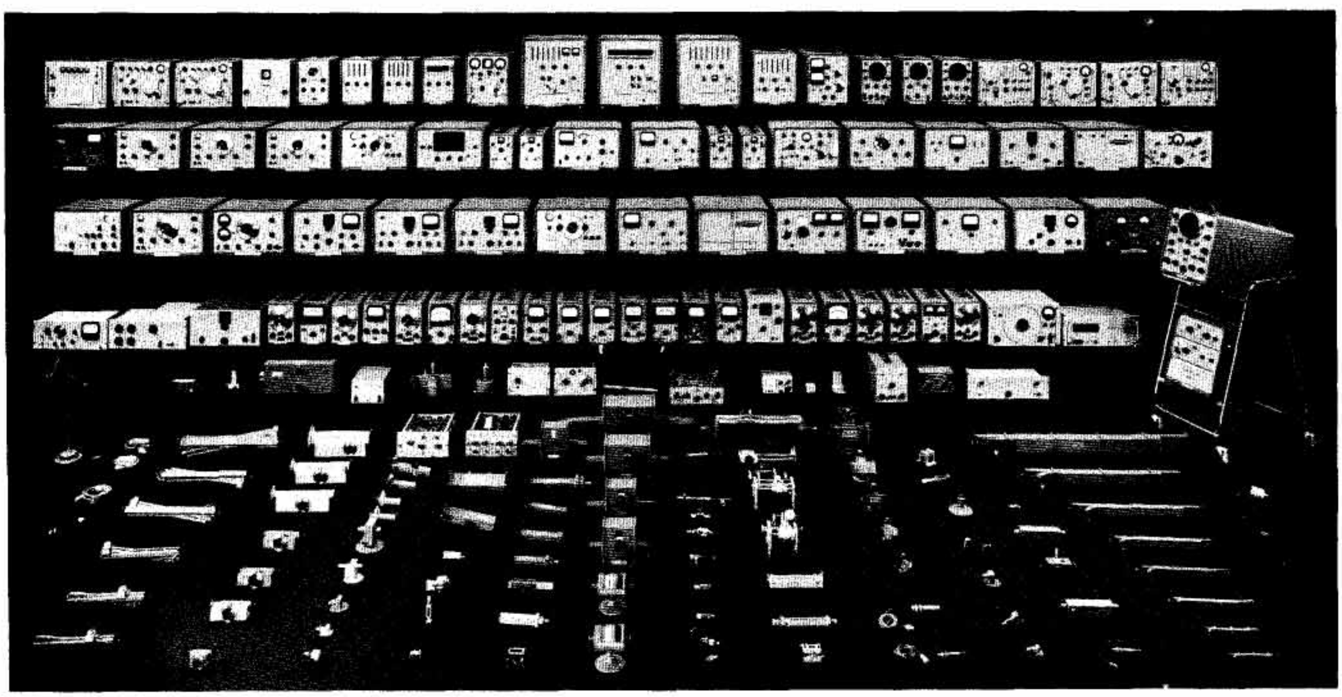
hp representatives will gladly demonstrate hp equipment on your bench; or, you may wish to view the latest in precision instrumentation at hp exhibits in leading electronic shows.

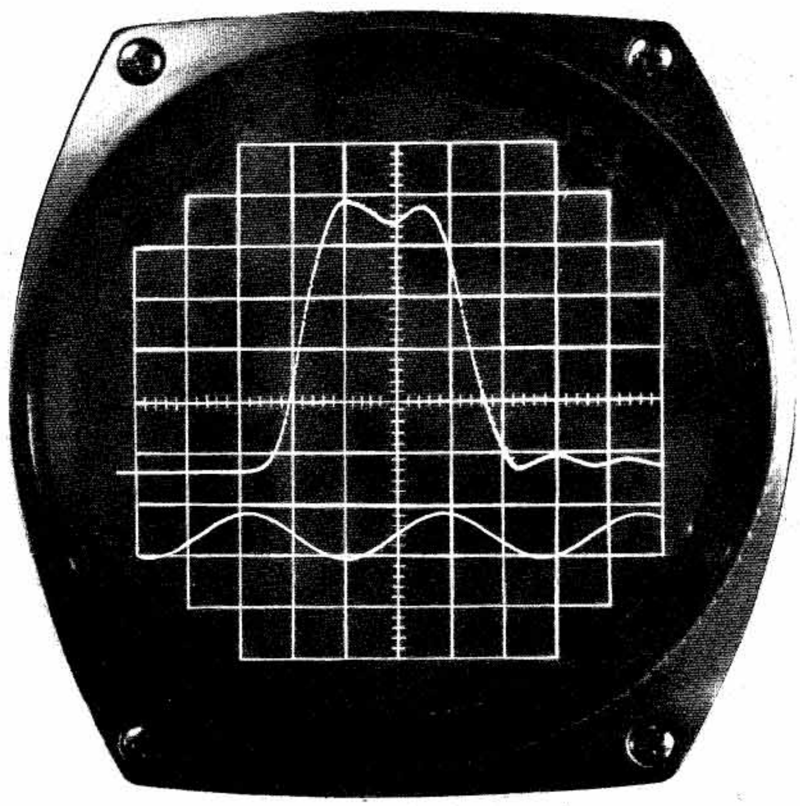
In sales and service, Hewlett-Packard makes a particular effort to provide customers with every assistance that will make the use of hp instruments more efficient and productive. Factory-trained field engineering representatives provide prompt, on-the-job consultation as well as operating and repair information. These men are constantly supplied with the latest in technical data and measurement technique, and are in almost daily contact with the plant at Palo Alto. On numerous occasions each year, members of the sales organization meet for one week at Palo Alto for new-information and retraining seminars which include not only theory but actual "field problem" measuring with hp instruments and allied equipment. On additional occasions, hp representatives return to the plant for special training or instruction on new instruments and measuring methods.

In addition to rigid standards of instrument quality, the best engineering and manufacturing possible, and thorough field engineering service, there is one more aspect of Hewlett-Packard which deserves mention here.

Through the years, there has come into being a definite attitude on the part of hp people toward the development, manufacture and service of hp instruments. This attitude is best described as a genuine and pervasive team spirit, a spirit of cooperation coupled with a common desire to excel. hp people are proud of the quality and the utility of the instruments they design, make and sell. This spirit translates itself continuously into better engineering, better manufacturing, and better service.

The net result to you is good instruments — the best possible, with broadest applicability and the lowest price consistent with quality. Dependable instruments that are not only the best dollar value when purchased, but the best investment for the future. hp instruments — the standard of the electronic test equipment field.





An oscilloscope is an instrument designed to display a wide variety of electrical signals on the face of a cathode ray tube. In the CRT, an electron beam, whose position is precisely controlled by horizontal and vertical deflection plates, activates the phosphor which emits light. A visible representation of the signal as a function of time is formed by moving the beam vertically in accordance with the signal while moving the beam at a uniform rate from left to right. The uniform left to right movement of the beam is controlled by applying a sawtooth voltage to the horizontal deflection plates. The simplified block diagram of Figure 1 illustrates the basic circuit functions of a typical oscilloscope.

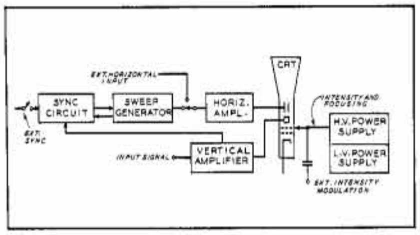


Figure 1. Simplified Block Diagram.

Operation

The input signal, amplified by the vertical amplifier and applied to the CRT vertical deflection plates, moves the beam vertically. The amplifier gain is set so that a certain input voltage, say 10 millivolts, causes 1 cm deflection of the beam on the face of the CRT. Lower sensitivities, such as 20 mv/cm, 50 mv/cm, etc., are achieved by placing a calibrated attenuator ahead of the vertical amplifier, or by reducing the amplifier gain.

A portion of the input signal (internal sync) or a related external signal is connected to the sync and sweep circuits. Here a recurrent sawtooth signal, locked in frequency to the input signal or a submultiple of it, is created. This sawtooth, or sweep signal, is applied to the horizontal amplifier and drives the horizontal deflection plates.

A suitable regulated power supply, with appropriate high voltage provision for CRT cathode, intensity grid, and focusing anodes completes the essential oscilloscope elements.

Types of Measurements

General

When the oscilloscope is utilizing the internal sweep circuit to drive the X axis, voltages are displayed as they vary with time. Time intervals between pulses or between various portions of a waveform are easily measured, as is frequency or period of a recurrent waveform.

The oscilloscope may also be driven with an external X-axis voltage to provide Lissajous patterns for frequency, time, or phase comparisons of two signals.

Pulse Testing

Many electronic systems employ signals that are fundamentally transient in nature — pulses, square waves, and steps. Digital computers, high speed switching networks, television, radar, and PCM communications equipment are among the important circuits in this category. An oscilloscope is an indispensable tool for the design, production, and maintenance of such circuits since the actual waveforms must be observed in detail to determine proper circuit operation.

Even in systems that are primarily designed to handle sinusoidal signals, it is frequently faster and more convenient to test system response with pulses.[1]

Because of the Fourier transform relationships between the transient response of a system and its frequency and phase characteristics, it is possible to optimize overall system response by optimizing the transient response. For example, if the transient for a desired frequency and phase characteristic is known, the actual transient response may be adjusted to the desired one by altering the circuit while observing the response on an oscilloscope.

A dual channel oscilloscope is particularly useful for pulse testing since the system output can easily be compared with the input.

A typical pulse, or amplifier response to a pulse, is shown in Figure 2.

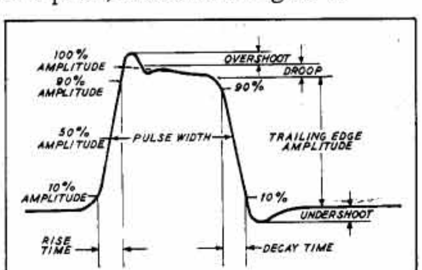


Figure 2. Pulse definitions.

The important characteristics are as follows:

Rise Time: t_r, is the time between the 10% and 90% amplitude levels on the leading edge of the pulse.

Fall Time: t_f, is the time between the 90% and 10% amplitude levels on the trailing edge of the pulse.

Pulse Width: t_w, is the time between the 50% amplitude point on the leading edge and the same amplitude point on the trailing edge.

Overshoot and Ringing: Overshoot is generally considered to be a damped oscillation occurring on the leading "corner" of the pulse. The amount of overshoot is expressed as a percentage of the 100% pulse amplitude. Overshoot is usually called ringing when more than 2 or 3 cycles of oscillation exist.

Droop: The amount of droop, tilt, or sag is a measure of the low frequency response of a system. It is often expressed as a percentage of the 100% pulse amplitude. This percentage, of course, will vary with pulse width even though the system remains unchanged.

Other pulse-response characteristics may be useful when testing specific circuits or components. When testing transistors, for example, the TURN ON DELAY and STORAGE TIME can be quite meaningful. TURN ON DELAY is usually defined as the time between the point at which the leading edge of the test pulse reaches 10% amplitude and the point where the output from the circuit under test reaches 10% amplitude. STORAGE TIME is similarly defined as the interval between the point at which the trailing edge of the test pulse reaches 90% amplitude and the point at which the output from the test circuit reaches 90%.

Rise Time and Bandwidth

A useful relationship $t_r \cong \frac{.35}{BW}$ exists between the rise time of an amplifier and its bandwidth, provided the overshoot is less than 5%, where t_r is the rise time in microseconds and BW is the bandwidth in megacycles. For example, if BW = 30 MC, $t_r \cong$ 12 nanoseconds.

In general, it is good practice to use a test pulse generator and an oscillo-

[1]See ⓗ Application Note 17.

scope which have rise times an order of magnitude faster than the system being tested. However, when observing very fast signals it is often impossible to neglect the rise time of the test pulse and oscilloscope. If the test pulse and oscilloscope rise times are not negligible, the following approximation is useful:

$$t_r \text{ observed} = \sqrt{\underset{\text{input pulse}}{(t_r)^2} + \underset{\text{system}}{(t_r)^2} + \underset{\text{oscilloscope}}{(t_r)^2}}$$

Selecting an Oscilloscope

General

Two important considerations in selecting an oscilloscope are the bandwidth and sensitivity. The bandwidth must be sufficient to display the highest anticipated frequency and the corresponding rise time sufficiently fast to provide an undistorted view of the fastest anticipated pulse. Oscilloscope sweep speeds should be commensurate with the rise time for viewing the fastest signals.

The sensitivity must be sufficient to provide a usable size display with the smallest signals anticipated. If high impedance 10:1 divider probes are to be used, the sensitivity may have to be correspondingly higher.

Also of importance is the decision regarding a single channel or dual channel approach. For example, relative phase can be measured on a single channel oscilloscope through the use of Lissajous Figures, or on a dual channel oscilloscope by presenting both signals simultaneously and measuring the time between zero-axis crossings of the same slope.

A single channel oscilloscope is useful for viewing one waveform as a function of time or for making phase and frequency measurements using Lissajous Figures.

A dual channel oscilloscope is indicated whenever time is the important parameter or where two related waveforms are to be compared.

In the low frequency area the selection involves the choice between hp 120A (single channel) and the 122A (dual channel) oscilloscopes. *(See pages 16-18.)* In the high frequency area the choice is simply the selection of the appropriate hp plug-in amplifier.

In the latter case, it is often desirable to have several plug-ins, each best suited for a specific set of measurement requirements. Other considerations, such as the need for operation in an adverse environment (where hp 160B and 170A militarized oscilloscopes shown on pages 24-27 excel) or the need for sweep delay and other special features, may also have a bearing on the selection of an oscilloscope.

Hewlett-Packard offers oscilloscopes to meet a wide variety of applications. At present there are 7 different oscilloscopes available in either cabinet or rack mounting. In addition, four of these oscilloscopes may be equipped with a wide variety of plug-ins to increase their versatility.

Ultra High Frequency Oscilloscope

hp 185A Oscilloscope *(pages 28-30)*, combined with Model 187B Plug-in Amplifier is an ultra high speed oscilloscope employing sampling techniques to achieve a bandwidth of 1,000 megacycles and a corresponding rise time of less than 0.4 nanoseconds, while retaining most of the convenient features and ease of operation of a conventional low frequency oscilloscope.

Calibrated vertical sensitivities, from 10 mv/cm to 200 mv/cm are provided by means of a 5 step attenuator. A vernier permits continuous adjustment of sensitivity between ranges and increases maximum sensitivity to 3 mv/cm. hp 187A-76C 10:1 divider permits viewing of signals up to ± 20 volts peak in amplitude. Horizontal sweep speeds are provided in 4 steps from 100 nanoseconds/cm to 10 ns/cm. A 100-times magnifier and vernier control increases fastest sweep to 0.03 ns/cm (approximately the speed of light). A delay control permits viewing of any portion of the unmagnified sweep.

Other features of Model 185A include wide dynamic range, high sensitivity, dual channel operation, and separate output for making X-Y recordings. A large group of specially designed accessories is available to further increase the number of applications for which hp 185A can be used.

Operation Described

The first step in building the 185A's cathode ray tube picture is to apply a staircase voltage to step the beam across the CRT face. (Figure 3.)

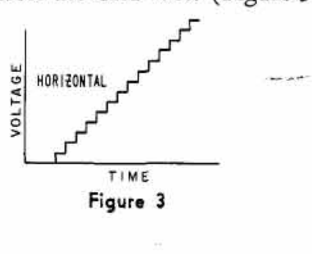


Figure 3

Next, input voltage samples, each taken from successive points on the waveform, are fed through the vertical amplifier to the scope face.

Now, between the staircase steps, the beam is blanked so that the signal becomes a series of dots. (Figure 4.) In operation, many dots are present, and the pattern appears continuous.

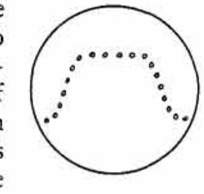


Figure 4

A basic element of the sampling technique as here applied is the incremental delay of each sampling pulse — such delay insuring that a different or successive portion of the wave is examined each time.

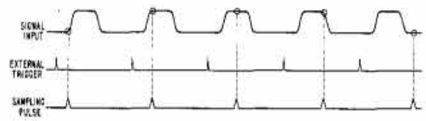


Figure 5

Figure 5 illustrates this delay process. So that the entire signal under examination is scanned, each succeeding sample is gated at a slightly later point along the waveform. Each time such a sample is taken the "spot" on the CRT is moved horizontally along the waveform. Thus, a complete picture of a repetitive high speed signal is synthesized by a build-up of image-retaining "dots" on the scope face.

High Frequency Oscilloscopes

Models 170A and 160B *(pages 24-27)*, are extremely rugged, general duty 30 and 15 MC oscilloscopes meeting MIL standards for shock, vibration, humidity, temperature and RFI. Guiding specification is MIL-E-16400; full environmental test details are available on request.

Model 170A achieves 30 MC bandwidth capability without the use of a complex distributed amplifier and adjustable delay line system. Simple triode amplifier stages provide a great simplification in the calibration and maintenance of the instrument.

Model 162A Dual Trace Amplifier offers unusually high sensitivity of 20 mv/cm while providing 24 MC bandwidth in Model 170A and 14 MC in Model 160B.

Model 162F Fast Rise Amplifier utilizes full bandwidth capability of the ⓗⓟ 170A and 160B oscilloscopes. Bandwidth is 30 MC with the 170A; 15 MC with the 160B.

Model 166D Sweep Delay Generator *(pages 24-27)* adds full sweep delay capabilities to either the 170A or 160B when plugged into second plug-in "pocket." In normal operation, this unit establishes the time interval between the sync pulse and the start of the main sweep. It can also be used as an auxiliary sweep generator in place of the main sweep. In a third mode of operation, it provides a unique mixed sweep feature which permits detailed study of part of a wavetrain while retaining a presentation of earlier portions.

Model 166C Display Scanner provides outputs from either the 170A or 160B to duplicate the trace on an X-Y recorder. Through the use of sampling techniques, fast, repetition waveforms are "slowed down" to drive the conventional X-Y recorders such as the Moseley Autograf Models 3S or 2D.

A third plug-in of the 166 series is ⓗⓟ 166B Time Mark Generator which provides intensity markers at 0.1 μsec, 1 μsec and 10 μsec intervals, accurate to ±1%. Markers are useful for checking sweep calibration and for convenient reference on scope photographs. The markers are also available to operate external circuitry.

Model 150A *(pages 22, 23)* is a dc to 10 MC instrument for general laboratory use. In addition to ⓗⓟ automatic triggering, the 150A offers a single shot sweep which may be reset electrically or manually. There are 24 direct reading calibrated sweeps providing sweep times from 0.1 μsec/cm to 5 sec/cm.

A series of plug-in amplifiers extend the versatility of the 150A. Briefly, these include a high gain amplifier providing sensitivity from 5 mv/cm to 50 v/cm, a dual trace amplifier providing differential input and dual traces, a very high gain amplifier providing sensitivity from 1 mv/cm, to 125 v/cm, and a current probe plug-in. Details of these plug-ins appear on pages 22 and 23.

Low Frequency Oscilloscopes

Hewlett-Packard offers three low frequency oscilloscopes, Models 120A, 122A and 130B.

Model 120A *(pages 16-18)* is a dc to 200 KC instrument with a maximum sensitivity of 10 mv/cm.

Model 122A *(pages 16-18)* is a dc to 200 KC *dual trace* instrument that permits the viewing of two phenomena simultaneously. The 122A has 10 mv/cm maximum sensitivity.

Model 130B *(pages 20, 21)* is a dc to 300 KC oscilloscope. The 130B has a maximum sensitivity of 1 mv/cm permitting the viewing of phenomena from many transducers without preamplification.

Oscilloscope Camera

Full-size, distortion free, *flat* photographs of oscilloscope traces may be made quickly and simply with the ⓗⓟ 196A Oscilloscope Camera. This instrument, employing a Polaroid® Land Camera back, takes sharp pictures in which an 8 x 10 cm graticule fills the full film area. The camera may be mounted on the oscilloscope by a "one-hand" clamp mount with quick-lock tab; thereafter, it is not necessary to remove the camera to change the shutter or lens settings.

Multiple exposures are simple; a one-hand adjustment moves the lens through 11 detented positions. Use of a professional camera bellows prevents light leaks. Tab pulling is simple due to the sturdy construction and mounting. In addition to conventional Polaroid® Land Camera prints, Model 196A also makes transparencies for slides and reproduction. For complete details of Model 196A Oscilloscope Camera, see page 31.

Further information on oscilloscopes and pulse testing is contained in ⓗⓟ Application Notes 17 and 44A, B and C, available on request.

ABOUT CRT PHOSPHORS

Four different phosphors are commonly used in oscilloscopes, and are available on Hewlett-Packard instruments.

Each of these phosphors has specific characteristics which give it, and hence the oscilloscope, maximum usefulness in a given application.

The four phosphors and their basic characteristics are:

P1—An ideal phosphor for visual observation and can be used for photography. The P1 has a brilliant green trace with medium persistence and is supplied with a green filter. It is most resistant to burning.

P2—A versatile phosphor for general visual observation and also suitable for photography. It is excellent for viewing fast pulses with fast sweeps. It is characterized by a short persistence blue green fluorescence and a long persistence yellow green phosphorescence. For general use, a green filter is supplied with the P2. A yellow filter, however, accentuates the long persistence characteristics. P2 is somewhat sensitive to burning.

P7—A dual phosphor excellent for viewing non-repetitive and slow phenomena. It is characterized by a short persistence blue-white fluorescence and a long persistence yellow phosphorescence. Short and long persistences are widely enough separated so that filters are effective and a short or a long persistence can be selected. An amber filter is supplied with the P7 and a blue filter is available. The tube is excellent for photography when used with the blue filter. It is also more sensitive to burning than the other phosphors.

P11—Best phosphor for photographing non-repetitive phenomena because it emits intense blue light for rapid exposure of films or plates. The P11 has a short persistence blue trace, and therefore, is supplied with a blue filter. The P11 is also sensitive to burning.

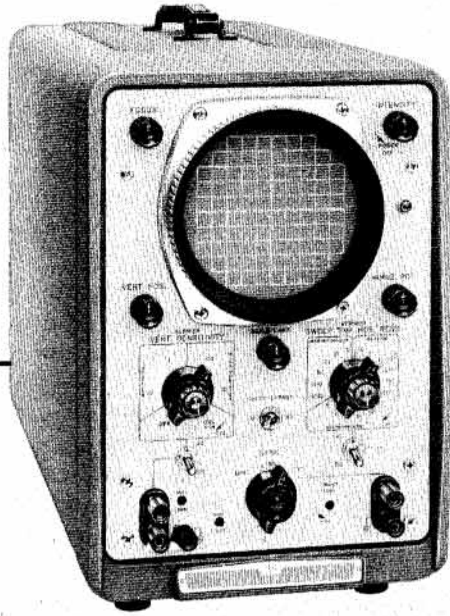
Primary Specifications of Hewlett-Packard Oscilloscopes

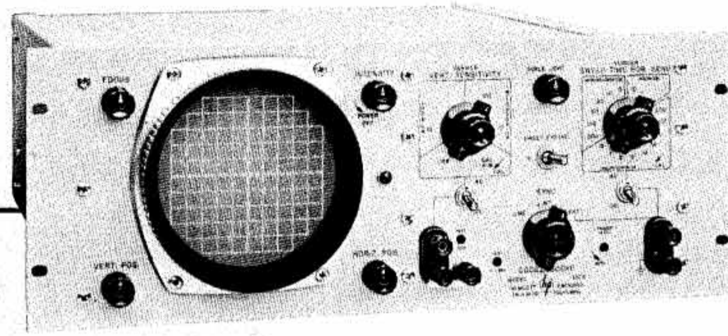
Model	Dual Channel	Band-Width	Rise Time	Calib. Sensitivity (v/cm)	Sweep Ranges	Sweep Magnifier	Signal Delay	Sweep Delay	X-Y Rec. Output	Price
185A/187B	Yes	1,000 MC	0.4 ns	0.01-0.2	0.1 ns-0.1 μs/cm	7 ranges, 1-100	No (1)	Yes	Yes	$3,000.00
170A/162A 170A/162F	Yes No	24 MC 30 MC	0.014 μs 0.012 μs	0.02-20 0.05-20	0.1 μs–5 s/cm	7 ranges, 1-100	Yes	Yes (2)	Yes (3)	2,500.00 2,295.00
160B/162A 160B/162F	Yes No	14 MC 15 MC	0.025 μs 0.023 μs	0.02-20 0.05-20	0.1 μs–5 s/cm	7 ranges, 1-100	Yes	Yes (2)	Yes (3)	2,200.00 1,995.00
150A/152B	Yes	10 MC	0.035 μs	0.05-20	1 μs–5 s/cm	6 ranges, 1-100	Yes	No	No	1,550.00
130B	No	300 KC	1.17 μs	0.001-50	1 μs–5 s/cm	X5	No	No	No	650.00
122A	Yes	200 KC	1.75 μs	0.01-10	5 μs–0.2 s/cm	X5	No	No	No	675.00
120A	No	200 KC	1.75 μs	0.01-10	5 μs–0.2 s/cm	X5	No	No	No	450.00

(1) Can be obtained with separate optional delay line, Model AC-16V. (2) Requires Sweep Delay Generator, Model 166D. (3) Requires Display Scanner, Model 166C.

(hp) 120A/AR 200 KC OSCILLOSCOPE

Quality Production or Lab Instrument at Low Price



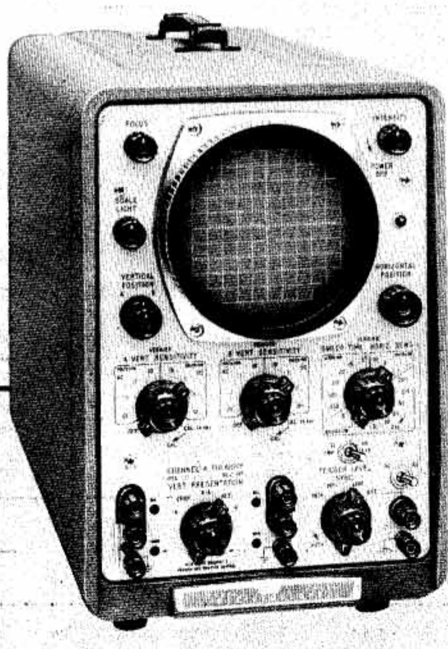


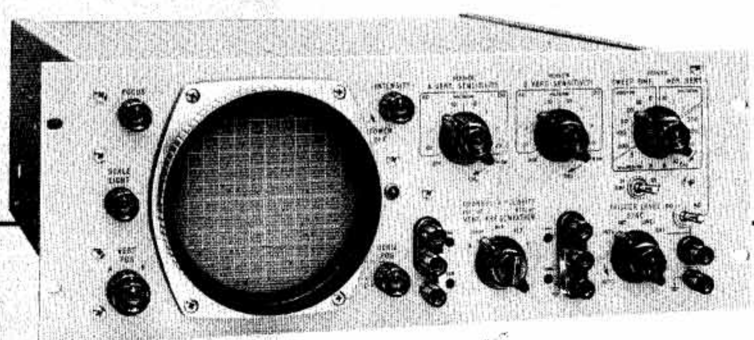
(hp) 120AR

(hp) 120A

(hp) 122A/AR DUAL TRACE 200 KC OSCILLOSCOPE

Big Scope Comparison Versatility at Moderate Price





(hp) 122AR

(hp) 122A

Both Oscilloscopes Opposite Have These Practical Advantages:

Simple operation, easily used by non-technical personnel

Direct reading calibration, automatic trigger, automatic baseline

"Times–5" sweep expander; linear integrator for accurate sweeps

Built-in amplifier calibrator assuring accurate voltage measurements

High quality 5″ cathode ray tube for sharp, clear trace

Slow sweep speeds for medical or mechanical work

Fast sweep speeds for measuring transients

And in Addition Dual Trace Model 122A/AR Offers:

Simultaneous comparison of two signals

Twin vertical amplifiers, each usable separately

Alternate and chopped presentation, differential input

Uses:

Measure complex voltages, stress, strain, vibration analysis, pressure, flow, displacement, other phenomena through proper transducers

and . . .

with ⓗⓟ 122A, also compare amplifier, filter input and output directly, use with vibration testing apparatus; study filter and amplifier characteristics

Models 120A and 122A are basically similar dc to 200 KC oscilloscopes, but Model 122A offers the added versatility of twin vertical amplifiers and dual trace operation.

Both are offered in either cabinet or rack mount styles, and both represent outstanding values in multi-purpose precision instruments suitable for either laboratory or production work.

An important aspect of both oscilloscopes is calibrated performance in a rugged instrument that is simple enough for use by non-technical personnel.

For example, there are no trigger controls to mis-set. The operator merely connects the synchronizing signal and a stable, steady trace appears. This same universal trigger eliminates "hunting" for the spot; it also establishes a baseline when the sync signal is disconnected. This automatic baseline may be over-ridden, however, by a front panel screwdriver adjustment and a ± 10 volt external trigger level established.

A further feature of both Models 120A and 122A is the Type 5AQP1 cathode ray tube which requires no astigmatism adjustment and is always in sharp focus over its full face.

Accurate, Calibrated Amplifiers

ⓗⓟ 120A makes accurate voltage measurements on all types of waveforms easily because the oscilloscopes' amplifiers are calibrated and accurate to within ± 5%. A built-in calibrator accurate to within ± 2% quickly verifies vertical amplifier sensitivity.

Accurate phase shift measurements are also easily available with the 120A. Relative phase shift between the vertical and horizontal amplifiers is less than 2° at 100 KC.

Special Features of Model 122A/AR

In the dual trace Model 122A/AR, the twin vertical amplifiers may be operated in four modes—independently, differentially on all ranges, alternately on successive sweeps, or electronically switched at a 40 KC rate.

AC or DC Coupled

Input and output signals of amplifiers, filters and similar networks can be viewed simultaneously and transmission or rejection characteristics seen immediately. Since dc coupling is available, very low frequency square waves may be used for testing; or the instrument may be ac coupled to eliminate an unwanted dc signal. In vibration studies, more rapid analysis is possible since both the vibration pattern and the driving source waveform may be seen at the same time and in relation to each other.

Phenomena from many transducers may be viewed with ⓗⓟ 122A since it will accept either single-ended or balanced input signals on all vertical amplifier ranges. For balanced input, a front panel switch connects the output from both vertical sensitivity switches to one amplifier so that differential and balanced signals may be examined. Since each attenuator operates independently, signals of differing amplitudes may be studied. Further, undesirable common mode signals such as hum are attenuated and only the difference signal is amplified.

"Times-5" Sweep Expander

A special convenience feature of both Models 120A and 122A is the "times-5" sweep expander. This circuit speeds observation and analysis of transients by expanding any 2 cm segment of a trace to 10 cm. It can be used on all sweep time settings and expands the instrument's fastest sweep time to 1 μsec/cm.

Models 120A and 122A are available in a convenient portable cabinet, or in rack mount configuration as Models 120AR and 122AR. The rack mount versions measure only 7″ high and can be supported on a standard 19″ relay rack by the sturdy front panel.

Specifications

Models 120A/AR, 122A/AR

Sweep

Sweep Range: 15 calibrated sweeps, accurate to within $\pm$ 5%, in a 1–2–5–10, . . . sequence, 5 μsec/cm to 200 millisec/cm. Vernier permits continuous adjustment of sweep time between calibrated steps and extends the 200 millisec/cm step 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 $\pm$ 10%.

Synchronization: Automatic from 50 cps to 250 KC; internally from vertical deflection signals causing 0.5 cm or more deflection; externally from 2.5 volts peak to peak; or from line voltage. Use of level control extends sync range to 10 cps.

Trigger Point: Automatic. Control overrides automatic and permits the trigger point to be set between -10 and $+10$ volts. Turning fully counter-clockwise into AUTO restores automatic operation.

Vertical Amplifiers

Bandwidth: DC coupled; dc to 200 KC. AC coupled: 2 cps to 200 KC. Bandwidth is independent of calibrated sensitivity setting.

Sensitivity: 10 millivolts/cm to 100 volts/cm. 4 calibrated steps accurate within $\pm$ 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 $\pm$ 2%.

Input Impedance: 1 megohm, approximately 50 pf shunt capacitance.

Phase Shift: Vertical and horizontal amplifiers have same phase characteristics within $\pm$ 2° to 100 KC when verniers are fully CW.

Balanced Input: On 10 mv/cm range on both amplifiers. Input impedance, 2 megohms shunted by approximately 25 pf. Common signal rejection is at least 40 db. Common signal must not exceed $\pm$ 3 volts peak.

Difference Input (Model 122A only): 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 signal rejection is at least 40 db with both switches on most sensitive range, 30 db on other ranges.

Vertical Presentation (Model 122A only): Switch selects: A ONLY, B ONLY, B-A, ALTERNATE or CHOPPED.

Horizontal Amplifier

Bandwidth: DC coupled: dc to 200 KC. AC coupled: 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 $\pm$ 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 steps to at least 100 v/cm.

Input Impedance: 1 megohm, nominal, shunted by approximately 100 pf.

Phase Shift: Horizontal and vertical amplifiers have same phase characteristics within $\pm$ 2° to 100 KC.

General

Cathode Ray Tube: 5AQP1 mono-accelerator normally supplied; 2,500 volt accelerating potential. P7 and P11 phosphors are also available. P2 is available if desired for special applications.

CRT Bezel: Light proof bezel provides firm mount for oscilloscope camera and is removed easily for quick change of filter.

CRT Plates: Direct connection to deflection plates via terminals on rear. Sensitivity approximately 20 v/cm.

Intensity Modulated: Terminals on rear. $+20$ v to blank trace of normal intensity.

Filter Supplied: Color of filter compatible with CRT phosphor supplied: Green with P1 and P2. Amber with P7. Blue with P11.

Illuminated Graticule: Edge lighted with controlled illumination, 10 cm x 10 cm, marked in cm squares. Major horizontal and vertical axes have 2 mm subdivisions.

Dimensions: Cabinet Mount: 9¾″ wide, 15⅝″ high, 20¾″ deep. Rack Mount: 19″ wide, 7″ high, 20-11/16″ deep. 19-7/16″ deep behind panel.

Weight: Cabinet Mount: Net 34 lbs. Shipping 43 lbs. Rack Mount: Net 32 lbs. Shipping 48 lbs.

Power: 115/230 v $\pm$ 10%, 50/1,000 cps; approximately 150 watts for 122A, 130 watts for 120A.

Accessories Available: AC-83A Viewing Hood, face-fitting molded rubber, $5.00.

Price:

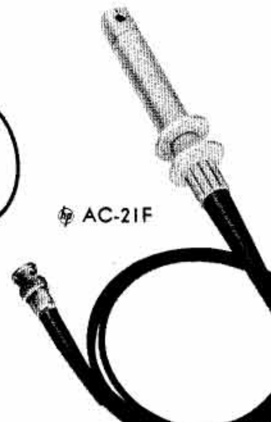
hp 120A or 120AR (cabinet or rack model), $450.00.

hp 122A or 122AR (cabinet or rack model), $675.00.

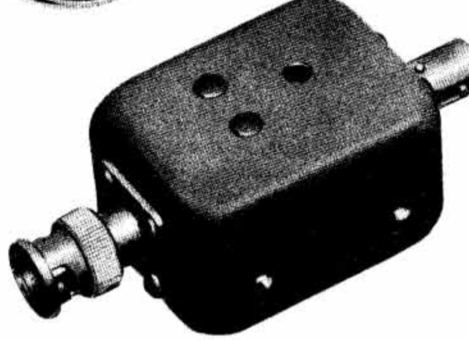
NOTE: Instrument normally supplied with P1 phosphor. When ordering P2, P7 or P11, specify by adding phosphor number after hp model number (i.e.: hp 122AR-11). Phosphor P2 is not recommended for general purposes.

Data subject to change without notice.

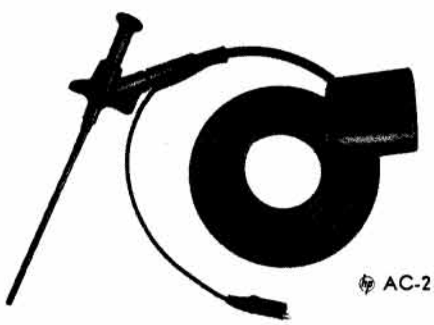
AC-21A



AC-21F



AC-67C



AC-21J

AC-115B

AC-21 PROBES, ACCESSORIES

Voltage Divider Probes

Slim, pen-style AC-21A and AC-21C are compensated voltage divider probes designed to work into 1 megohm shunted by not more than 100 pf. Model AC-21A has a 10:1 division ratio and an input impedance of 10 megohms shunted by 10 pf. Model AC-21C has a 50:1 division ratio and an input impedance of 9 megohms shunted by 2.5 pf. Both probes are useful from dc to more than 30 MC. Response is down 0.5 db or less at 30 MC. Their high input resistance and low shunt capacitance make them useful for reducing circuit loading of oscilloscopes, voltmeters and electronic counters, as well as for attenuating signals. Model AC-21A, $30.00, Model AC-21C, $30.00.

Current Probe, Terminations

Model AC-21F "clamp-around" probe permits measurement and observation of ac currents and pulses in circuits without breaking the circuit or inserting a resistor. The probe clamps around a wire and forms a transformer with a single-turn primary. DC current up to 0.5 amp has no appreciable effect on probe's operation. Price, $100.00.

Two 100-ohm terminations are available for use with the AC-21F Current Probe: Model AC-67B Feed-Through Termination, 2,500 cps to 30 MC bandpass, $17.50; Model AC-67C Compensated Termination, 1,400 cps to 30 MC bandpass, $30.00.

Low Frequency Probe

Model AC-21J Low Frequency Probe provides straight-through connection between circuit test points and voltmeters, ohmmeters, oscilloscopes. Small size and push-button jaws make it ideal for use in tight places, on small contact points. Maximum input voltage is 600 v peak (dc + peak ac), and shunt capacity is approximately 150 pf. Price, $9.00.

AC-115B Oscilloscope Testmobile

More convenient viewing and greater mobility for oscilloscopes are provided by this sturdy, attractive cart, also usable with other instruments of suitable dimensions. Mounted on the cart, instruments tilt up to 30° in 7½° increments.

The 115B Testmobile rolls easily on large, 4″ rubber-tired wheels. Construction is of rugged ⅞″ chrome plated tube stock. Overall size of the cart (less oscilloscope) is 40″ high x 25-7/16″ wide x 29″ deep. It weighs only 28 lbs. and folds compactly for shipment or storage. Price, $85.00.

Data subject to change without notice.

hp 130B/BR 300 KC OSCILLOSCOPE

Versatile, Dependable Laboratory, Production Oscilloscope

Advantages:

Extreme operating dependability

Brilliant, high resolution trace

Automatic triggering system

Sensitivity 1 mv per centimeter

High stability, unique versatility

High gain, balanced input

21 calibrated sweeps; direct reading

Wide pass band, dc to 300 KC

Similar vertical, horizontal amplifiers

Uses:

Provides new convenience in evaluating complex voltages. Particularly ideal for measuring mechanical quantities, through a transducer, such as stress, strain and vibration, pressure, displacement and acceleration.

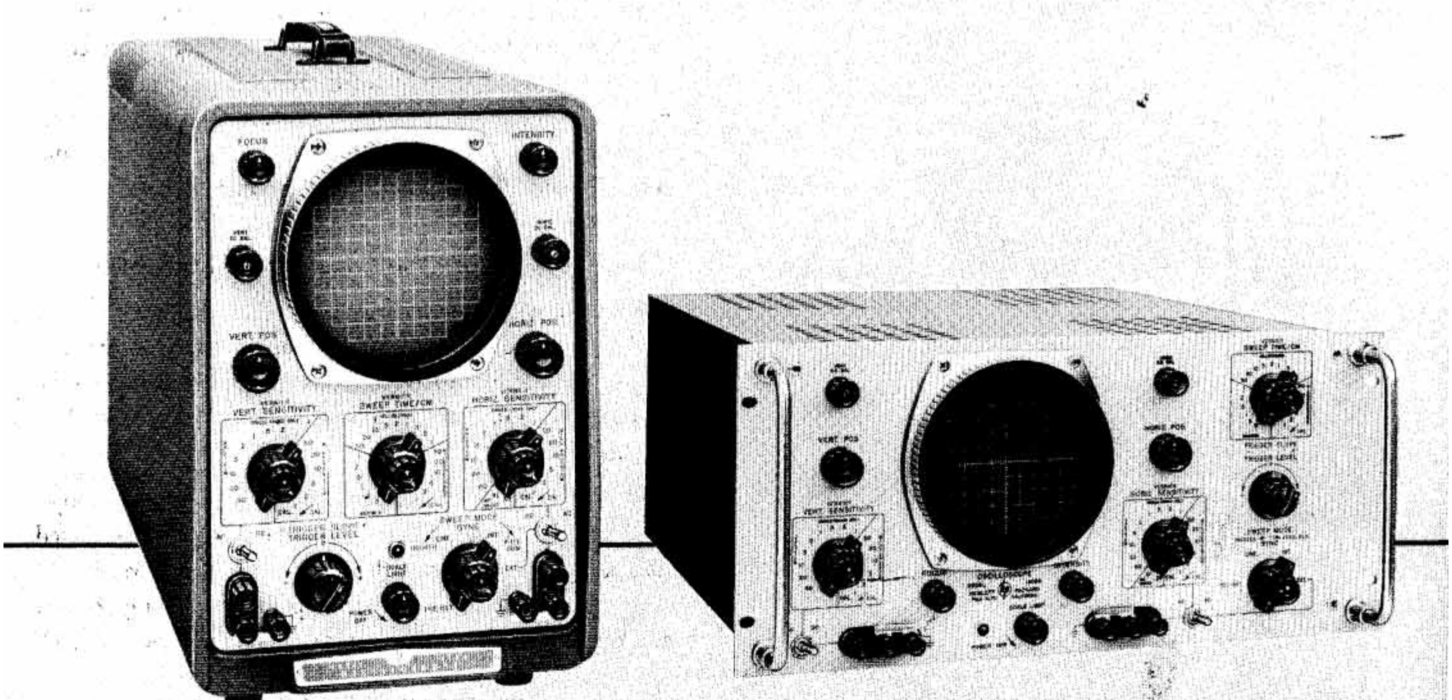
This oscilloscope is actually the first commercial instrument to combine three basic features you want most—broad usefulness, simple operation, and the degree of dependability you expect from time-tested hp instruments.

Covering frequencies from dc to 300 KC, hp 130B is a versatile, all-purpose tool for laboratory, production line and industrial processing measurements. In addition to its versatility as an oscilloscope, hp 130B can be used as a millivoltmeter or voltmeter.

Simple operation is an outstanding characteristic of the instrument. Controls are at a minimum, are color-coded to front panel markings and are arranged by function. 21 sweep times may be directly set on the panel control; no arithmetic or interpolation is required to determine sweep settings. Horizontal sweeps are calibrated from 1 μsec/cm to 5 sec/cm. Accuracy is within 5%, and sweeps are highly linear. A "times - 5" magnifier, for all ranges, expands the fastest sweep to 0.2 μsec/cm.

Automatic Triggering

Two circuit features contribute to the instrument's unique operating convenience. First, the oscilloscope accepts signals direct from conventional transducers without preamplification in the majority of cases. Findings are presented in a brilliant, high resolution trace visible under all lighting condi-



hp 130B   hp 130BR

tions. Second, the instruments contain a "universal" automatic triggering system. Under almost all circumstances, one single preset condition provides optimum triggering. The sweep may be operated free-running when it is desired to determine the base line. A high degree of stability and freedom from horizontal jitter is maintained under all sweep conditions.

Similar Vertical, Horizontal Amplifiers

Horizontal and vertical amplifiers are similar, and provide high sensitivity of 1 mv/cm or 10 mv full scale deflection. The amplifiers have wide pass bands from dc to 300 KC, and offer balanced input circuits on the six most sensitive ranges. (These circuits are particularly useful in industrial, medical and similar applications where it is more convenient to accept a low level balanced signal direct from a transducer.) The amplifiers also provide single ended input, and may be either ac or dc coupled.

Use as Voltmeter

Both amplifiers on the hp 130B are highly stable, requiring virtually no adjustment during operation. Their gain may be standardized by an internal 300 cycle 300 millivolt source. These features, together with the instrument's precision input attenuator, make possible use of the oscilloscope as a millivoltmeter or voltmeter accurate within 5%.

The instrument's CRT bezel removes easily to simplify changing tubes and filters; also provides a firm mount for oscilloscope cameras.

Specifications

Sweep

Sweep Range: 0.2 μsec/cm to at least 12.5 sec/cm. 21 calibrated sweeps, accurate within $\pm 5\%$, in a 1–2–5–10 sequence, 1 μsec/cm to 5 sec/cm. Vernier permits continuous adjustment of sweep time between calibrated steps and extends slowest sweep time to at least 12.5 sec/cm.

Magnifier: X5 magnifier may be used on all ranges and expands fastest sweep to 0.2 μsec/cm. Accuracy within 10%.

Synchronization: Internally from line voltage or from signals causing $\frac{1}{2}$ centimeter or more vertical deflection. Externally from 0.5 volts peak-to-peak or more.

Trigger Point: Continuously adjustable from -30 to $+30$ volts on either positive or negative slope of external synchronizing signal, or from any point of the vertical signal presented on the screen.

Preset Triggering: Switch position on sweep mode control selects optimum setting for automatic triggering.

Input Amplifiers

Vertical and horizontal amplifiers have same characteristics.

Sensitivity: 1 mv/cm to at least 125 v/cm. 15 calibrated ranges, accurate within $\pm 5\%$, in a 1–2–5–10 sequence, 1 mv/cm to 50 v/cm. Vernier permits continuous adjustment between ranges and decreases sensitivity of 50 v/cm range to at least 125 volts/cm. Input voltage rating 600 volts dc or rms.

Phase Shift: Within $\pm 1°$ relative phase shift at frequencies up to 50 KC between vertical and horizontal amplifiers with verniers in CAL.

Stability: 1 mv/hr after warmup.

Bandwidth: dc coupling: dc to 300 KC. ac coupling: 2 cps to 300 KC. Specified bandwidth is independent of sensitivity setting.

Balanced Input: On 1, 2, 5, 10, 20, and 50 mv/cm ranges. Cabinet mount input impedance: 2 megohms shunted with approximately 25 pf. Rack mount input impedance: 2 megohms, approximately 125 pf shunt capacity. Disconnecting the wires at the front panel which connect to the rear terminals reduces the input capacity to approximately 25 pf.

Common Signal Rejection: (Balanced input only.) Rejection at least 40 db. Common signal must not exceed 1.5 volts.

Single Ended Input: Cabinet mount input impedance: 1 megohm shunted with approximately 50 pf. Rack mount input impedance: 1 megohm, approximately 200 pf shunt capacity. Disconnecting the wires at the front panel connecting to the rear terminals reduces the input capacity to approximately 50 pf.

Internal Calibrator: 300 millivolts peak-to-peak $\pm 2\%$, 300 cycle squarewave applied to vertical or horizontal amplifiers by CAL position of input attenuators.

General

Illuminated Graticule: Edge-lighted graticule with controlled illumination, 10 cm x 10 cm, marked in centimeter squares with 2 mm subdivisions, on major horizontal and vertical axes. Effectively shielded from ambient light.

CRT Plates: Direct connection to deflection plates via terminals on rear. Sensitivity approximately 20 v/cm.

Intensity Modulation: Terminals on rear; 20 v positive signal blanks CRT at normal intensity.

Cathode Ray Tube: 5AQP mono-accelerator flat face type with 3000 volt accelerating potential. Available with P1, P2, P7, or P11 screen.

Dimensions: Cabinet Mount: $9\frac{3}{4}''$ wide, 15″ high, $21\frac{1}{4}''$ deep. Rack Mount: 19″ wide, $8\frac{3}{4}''$ high, 22″ deep, depth behind panel $19\frac{3}{4}''$.

Weight: Cabinet Mount: Net 41 lbs. Shipping 54 lbs. Rack Mount: Net 47 lbs. Shipping 62 lbs.

Power Supply: 115/230 volts $\pm 10\%$, 50/1000 cycles, 160 watts.

Filter Supplied: Color of filter compatible with screen phosphor: green for P1 and P2, amber for P7, blue for P11.

Accessories Available: AC-83A Viewing Hood; face-fitting molded rubber, \$5.00. AC-21 series probes (see page 19).

Price: hp 130B (cabinet) or hp 130BR (rack mount), \$650.00. Normally supplied with P1 screen. When ordering with P2, P7 or P11 screen, specify model and phosphor number.

Data subject to change without notice.

hp 150A 10 MC OSCILLOSCOPE

High Sensitivity, Dual Trace, Outstanding Scope Value

Advantages:

Maximum usefulness, reliability

24 direct reading calibrated sweeps

Automatic sweep triggering

0.25 μsec distortionless delay line

Calibrated horizontal amplifier

Plug-in vertical pre-amplifiers, single or dual trace

Sweep magnification of 5, 10, 50 and 100 x

Single shot sweep with lock-out

Quick CRT interchange

Unitized construction

Color-coded, concentric controls, simplified and functionally grouped

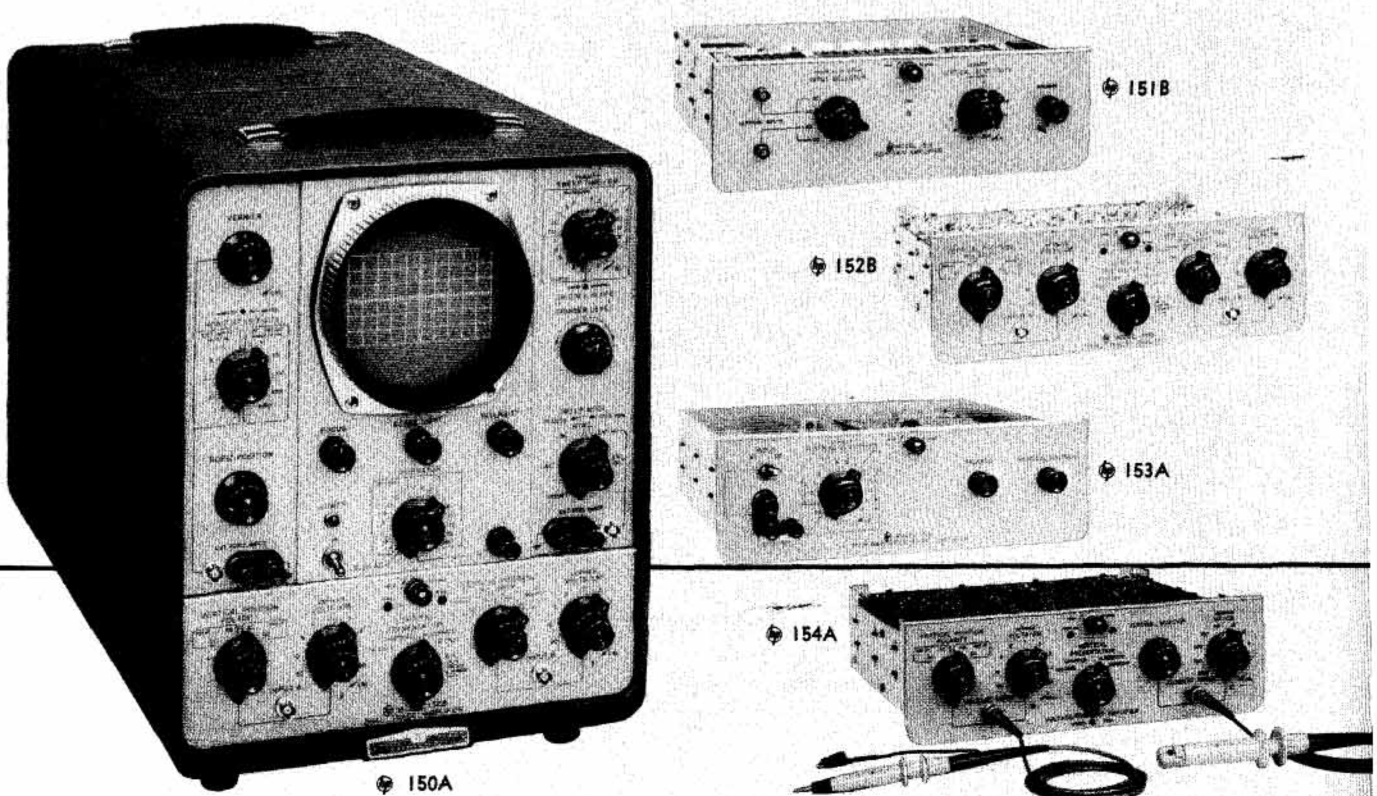
Uses:

General purpose laboratory instrument for fast circuit work in pulse applications such as radar, TV, nucleonics and guidance systems. Presents the ultimate in waveform observation and complex voltage measurement.

For maximum usefulness, hp 150A is designed for operation with a variety of plug-in vertical amplifiers. These include hp 151B, a high gain unit with 5.0 mv/cm maximum sensitivity and frequency response from dc to 10 MC; and hp 152B, a dual amplifier permitting two phenomena to be presented on the CRT simultaneously. Either of hp 152B's dual amplifiers may be used separately. For dual trace presentation, an electronic switch applies amplifier outputs to alternate traces, or switches outputs at a 100 KC rate. hp 153A is a high-gain differential amplifier permitting direct measurement from many transducers. hp 154A is a dual channel amplifier permitting the viewing and comparison of ac voltage and current waveforms simultaneously, or viewing current without direct connection and consequent circuit loading.

Two special features of hp 150A add much to the instrument's convenience and versatility. One is the automatic triggering circuit by which one single preset adjustment establishes optimum triggering for almost all conditions and eliminates most adjustment during or even before measurement. The other feature is the single shot sweep circuit which permits an unlimited expansion of the sweep. The sweep may be armed manually or electronically. An indicator light shows when the circuit is armed.

Further details of these useful plug-ins appear on the opposite page together with complete specifications of the high quality hp 150A itself.



Specifications

ⓗ 150A Oscilloscope

Sweep

Range: 0.02 μsec/cm to 15 sec/cm.

Calibrated: 24 calibrated sweeps in 1, 2, 5, and 10 sequence, 0.1 μsec/cm to 5 sec/cm. Accuracy within 3%.

Sweep Magnification: Sweep may be expanded 5, 10, 50 or 100 times. Increases fastest sweep speed to 0.02 μsec/cm.

Vernier: Permits continuous adjustment of sweep time; extends slowest sweep to 15 sec/cm.

Triggering: Internally, line voltage; externally with 0.5 v or more.

Trigger Point: Any positive or negative level on positive or negative slope of signal triggering sweep. + 30 v to −30 v range for external trigger.

Single Sweep: In single sweep operation, after being triggered, sweep remains locked out until reset.

Horizontal Amplifier

External Input: Pass band dc to over 500 KC. Sensitivity range 200 mv/cm to 5 v/cm. Five calibrated ranges plus vernier.

Input Impedance: 1 megohm shunted by 31 pf.

Vertical Amplifier

Main Vertical Amplifier: Pass band dc to more than 10 MC. Optimum transient response and rise time less than 0.035 μsec.

Signal Delay: 0.25 μsec delay permits viewing leading edge of signal triggering sweep.

General

Amplitude Calibrator: 18 calibrating voltages, 0.2 mv to 100 v peak-to-peak. Accuracy within 3%. Approximately 1 KC square wave with rise and decay times approximately 1 μsec.

Sawtooth Output: + 20 to −20 v sawtooth waveform.

Gate Output: + 20 v signal for duration of sweep.

Illuminated Graticule: Edge-lighted graticule with controlled illumination, marked in centimeter squares with 2 mm subdivisions on major horizontal and vertical axes.

CRT Bezel: Provides firm mount for standard oscilloscope camera equipment; easy access to CRT.

CRT Plates: Direct connection to deflecting plates via terminals in access compartment.

Intensity Modulation: Terminals provided; 20 v positive signal blanks CRT at normal intensity.

Power Supply: 115/230 v ± 10%, 50/60 cycles. Approximately 610 watts.

Cathode Ray Tube: 5AMP mono-accelerator flat face type with 5,000 v accelerating potential. Available with P1, P2, P7 or P11 screen.

Dimensions: 14" wide, 17½" high, 24½" deep.

Weight: Net 83 lbs. Shipping 125 lbs.

Accessories Furnished: 2—AC-21A Low Capacity Probes. 2—AC-76A BNC to binding post adapters.

Accessories Available: Probes, Adapters, page 19. Cables, page 193. Viewing Hood, page 18.

Price: ⓗ 150A, $1,300.00 (cabinet). (Normally supplied with P2 screen. For P1 screen, specify 150A-1; for P7 screen, specify 150A-7; for P11 screen, specify 150A-11.)

ⓗ 151B High Gain Amplifier

Sensitivity Range: 5 mv/cm to 50 v/cm.

Input Attenuator: 12 calibrated ranges, in 1, 2 and 5 sequence, from 5 mv/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.

Input Impedance: 1 megohm shunted with 31 pf.

Pass Band: DC to 10 MC, 0.035 μsec rise time, dc coupled. 2 cps to 10 MC, 0.035 μsec rise time, ac coupled.

Dual Inputs: Two signal inputs with Type BNC. Selection of either input by panel switch.

Weight: Net 4 lbs. Shipping 9 lbs.

Price: ⓗ 151B, $200.00.

ⓗ 152B Dual Channel Amplifier

Sensitivity Range: 0.05 v/cm to 50 v/cm.

Input Attenuator: 9 calibrated ranges, in 1, 2, 5 and 10 sequence, from 0.05 v/cm to 20 v/cm. Vernier.

Input Impedance: 1 megohm shunted with 30 pf.

Pass Band: DC to 10 MC, 0.035 μsec rise time, dc coupled. 2 cps to 10 MC, 0.035 μsec rise time, ac coupled.

Differential Input: Both inputs may be switched to one channel. Common signal rejection is at least 40 db when both input attenuators are set for maximum sensitivity.

Electronic Switching: By alternate sweeps or chopped at approximately 100 KC.

Vertical Positioning: Channels individually adjustable.

Polarity of Presentation: Pos. up or neg. up.

Input Connectors: Type BNC both channels.

Weight: Net 6 lbs. Shipping 10 lbs.

Price: ⓗ 152B, $250.00.

ⓗ 153A Differential Amplifier

Sensitivity Range: 1 mv/cm to 125 v/cm.

Input Attenuator: 15 calibrated ranges, in 1–2–5–10 sequence, from 1 mv/cm to 50 v/cm. Vernier.

Pass Band: DC to 500 KC, dc coupled. 2 cps to 500 KC, ac coupled.

Input Impedance: 2 megohms shunted with 17 pf (balanced). 1 megohm shunted with 35 pf (single-ended).

Common Signal Rejection: (Balanced input only.) At least 40 db on 1 mv/cm to 50 mv/cm ranges when common mode signal does not exceed 1.5 volts. 30 db on other ranges.

Weight: Net 5 lbs. Shipping 9 lbs.

Price: ⓗ 153A, $150.00.

ⓗ 154A Voltage-Current Amplifier

Sensitivity Range: Current: 1 ma/cm to 1,000 ma/cm. Voltage: 0.05 v/cm to 20 v/cm.

Pass Band: Current: 50 cps to 8 MC. Voltage: DC to 10 MC, dc coupled. 2 cps to 10 MC, ac coupled.

Input Impedance: Current channel: probe adds approx. 0.01 ohm with 1μh shunt in series with circuit. Voltage channel: 1 megohm, 30 pf shunt.

Maximum Current: AC 10 amps rms, 20 KC and above ½ amp at 1 KC; dc up to 0.5 amp has no appreciable effect.

Vertical Presentation: Either voltage or current signal continuously; or voltage and current signals sampled at 100 KC or on alternate traces.

Weight: Net 5 lbs. Shipping 10 lbs.

Price: ⓗ 154A, $430.00 (includes AC-21F Current Probe).

Data subject to change without notice.

hp 160B 15 MC AND hp 170A 30 MC OSCILLOSCOPES

MILITARIZED Oscilloscopes Offer Unique Plug-In Versatility

Advantages:

- Extra rugged; meet military environmental requirement*
- Simplified calibration — no distributed amplifiers or multi-section delay lines
- Versatile dual plug-in system
- Reliable operation in extreme environments
- Premium components for dependability
- 24 calibrated sweeps, 0.1 μsec/cm to 5 sec/cm
- Magnifier increases fast sweep to 0.02 μsec/cm
- Easy to use: simplified controls, automatic beam finder

Uses:

- Aircraft, missile check-out systems
- Test installations in adverse environment
- General-purpose laboratory measurements involving fast circuit pulse applications including radar, TV, nucleonics and guidance systems

Both the hp 160B and the new 30 MC hp 170A combine militarized design with conventional controls and dual plug-in systems for wide application, unusual versatility and utmost convenience— all with hp's standards of dependability and reliability.

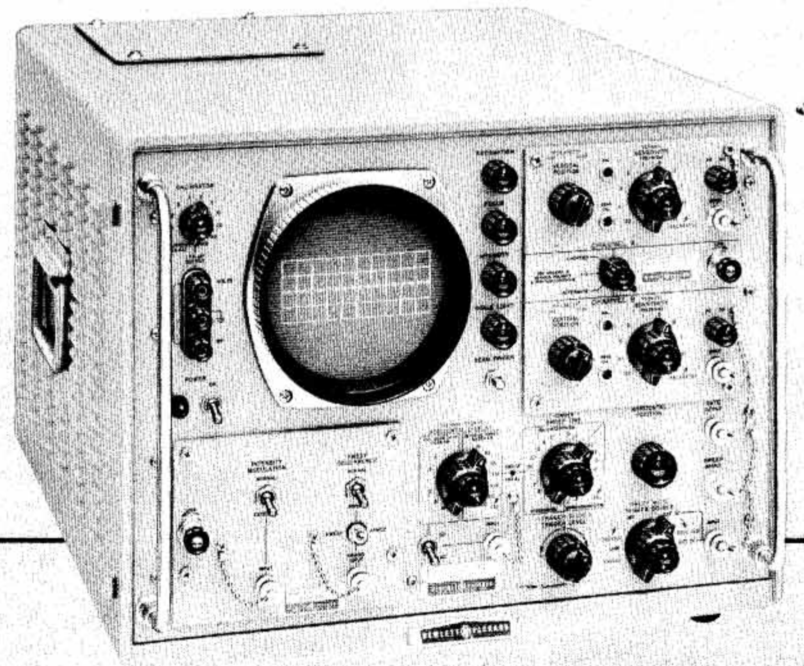
Both are designed to military specifications for RFI, and to withstand altitude, shock, vibration, humidity and temperature variations using MIL-E-16400 as design guide.

Interchangeable vertical and time-axis plug-ins provide instantly expandable measurement capability as it is needed. Selection of plug-ins with minimum investment offer X-Y records of repetitive waveforms, new sweep delay convenience and widely versatile input capabilities.

Calibration adjustments and maintenance problems are materially reduced in Models 160B/170A by the elimination of multi-section delay lines and distributed amplifiers usually associated with high frequency oscilloscopes. Improved preset triggering insures optimum operation for almost all conditions with just one adjustment—even on signals down to 2 mm deflection. A push-button beam finder automatically locates off-screen beam or trace (especially useful for operation by inexperienced personnel).

Important features include reliable tube-transistor cir-

*See "Environmental Specifications for hp Models 160B and 170A Oscilloscopes and Models 166A, 162A, 166D Plug-in Units" for detailed specifications. Available from Hewlett-Packard Co. or your hp representative.



hp 170A with 162A and 166A plug-ins.

cuits, regulated dc filament voltages and premium components throughout. Power transistors in efficient heat sinks insure cool operation. Etched circuits on translucent epoxy glass simplify circuit tracing and servicing.

Specifications ⓗ 160B/170A

(With ⓗ 166A Auxiliary Unit plugged in.)

Sweep Generator:

Internal Sweep: 24 ranges, 0.1 μsec/cm to 5 sec/cm; ±3%. Vernier extends slowest sweep to 15 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 (½ v peak-to-peak or more).

Trigger Point: Positive or negative going voltage. Trigger level of external sync signal adjustable —30 to + 30 v.

Sawtooth Output: — 50 to + 50 v.

Gate Output: + 50 v 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: ⓗ 160B, dc to 15 MC.
ⓗ 170A, dc to 30 MC.

Calibrator:

Type: 1,000 cycle square wave, 1 μsec rise and decay time.

Voltage: 18 calibrated ranges ±3%, 0.2 mv to 100 v peak-to-peak.

Current: 5 ma peak-to-peak, ± 3%.

Cathode Ray Tube:

Type: Model 160B: 5 AMP mono-accelerator, flat face, P1, P2, P7, or P11 screen. 5,000 v accelerating potential. Model 170A: 5 BHP post-accelerator, P1, P2, P7, or P11 screen. 10,000 v accelerating potential.

Filter Supplied: Compatible with phosphor, green with P1 and P2, amber with P7, and blue with P11.

Graticule: 10 cm long x 6 cm high (ⓗ 170A, 10 cm x 4 cm) marked in centimeter squares; 2 mm subdivisions on horizontal and vertical axes.
Controlled edge lighting.

Deflection Plate Connection: Pin type terminals.

Deflection Sensitivity: Model 160B, approx. 20 v/cm; Model 170A, approx. 7 v/cm.

Intensity Modulation: + 20 v pulse will blank CRT trace of normal intensity.

General:

Power Requirements: 115/230 volts ± 10%, 50/440 cps, approx. 480 watts (ⓗ 170A approx. 500 watts).

Color: Grey enamel in accordance with Type III Class 2 of Specification MIL-E-15090.

Dimensions: Cabinet Mount: 14⅜" high, 19" wide, 22⅛" deep. Rack Mount: 12¼" high, 19" wide, 21" deep behind panel.

Weight: Cabinet Mount: Net 85 lbs., shipping 100 lbs. Rack Mount: Net 85 lbs., shipping 100 lbs.

Plug-In Vertical Amplifiers: Model 162A Dual Trace Amplifier or Model 162F Fast Rise Preamplifier *(see next page for details and prices).*

Time Axis Plug-In Units: Model 166A Auxiliary Unit (supplied with ⓗ 160B and 170A, provides Z-axis input and single sweep arming input connections).
Model 166B Marker Generator *(see page 27).* Model 166C Display Scanner *(see page 27).* Model 166D Sweep Delay Generator *(see page 27).*

Accessories Available: AC-83A Viewing Hood; AC-21A Probe, 10:1 division; AC-21C Probe, 50:1 division; AC-21F Current Probe, 1 mv/ma; AC-67B Feed-thru Termination for AC-21F, 2.5 KC to 30 MC; AC-67C Compensated Termination for AC-21F, 1.4 KC to 30 MC; AC-76A BNC male to binding post adapter; AC-115B Testmobile. *(See page 19 for accessory details.)*

Accessories Furnished: Two AC-21A Probes, two AC-76A Adapters.

Options: 50 to 60 cps ac fan in lieu of dc fan, no extra charge.

With all tubes and transistors MIL approved types, specify H02-160B or H02-170A, add $185.00, and specify H02-162A, add $45.00. (Environmental specifications are met with or without this option.) For H02-166D, add $40.00.

Chassis Track Detented Tilting slides for rack mount, specify C99-160BR, C99-170AR, add $85.00. 160B-44-A1, 170A-44A-1 Front Cover required for drip proofing, (includes adapters; 2-UHF female to BNC male UG-255/U, 2-Dual Banana Plug to BNC male UG-1035/U, 2-UHF male to BNC female UG-273/U, 2-BNC Tees UG-274A/U and 2-8 ft. BNC male to BNC male cables CG-409E/U), add $75.00. (Not compatible with rack mount.)

Price: With line filter, dc fan and Model 166A plug-in unit.
160B* (cabinet or rack mount), $1,850.00.
162A* Dual Trace Amplifier, $350.00.
162F Fast Rise Preamplifier, $145.00.
166B Time Mark Generator, $130.00.
166C Display Scanner, $300.00.
166D* Sweep Delay Generator, $325.00.
170A* (cabinet or rack mount), $2,150.00.

*Available with all tubes and transistors. MIL approved types (extra cost option).

Data subject to change without notice.

MILITARIZED AMPLIFIERS

162A Dual Trace Amplifier

This vertical plug-in for the 160B/170A Oscilloscopes gives sensitivity to 20 mv/cm, permits viewing of two phenomena simultaneously, offers differential input for common mode rejection, meets environmental requirements of MIL-E-16400.*

Specifications

Each Channel:

Sensitivity Range: 0.02 v/cm to 50 v/cm. Ten calibrated ranges in 1, 2, 5, 10 sequence from 0.02 v/cm to 20 v/cm. Accuracy ± 5%.
Vernier extends minimum sensitivity to at least 50 v/cm.

Pass Band: With 160B: dc coupled; dc to 14 MC, 0.025 μsec rise time. AC coupled; 2 cps to 14 MC.
With 170A: dc coupled; dc to 25 MC, 0.014 μsec rise time. AC coupled; 2 cps to 24 MC.

Input Impedance: 1 megohm (nominal) shunted by 25 pf.

Polarity of Presentation: + up or − up, selectable.

Electronic Switching: By alternate sweep or chopped at approximately 1 MC, with blanking during switching.

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.

General:

Weight: Net 6 lbs.

Power: Supplied by 160B or 170A Oscilloscope.

*See "Environmental Specifications for 160B and 170A Oscilloscope."

Accessories Available: AC-21F Current Probe, $100.00; AC-67B Feed-through Termination (for AC-21F, 2.5 KC to 30 MC), $17.50; AC-67C Compensated Termination (for AC-21F, 1.4 KC to 30 MC), $30.00; AC-21C Probe, 50:1 division, $30.00.

Price: 162A Dual Trace Amplifier for 160B or 170A Oscilloscope, $350.00.
With all tubes and transistors MIL approved types, specify H02-162A, $395.00. (Environmental specifications are met with or without this option.)

162F Fast Rise Preamplifier

The low cost new 162F allows full utilization of the excellent transient response of the 160B/170A main vertical amplifiers. Rise time with the 170A is 12 nsec, bandpass dc to 30 MC (3 db points). With the 160B rise time is 23 nsec, bandwidth dc to 15 MC. Sensitivity is 50 mv/cm with either 170A or 160B. Meets environmental requirements of MIL-E-16400.*

Specifications

Pass Band: With 170A: DC coupled; dc to 30 MC, 12 nsec rise time. AC coupled; 2 cps to 30 MC, 12 nsec rise time.
With 160B: DC coupled; dc to 15 MC, 23 nsec rise time. AC coupled; 2 cps to 15 MC, 23 nsec rise time.

Sensitivity Ranges: 0.050 v/cm to 50 v/cm. Nine calibrated ranges in 1, 2, 5, 10 sequence from 0.05 v/cm to 20 v/cm. Vernier provides continuous adjustment between ranges and extends minimum sensitivity to at least 50 v/cm.

Input Impedance: 1 megohm (nominal) shunted by 25 pf.

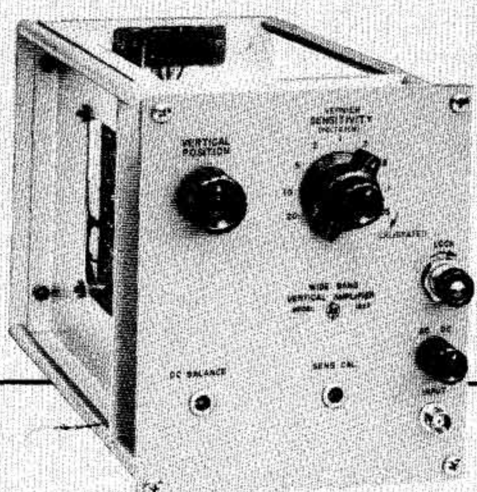
Weight: Net 5 lbs.

Power: Supplied by 160B or 170A Oscilloscope.

Price: 162F, $145.00.

Data subject to change without notice.

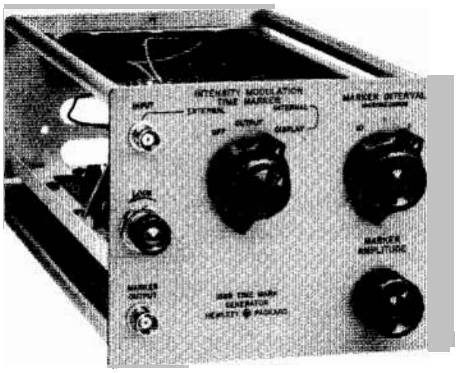
162A



162F

hp 166B Time Mark Generator

Precise time measurements are easy to make with the new hp 166B Time Mark Generator, which provides intensity modulated time markers on the oscilloscope trace when plugged into either hp 160B or 170A. Model 166B is also useful for photographs, for calibration of the faster oscilloscope sweeps and for operation between calibrated sweep ranges with the sweep vernier. External output features make possible the use of markers as triggers or for calibration of other devices.



Specifications

Range: 10 μsec, 1 μsec, and 0.1 μsec intervals.
Accuracy: ± 0.5%.
Output Markers:
- **Amplitude:** 0 to 1 volt, adjustable.
- **Duration:** Less than 40% of marker interval.

Functions:
- **Time Marker:**
  - **Off:** Marker de-energized.
  - **Output:** Marker provided at BNC output jack.
  - **Display:** Marker provides intensity modulation on display.
- **Intensity Modulation:**
  - **External:** Provides for normal external intensity modulation.
  - **Internal:** Connects internal time markers to display.

Weight: Net 3½ lbs. Shipping 6 lbs.
Power: Supplied by hp 160B or 170A Oscilloscope.
Price: hp 166B, $130.00.

hp 166C Display Scanner

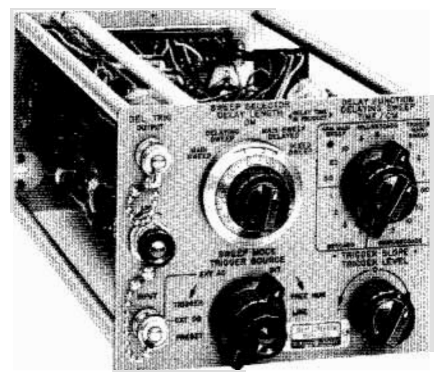
A time-axis plug-in for the hp 160B/170A Oscilloscopes, the hp 166C provides output to duplicate, on an X-Y recorder, any repetitive waveform appearing on the CRT trace. Resolution, with permanent, large-scale records, is higher than either the CRT display or a photograph. The trace can be viewed on the CRT while records are being made.

Specifications

Vertical Output: With 160B: Approximately + 0.7 v for 3 cm above middle of CRT, −0.7 v for 3 cm below middle of CRT.
With 170A: Approximately + 0.55 v for 2 cm above middle of CRT, −0.55 for 2 cm below middle of CRT.
Horizontal Output: 0 cm, approximately + 50 v; 10 cm, approximately − 50 v.
Bandwidth: 14 MC with 160B/162A; 20 MC with 170A/162A.
Scanning: Manual, internal (with pen speed stabilized or linear) or external.
Scanning Time: Internal linear, approximately 1½ min. Internal with pen speed stabilized, approximately 25 sec when displaying base line only.
Oscilloscope Sweep Speed: From fastest sweep to 5 msec/cm; signal repetition rate greater than 20 cps.
Price: hp 166C Display Scanner for 160B or 170A Oscilloscope, $300.00.

hp 166D Sweep Delay Generator

Detailed examination of a complex signal or pulse train is possible with this time-axis plug-in for the hp 160B/170A Oscilloscopes. A unique mixed sweep feature permits viewing of an expanded waveform segment while still retaining a presentation of earlier portions of the waveform.



Specifications

Delay Time: 1 μsec to 10 sec.
Delaying Sweep: 18 calibrated ranges from 2 μsec/cm to 1 sec/cm in 1, 2, 5, and 10 sequence.
Delayed Length: 0 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.
Accuracy: ± 1% 2 μsec to .1 sec ranges; ±3% .2, .5, 1 sec ranges. ±0.2% linearity, all but 2, 5 and 10 μsec ranges. ±0.5% 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 (2 mm or more vertical deflection). External, ½ volt peak-to-peak or more.
Triggering Point: Positive or negative going voltage. Trigger level of external sync signal adjustable from − 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.
Price: hp 166D Sweep Delay Generator for hp 160B and 170A Oscilloscopes, $325.00. With all tubes and transistors MIL approved types specify H02-166D, $365.00. (Environmental specifications are met with or without this option.)

Data subject to change without notice.

ⓗⓟ 185A 1,000 MC OSCILLOSCOPE

Conventional Measuring Ease in Nanosecond Region

Advantages:

- Bright, clear, 5" scope presentation, DC to 1,000 MC
- Bright, steady traces even at low repetition rates
- Less than 0.4 nanosecond rise time for brilliant picture of nanosecond pulses
- Dual channel, differential input permits study of two high-speed signals
- Sweep expansion to 0.1 ns/cm for extreme resolving capability
- High sensitivity for viewing small signals; wide dynamic range for viewing small voltages on high voltage plateaus
- X–Y recorder output; time, amplitude calibrators, beam finder, conventional oscilloscope controls

Uses:

- Analyze nanosecond pulses
- Measure transistor response time
- Make fractional nanosecond time comparisons
- Measure diode switching times
- Determine pulse jitter
- Make permanent X–Y plots
- Measure memory-unit switching time
- Measure uhf voltage amplitude

The new ⓗⓟ 185A is the oscilloscope to use anywhere from DC to 1,000 MC. It offers the same simplicity of operation, the same big, bright, steady trace as conventional low-frequency scopes, yet the ⓗⓟ 185A is swift and easy to use all the way to 1,000 MC.

In such fields as computer and radar research and design, and semiconductor research, Model 185A is the first practical, commercially available answer to the need for measuring and viewing nanosecond pulses.

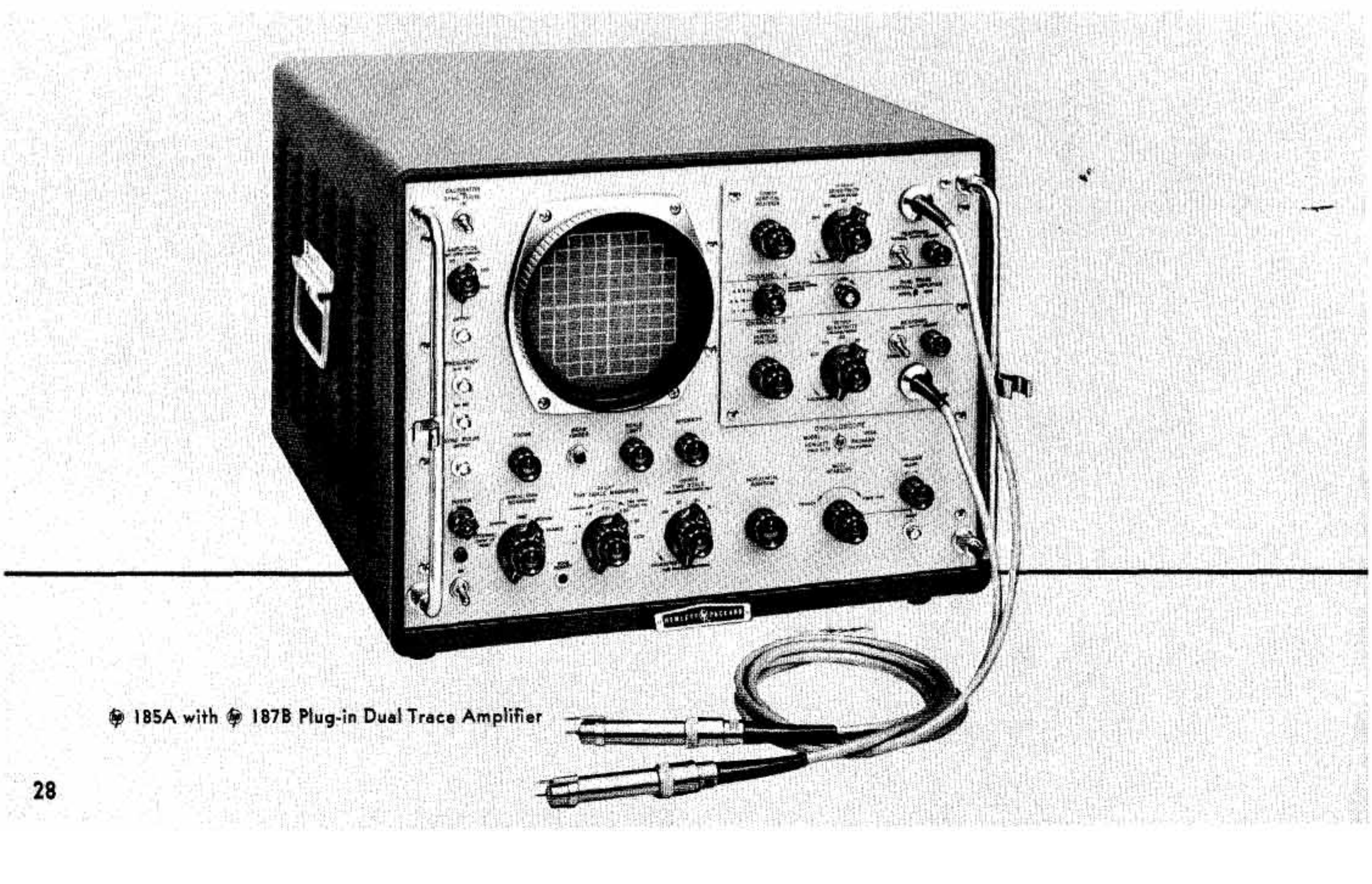
Sampling Oscilloscope

Whereas most previous high frequency oscilloscopes have been broadband instruments, the new ⓗⓟ 185A is a sampling oscilloscope.

Broadband instruments have inherent limitations at very high frequencies. One is the sensitivity-bandwidth-display size limits of cathode ray tubes. Another is the gain-bandwidth limitation of associated amplifiers. A third involves low repetition rates often associated with fast pulses—the writing rate is often not adequate for a bright trace.

Model 185A sidesteps each of these objections by first translating the input signal to a much lower frequency, then proceeding along conventional oscilloscope signal processing techniques.

The translation is achieved by the sampling process, an approach analogous to stroboscopic light in that both simulate slowing down the "motion" for better visual perception—and both depend on repetition for a faithfully simulated signal. The sampling process, however, will operate with an aperiodic signal.



ⓗⓟ 185A with ⓗⓟ 187B Plug-in Dual Trace Amplifier

To permit study of fast pulses in great detail, and under varied trigger conditions, the 185A has a variable time delay and 4-range time scale with 6-step magnifier.§

Built-in Delay Feature

Model 185A syncs with external triggers to 100 MC, and also provides a front panel delayed sync pulse which may be used to trigger the circuit under test. In situations where the circuit will respond to this trigger, a delay line is unnecessary. An accessory, the H01-184A Synchronizing Trigger Unit *(page 30)* provides synchronization for signals up to 800 MC.

Recorder Output

An unique feature of the 185A is its X–Y recorder output. The instrument's Manual Scan control slows the input signal, permitting X–Y plotting for permanent records, reports, etc., with such instruments as the Moseley Model 2D Autograf Recorder.

Dual or Differential Input

Model 187B Dual Trace Amplifier is a plug-in unit for Model 185A permitting comparison of two high speed signals simultaneously, or comparison of time, duration and spacing. The amplifier has a wide dynamic range of 3 mv to 2 volts peak, and independent sensitivity controls on each channel.

Special, Easy-to-Use Probes

An outstanding feature of the ℎ𝑝 187B is the pair of compact, new-concept probes arranged for easy application to the test circuit. The probes provide a high, 100,000 ohm input resistance shunted by 2 pf to virtually eliminate loading of the test circuit. For maximum versatility, the probes may be used with Type N, BNC or other fittings. *(See page 30.)*

Calibrated vertical sensitivity controls permit measurements of a wide range of input levels from 10 to 200 mv/cm. A vernier between steps further increases sensitivity to 3 millivolts/cm.

§Characteristics and features are described more fully in the Hewlett-Packard Journal, Vol. 11, No. 5-7, Jan.-Mar., 1960.

Additional information on uses of the 185A/187B oscilloscope is included in ℎ𝑝 Application Notes 44A, 44B and 44C.

Specifications

ℎ𝑝 Model 187B Dual Trace Amplifier

(When plugged into Model 185A Oscilloscope)

Vertical (Dual Channel):

Bandwidth:* (A) Greater than 800 MC at 3 db point, less than 0.5 nsec rise time for any input signal. (B) For most signals a passband of dc to 1,000 MC at 3 db point, less than 0.4 nsec rise time, may be obtained. Conditions that must be satisfied are that the waveforms be identical from occurrence to occurrence and that the rise time be displayed by at least 12 samples*

Overshoot or Undershoot: Less than 5%.

Sensitivity: Calibrated ranges 10 mv/cm to 200 mv/cm in a 1, 2, 5 sequence. Vernier control between steps which increases sensitivity to 3 mv/cm.

Voltage Calibrator: 10 mv to 500 mv, accuracy ± 3%.

Input: By means of input probe for each channel.

Noise: Approximately 2 mv peak-to-peak; reduced by approximately 5:1 in smoothed (noise compensation) position of response switch.

Input Impedance: 100,000 ohms shunted by 2 pf.

Accessories Furnished: 187A-76A BNC Adapter, 2 supplied. 187B-76F Adapter, 2 supplied; permits use of ℎ𝑝 187A accessories with ℎ𝑝 187B probes.

Price: ℎ𝑝 187B, $1,000.00.

ℎ𝑝 Model 185A Oscilloscope

Horizontal:

Sweep Speeds: 0.1 nsec/cm to 100 nsec/cm. Calibrated within ± 5% using any combination of Time Scale and Time Scale Magnifier settings with the exception of the first 50 nsec of the 100 nsec/cm Time Scale and first 20 nsec of the 50 nsec/cm Time Scale.

Time Scale: 4 ranges, 10, 20, 50, and 100 nsec/cm. Vernier control between steps which increases speed.

Time Scale Magnifier: X2, X5, X10, X20, X50, X100; may be used with any Time Scale.

Jitter: Less than 0.03 nsec peak-to-peak; reduced by approximately 5:1 in smoothed (noise compensation) position of vertical response switch.

Sample Density: Fine (approximately 1,000 samples/trace), medium (approximately 200 samples/trace), and coarse (approximately 50 samples/trace).

Manual Scan: Permits making X–Y pen recordings.

Time Calibrator: 500 MC and 50 MC damped sine waves (frequency accuracy ± 1%).

Minimum Delay: Less than 120 nsec.

Variable Delay Range: Any portion of the unmagnified trace may be viewed in detail using the Time Scale Magnifier and the time delay.

External Trigger: ± 50 mv for 20 nsec or longer, ± 0.5 v for 1 nsec; approximately 120 nsec in advance of signal to be observed.

"Sampling" Repetition Rate: 100 KC maximum.

Trigger Rate: 50 cps to at least 100 MC (holdoff circuit in operation above 100 KC).

Trigger Input Impedance: With Sync Probe, greater than 700 ohms; without probe, 50 ohms at panel. Capacitive coupling.

Sync Pulse Output:

Amplitude: Positive, at least 2.5 v into 50 ohms.

Rise Time: Less than 1.5 nsec.

Width: Greater than 1 μsec.

Timing: Approximately 20 nsec after start of undelayed trace.

Recurrence: One pulse per sample.

General:

X–Y Recorder Output: Available in Manual Scan for making pen-recording of waveforms:
Horizontal Output, 0 at left to approx. 12 v at right of CRT face, source impedance 20,000 ohms. Vertical Output, −1 v at bottom to + 1 v at top of CRT face, source impedance 10,000 ohms.

Beam Finder: Facilitates location of beam that is off scale.

Cathode Ray Tube: 5 in. type 5AQP.

Useful Deflection: 10 cm x 10 cm.

Power: 115/230 v ± 10%, 50/60 cps, approx. 250 w.

Dimensions: Cabinet Mount: 14⅝" high, 19" wide, 22⅛" deep. Rack Mount: 12¼" high, 19" wide, 21" deep behind panel.

Weight: Net 75 lbs. Shipping 120 lbs.

Accessories Furnished: 185A-21A Sync Probe.

Accessories Available: See next page.

Price: ℎ𝑝 185A, $2,000.00 (cabinet).

*The present lack of pulse generator which can provide a pulse sufficiently fast and distortion free to serve as a waveform standard makes it difficult to specify the step response of ℎ𝑝 187B. The specified rise time of less than 0.5 nsec is that observed from a tunnel diode pulse generator and includes the rise time of the pulse generator itself, estimated at 0.2 nsec. The actual rise time of the 187B, based on its measured bandwidth (over 800 MC), is less than 0.44 nsec in case (A), less than 0.35 nsec in case (B).

Data subject to change without notice.

ACCESSORIES FOR 185A 1,000 MC OSCILLOSCOPE, 187B DUAL TRACE AMPLIFIER

185A-21A Sync Probe

Furnished with the 185A Oscilloscope, this probe provides a convenient means for connecting synchronizing signals to the scope. The probe increases input impedance to at least 700 ohms, reduces trigger sensitivity about 6:1. Price, $51.00.

187A-76A BNC Adapter

These adapters, two of which are furnished with the 187B Scope, convert the signal probe of the 187B to a male BNC connector, permit viewing of signals from BNC fittings. Price, $8.00.

187A-76B Type N Adapter

This adapter converts the 187B signal probe to a Type N connector. It is a straight-through connection and not a cable matching termination. Price $10.00.

187A-76C 10:1 Divider

Signals as large as 20 v peak-to-peak may be observed with this divider, which increases the input impedance of the probe to 1 megohm shunted by 3 pf. The divider has an axial pin for contacting test points and will accept most other accessories. Does not fit 187B-76E 50-ohm T Connector. Price, $40.00.

187A-76D Blocking Capacitor

Used directly with the signal probe or with the probe and 187A-76C 10:1 Divider, this blocking capacitor permits the observation of signals ±600 v from ground. The blocking capacitor contributes negligible sag, adds to the input no more than 0.5 pf shunt capacitance. Price, $3.50.

187B-76E 50-ohm T Connector

The 187B-76E T connector may be inserted into a 50-ohm transmission line so that the scope probe can be used to monitor the signal on the line. Insertion loss is low, so that the T (with probe inserted) does not disturb the line or appreciably attenuate the signal being transmitted. The T Connector and a low reflection load (such as the 908A) may be used to terminate the 50-ohm line in its characteristic impedance while observing the signal with the oscilloscope. Price, $35.00.

908A 50-ohm Coaxial Termination

908A is a low power termination for 50-ohm transmission lines. Its SWR is 1.05 or less at any frequency, dc to 4,000 MC. Dissipation is ½ w. Price $35.00. *(See also page 189.)*

AC-16V Delay Line

The AC-16V Delay Line is designed expressly for use with the 185A when a signal delay must be inserted in the signal path. Bandpass is approximately 1 GC (KMC), and delay is 120 ns. Price, $200.00.

185A-76A Sync Take-off

For synchronizing the 185A Oscilloscope from the signal to be viewed, the 185A-76A is connected at the input end of the AC-16V Delay Line to split the signal into two parts. One part goes through the delay line to the scope signal input; the other goes directly to the trigger input of the scope and arrives 120 ns before the signal to be viewed. Insertion loss is approximately 6 db for both signal and trigger channels. Price, $50.00.

185A-21 Divider Probes; AC-16W Cable

4 probes, with division ratios (when terminated by 50-ohms) of 5, 10, 50 and 100 to 1 provide a high impedance signal input while triggering the 185A from the signal itself. Input capacity is 0.4 pf, resistance 250 to 5000 ohms, depending on division. AC-16W Cable connects dividers to 185A-76A or 187B-76E; gives you a flexible lead input to AC-16V. Price, 185A-21C, D, E or F, $40.00. AC-16W, $10.00.

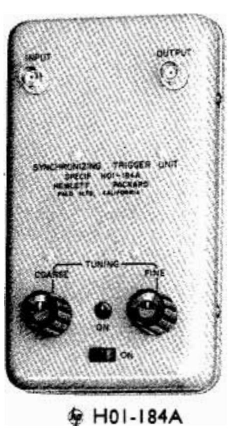
H01-184A Synchronizing Trigger Unit

This count-down device permits viewing of signals up to 800 MC with the 185A Oscilloscope. The H01-184A generates trigger signals at a rate suitable for the 185A from signals between 50 and 800 MC. Its output is approximately a squarewave and is locked to the input frequency.

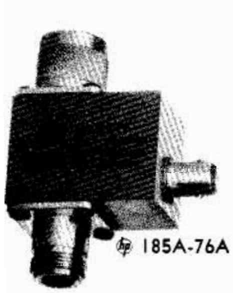
Specifications

Input Frequency: 50 to 800 MC.
Input Impedance: 50 ohms; SWR less than 1.2, 50 to 800 MC.
Sensitivity: 200 mv p-p sine wave; less for other wave shapes. Will operate with smaller signals with some increase in jitter.
Jitter: When viewing signal on 185A: less than 2% of one rf cycle, 50 to 400 MC; less than 5% of one rf cycle, 400 to 800 MC.
Output Frequency: 10 to 20 MC; submultiple of input frequency.
Output Waveform: Approx. square wave, 500 mv p-p into 50 ohms.
Output Signal at Input Jack: Less than 15 mv p-p.
Power: Two size D flashlight cells, life approx. 300 hrs.
Price: $215.00.

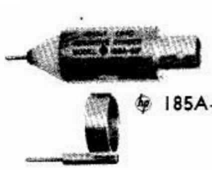
Data subject to change without notice.



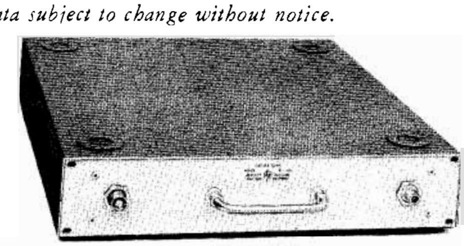
H01-184A



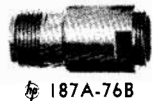
185A-76A



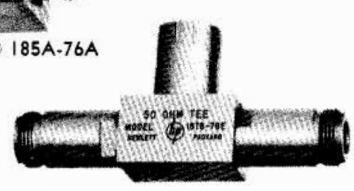
185A-21F



AC-16V



187A-76B



187B-76E

187A-76D

187A-76C

196A OSCILLOSCOPE CAMERA

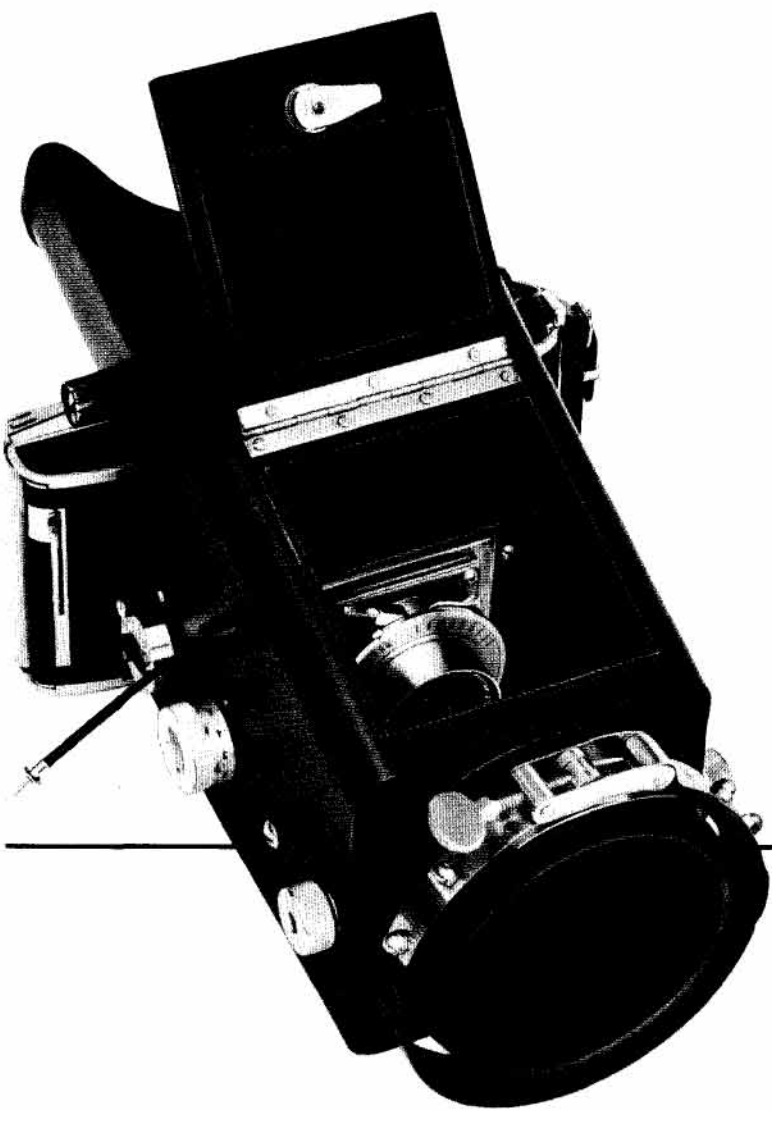
Full-Sized, Distortion-Free, Scalable Photos, Transparencies Quickly

Model 196A Oscilloscope Camera is the most convenient and versatile means yet devised for recording oscilloscope traces on either film or transparency.

Results are as sharp and clear as the cathode ray tube trace itself; the camera's new $f/1.9$ lens has imperceptible distortion which means pictures may be scaled accurately. A 10 cm graticule fills the full film area, and multiple exposures are easily achieved by a one-hand adjustment moving the lens through 11 detented positions. Model 196A may be used with new Polaroid® Land Type 47 film which offers materially improved resolution and 10 second development time.

Mount, Unmount in Seconds

Operation is simplicity itself. The camera mounts in seconds on the oscilloscope with a sturdy, one-hand clamp fitted with a quick-lock tab. The f-stop and shutter may be adjusted while the camera is mounted on the scope. Use of a professional camera bellows prevents film loss from light leakage. The entire unit, including the Polaroid Land Camera back, is compact, rugged, lightweight and extremely convenient.



Specifications

Object/Image Ratio: 1 to 0.9. Available with 1 to 1 ratio.

Lens: Wollensak 3″ (75 mm) $f/1.9$ Oscillo-Raptar.

Focus: Factory adjusted for CRT face 5/16″ behind front surface. May be adjusted for other distances.

Lens Opening: $f/1.9$ to $f/16$.

Shutter: Alphax #3. Time, Bulb, 1/100, 1/50, 1/25, 1/10, 1/5, 1/2, 1 second.

Print Size: 3¼″ x 4¼″. Image Area 2⅞″ x 3-13/16″ (7.3 cm x 9.6 cm).

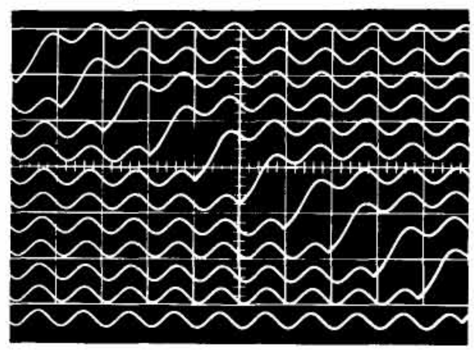
Film: Polaroid® Land types 42, 44, 46, 46-L, 47.

Size: 13½″ long, 9¼″ high, 10″ wide. Weights: net 9 lbs., shipping 18 lbs. (32 lbs. in carrying case).

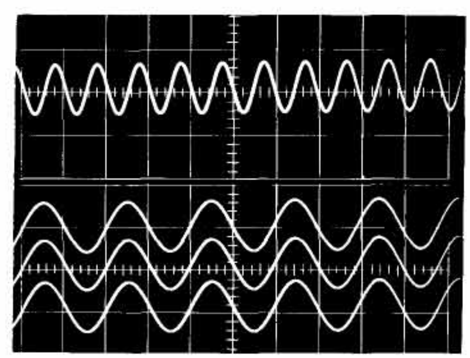
Accessories Available: hp 196A-45 Carrying Case, \$40.00; hp 196A-20 Tektronix Adapter, \$4.50.

Price: \$440.00.

Data subject to change without notice.

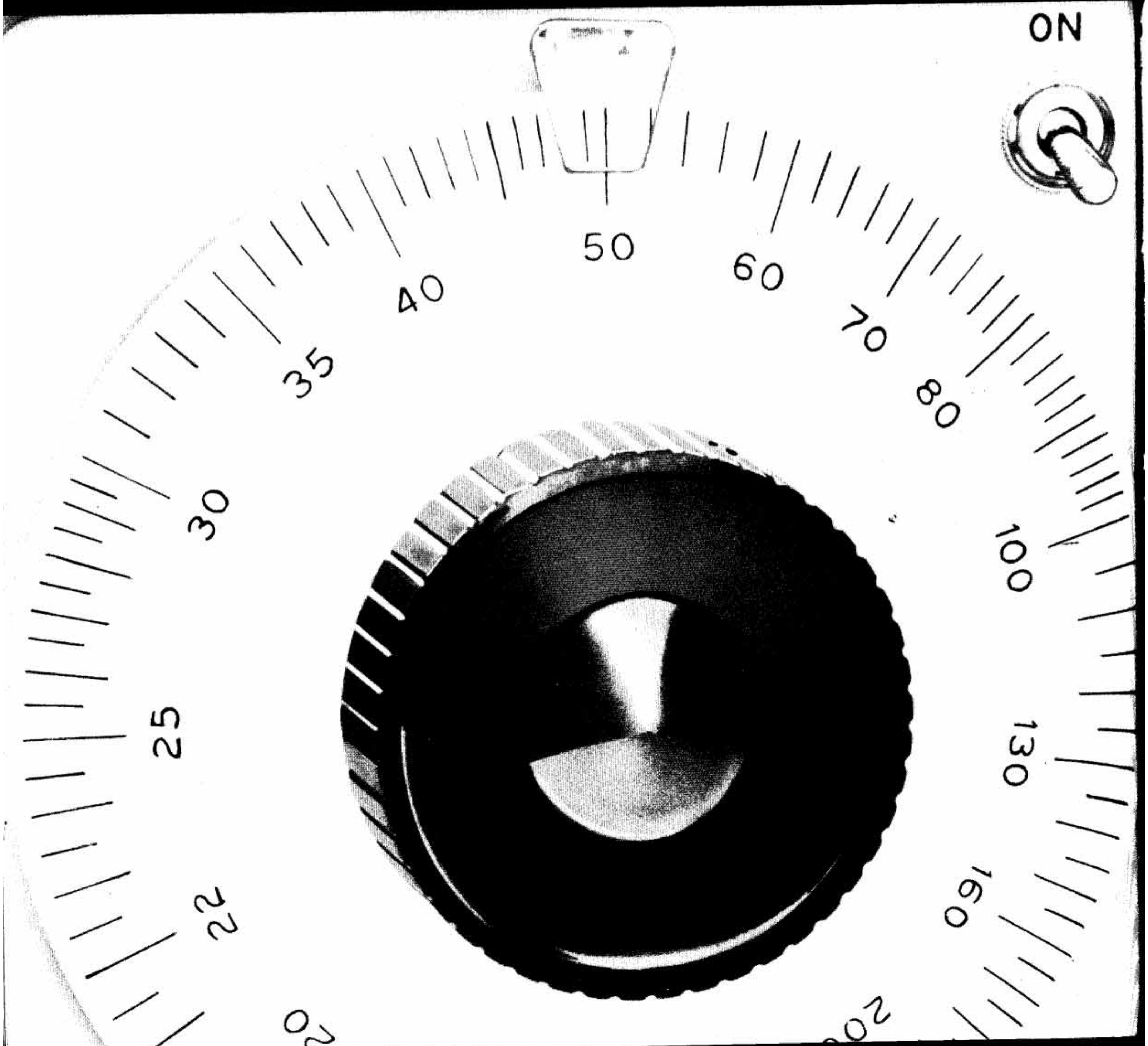


Up to 11 equally spaced exposures available.



Two 4 x 10 cm field exposures—note no overlapping.

OSCILLATORS



Oscillators are among the most basic and useful of all electrical and electronic measuring instruments. They provide a convenient source of power or test voltage for almost all measurements, including frequency, gain, impedance, distortion, etc.

There are three primary types of oscillators. These may be defined as (1) Beat-Frequency, (2) Coil Capacitor or LC and (3) Resistance-Capacity or RC oscillators.

Throughout the years, the RC oscillator has become recognized as the most versatile, practical, dependable and easiest to use of all oscillator types. Hewlett-Packard pioneered and developed the RC oscillator, and is today the leader and largest manufacturer of this superior type of instrument. hp RC oscillators are highly stable, have wide frequency range and provide operating flexibility which makes them useful for many different kinds of measurements. They are extremely simple to operate and require no tedious re-setting or adjustment during operation. They are lightweight, easily portable, and compact in size to occupy a minimum of bench space. Dependability of operation is assured by clean, simple circuitry and painstaking construction from quality components.

These many advantages may be compared with the low stability, constant need for adjustment, narrow frequency range, inflexibility, large size and considerable weight of other oscillator types.

The hp series of oscillators includes 11 separate instruments which are essentially resistance-capacity oscillators. Collectively, they operate from 0.008 cps to 10 MC, covering the audio, subsonic, ultra-sonic and low rf regions.

The circuit of the hp RC oscillator is shown in Figure 1. It is fundamentally a two-stage amplifier having both negative and positive feedback loops. The positive loop, which includes the frequency-selective network, causes the circuit to oscillate.

Figure 3 illustrates the amplitude and phase characteristics of the frequency determining network. Note that at the resonant frequency f_0 phase shift is zero and amplitude is maximum. The resonant frequency is given by the expression

$f_0 = \frac{1}{2 \pi RC.}$ This expression shows that the frequency or tuning span can be made as wide as the capacity variation in a tuning capacitor. Thus 10:1 frequency variations in a single sweep are easily obtained, and a number of bands can be used by changing the pairs of resistances. The negative loop employs a non-linear ballast resistance R_K (usually a lamp), which automatically adjusts its resistance to compensate for variations in output amplitude. This results in very flat frequency response and low distortion over the entire range. *(See Figure 2.)*

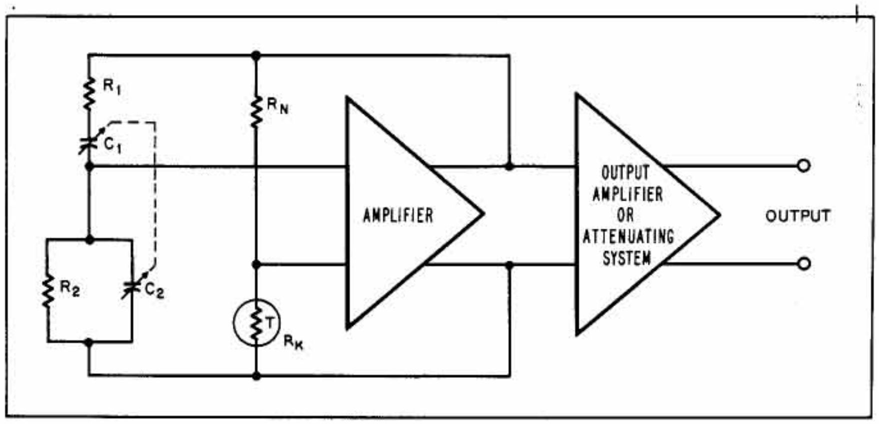


Figure 1. Basic Circuit hp RC Oscillator.

Low Frequency Oscillators

hp RC oscillators have been designed to generate frequencies below 1 cps and over 1 MC. The low frequency limit is set by the ballast element. The thermal time-constant of the lamp (ballast element) is such that at lower frequencies, lamp resistance tends to change in accordance with the variations in amplitude of the individual cycles of operation. This results in severe distortion of the output waveform. Therefore it is necessary to (1) use a ballast element having relatively greater thermal inertia, or (2) operate the lamp at a point where radiation from the lamp is low.

High Frequency Oscillators

The high frequency limit of the RC oscillator is determined by the plate loading on the second tube of the oscillator. The impedances of the positive and negative feedback loops are in parallel and the combination is in parallel with the plate feed resistor for the tube. At high frequencies, the combination impedance becomes low and reactive, thereby reducing the gain of the circuit and introducing phase shift. As a result, the distortion increases and the errors in calibration become severe. To cut down the plate loading effect, the combination impedance is made as high as possible. This is achieved partially by reducing the capacity of the tuning capacitor, and partially by raising the gain of the second stage (through use of tubes with higher transconductance values). At higher frequencies the reduction of gain and negative feedback makes the oscillator more susceptible to drifts or variations caused by tube aging and supply voltage changes. As a result it is common practice to operate the circuit from a regulated power supply.

Most hp oscillators use an output amplifier whose main function is to isolate the oscillating circuit from the "work" circuit. Thus, change in the work circuit does not reflect back to the oscillator and alter its amplitude, frequency or distortion characteristics. However, a unique arrangement is used in the hp 200CD Wide Range Oscillator where the output is taken from push-pull cathode followers directly to the output transformer. The cathode followers offer a very low impedance source to the load and thus provide

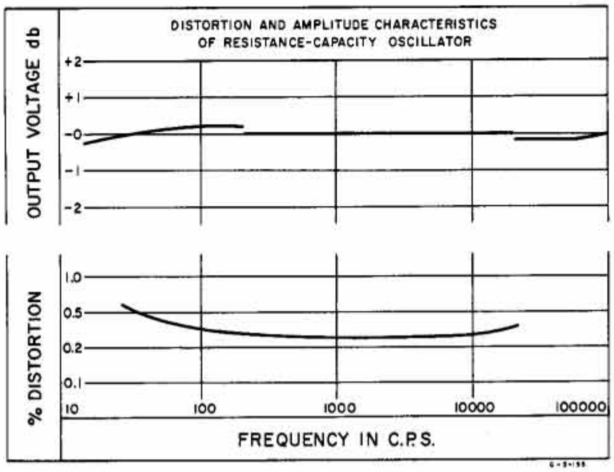


Figure 2. Distortion and Amplitude Characteristics RC Oscillator.

effective isolation of the oscillator section.

There are, in general, two types of output circuitry used in ⓗⓟ oscillators depending upon the desired results. For very low distortion, low frequency, and low power output, RC coupled output is used. For high power or where variable source impedance is required, transformer output is generally employed.

Distortion

Inherently, the RC oscillator is a generator of low distortion voltages. Distortion depends upon the linearity of the transfer characteristics of the tubes. By a suitable selection of tubes, distortion in ⓗⓟ oscillators is approximately ¼%. The very low distortion obtained is primarily third harmonic. (Second harmonic distortion is minimized by adjusting the dc voltages on the tube electrodes so that second harmonic distortion generated by one tube of the oscillator is partially cancelled by the other tube's transfer characteristics.) For applications requiring very low distortion, a selective amplifier following the oscillator can be used.

Hum

Hum is defined as alternating currents appearing in the output of an oscillator as a result of power-frequency voltages, currents and fields. Causes of hum are stray electrostatic and magnetic fields, alternating current in tube filaments or heaters, and discrepancies in filtering of power supplies.

As the output voltage of the audio oscillator is reduced, the hum voltage tends to remain constant. At lower output levels this hum voltage becomes quite large relative to the sine wave output voltage. This undesirable condition can be remedied by operating the RC oscillator at or slightly below rated output, and inserting a suitable attenuator between the oscillator and the equipment driven. The "voltage divider" circuit shown in Figure 4 is satisfactory for most applications. Other values of resistance may be used to obtain different voltage division, but the total load presented to the oscillator should be less than the rated load to prevent distortion of the signal due to saturation of the oscillator output stages.

Accuracy

"Overall accuracy" as applied to a variable-frequency oscillator is a general term including factors such as inherent circuit stability, mechanical stability, resettability of the tuning system, readability of the tuning dial, dial calibration, component aging, power supply variations and temperature changes. Some of these factors affect short time stability; others affect long time stability. The accuracy specification of within 2% usually given for RC oscillators

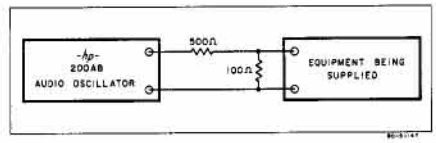


Figure 4. Voltage Divider Circuit.

includes all of these factors. *(Typical long time and short time stability are shown in Figures 5 and 6.)*

Description of ⓗⓟ Oscillators

ⓗⓟ 200 series Oscillators *(see pages 36 to 43)* are designed for general-purpose applications, such as checking performance of audio amplifiers, broadcast transmitters and similar equipment, checking vibration and stability of mechanical systems, and as voltage sources for bridge measurements, etc. Their outputs are sufficient to modulate signal generators and drive other equipment requiring considerable power. The usefulness of these oscillators is greatly increased by their compact size, light weight and easy portability. ⓗⓟ 200J is especially suitable for interpolation work and for applications where the frequency of oscillation must be known very accurately.

ⓗⓟ 650A *(pages 40, 41)* provides the widest range of any of the general-purpose oscillator group. It operates up to 10 MC and down to 10 cps. It is designed with an output voltage metering system followed by an adjustable attenuator. In these respects, the instrument resembles a signal generator. As a basic laboratory tool, the 650A is popular because of its high degree of flexibility. It can be used to test rf, video, ultra-sonic and audio equipment.

ⓗⓟ 202A Low Frequency Function Generator *(pages 38, 39)* incorporates a circuit concept developed by ⓗⓟ. The instrument's nominal low frequency

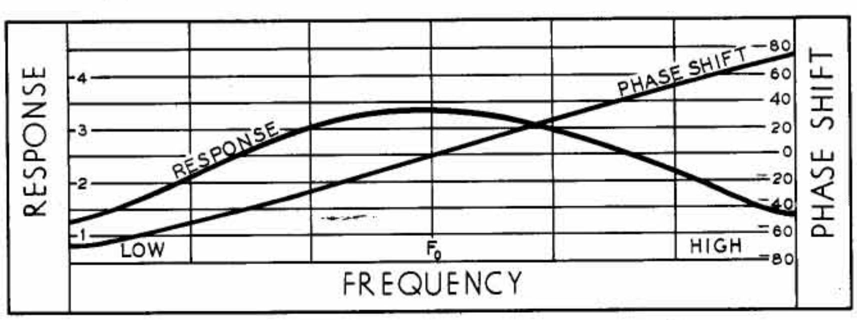


Figure 3. Characteristics of Frequency Determining Network.

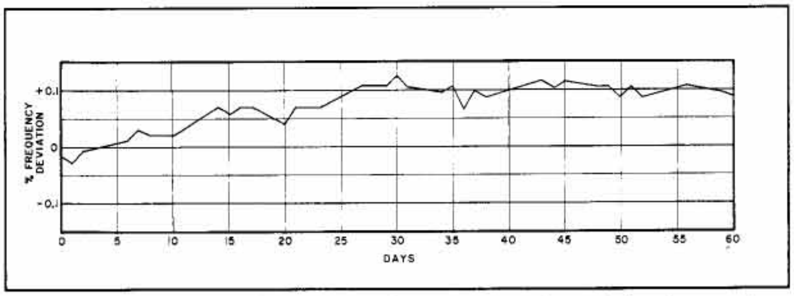


Figure 5. Long-term stability curve of circuit using wire-wound resistors and temperature compensation.

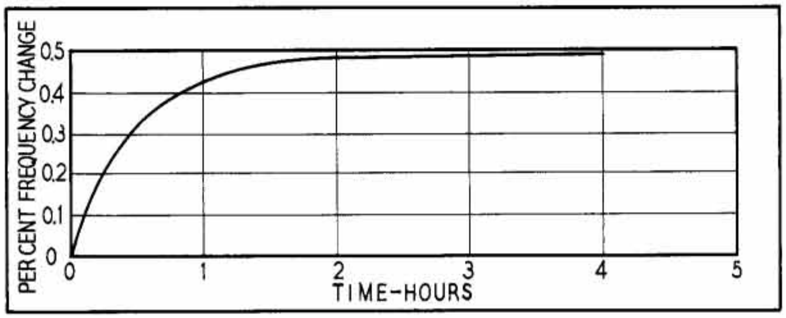


Figure 6. Typical short-term stability of RC oscillator.

limit is 0.008 cps and it can generate sinusoidal, square and triangular output waveforms. The circuit design of this instrument is such that transient conditions caused by range switching or frequency changing are virtually non-existent. This is of considerable convenience in low frequency work where much time is required for ordinary circuits to stabilize.

hp 202C *(page 37)* is an RC type low frequency oscillator. Its applications include geophysical and medical work, and the study of servo and other low-frequency electrical and mechanical systems.

An inexpensive but particularly versatile oscillator covering the audio band is the hp 201C, *(page 37)* which combines the features of high output (3 watts or 42.5 volts into 600 ohms), an accurate step attenuator, and a very low distortion output. Distortion is less than 0.5% at power levels up to 1 watt, making the instrument ideally suited for high fidelity audio work. *(See also the hp 206A, page 49.)*

hp 233A Oscillator *(page 42)* is widely used in testing carrier-communications equipment. The output system of this instrument is balanced, thus permitting operation directly into balanced lines.

Its high power output (3 watts into 600 ohms) makes possible tests over loops of 100 to 200 miles in length. A unique feature is the incorporation of an internal modulator which allows the generated frequency to be modulated by a standard telephone set, thus permitting voice communication between the test point and terminal.

These features, plus wide frequency coverage (50 cps to 500 KC) make the 233A suitable for testing many types of carrier communication systems, as well as a wide variety of other applications.

hp 200S is a version of hp 200CD Oscillator designed to provide 3 volts into 50 ohms required by hp 739AR Frequency Response Test Set. Together Models 200S and 739AR quickly and accurately determine frequency response of ac vacuum tube voltmeters between 5 cps to 10 MC. In addition, these instruments in combination may be used to measure frequency response of oscilloscopes, amplifiers and filters. hp 200S is also part of the 3-instrument Hewlett-Packard Voltmeter Calibration System which provides both frequency response and voltage calibration. Further details of this system appear on page 83.

Waveform distortion and output impedance of Model 200S have been made low to insure reliable measurements.

hp Model 200T is a precision telemetering test oscillator specifically designed to provide the highest possible frequency stability in a commercial, wide range audio oscillator. It covers the frequency range from 250 cps to 100 KC. The band spread is arranged to provide wide overlap so that the entire IRIG spectrum for FM-FM telemetering is covered without splitting a single telemetering channel.

The newest hp oscillator, Model 204B, fills the need for a portable, battery operated oscillator. This unit covers the frequency range from five cycles to 500 KC and is particularly useful in combination with the battery operated hp 403A voltmeter for field test work or in any situation where portability of instruments is needed. In many cases, the hp 204B will be very useful because of its freedom from any ground connection and, therefore, from any power line frequency components, as in the case when measuring 60 cycle beat effects in ac voltmeters. The familiar lamp element in the hp Weinbridge circuit has, in this case, been omitted, and amplitude stability depends upon diode peak rectifiers which compare the rectified signal against a stabilized dc source. This circuit then feeds back to the oscillator and controls amplitude level. Flat frequency response of $\pm 3\%$ is obtained across the entire frequency range. The all-solid state circuitry may make this instrument desirable in cases where high sound levels or vibrations are present in magnitudes that would excite vibrations in tube elements.

Oscillator Output System

hp 200AB and 200CD Oscillators have been designed with balanced output transformers. Excellent balance is available with the 200AB throughout its frequency spectrum. Power output is controlled by increasing or decreasing the drive to the power amplifier.

The output level of the 200CD (5 cycles to 600 KC) is controlled by means of a single bridged T attenuator following the transformer. This system has the advantage of attenuating noise and hum in the same proportion as the signal. At high frequency and high attenuation levels some unbalance is present. If a high degree of balance at these levels is required, hp AC-60A Line Matching Transformer can be used. Complete specifications and application data on the AC-60 series of line matching transformers is given on page 192.

hp 200 SERIES AUDIO OSCILLATORS

Exceptional Value, Highest Quality Throughout

Advantages:

- No zero setting. High stability
- Constant output
- Wide frequency range
- Logarithmic scale
- Low distortion
- Compact, light weight

Use For:

- Amplifier testing
- Transmitter audio response
- Voltage source for bridge measurements
- Modulating signal generators
- Ultrasonic voltage source
- Driving mechanical systems
- Synchronizing pulse generators
- Loudspeaker resonance tests

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.

hp 200AB Audio Oscillator Low Cost, 20 cps to 40 KC

This basic oscillator is a compact, convenient source of precision audio test voltages at 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, syncing pulse generators and making loudspeaker resonance tests. hp 200 AB, $165.00 (cabinet); hp 200ABR, $170.00 (rack mount).

hp 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 warmup, aging, tube changes, etc. Frequency response is ± 1 db full range. hp 200CD, $195.00 (cabinet); hp 200CDR, $200.00 (rack mount).

Specifications

Model	Frequency Range	Calibration Accuracy	Output to 600 ohms	Recommended Load	Maximum Distortion	Max. Hum & Noise ¶	Input Power	Weight—Lbs. Net	Ship	Size (Inches) W H D	Price
200AB	20 cps to 40 KC (4 bands)	± 2%	1 watt (24.5 v)	600 ohms	1% 20 cps to 20 KC 2% 20 KC to 40 KC	0.05%	70 watts	15	20	7½ x 11½ x 12	$165.00
200CD	5 cps to 600 KC (5 bands)	± 2%	160 mw (10 volts)	600 ohms*	0.5% below 500 KC 1% 500 KC and above	0.1%	75 watts	22	27	7½ x 11½ x 14⅜	195.00
201C	20 cps to 20 KC (3 bands)	± 1%†	3 watts (42.5 v)	600 ohms**	0.5%‡	0.03%	75 watts	16	23	7½ x 11½ x 12½	250.00
202C	1 cps to 100 KC (5 bands)	± 2%	160 mw 10 volts	600 ohms*	0.5%§	0.1%	75 watts	27	33	7½ x 11½ x 14¼	300.00

*Internal impedance is 600 ohms. Frequency and distortion unaffected by load resistance. Balanced output with amplitude control at 100. Use line matching transformer for other control settings. **Internal impedance approximately 600 ohms with output attenuator at 10 db or more. Approximately 75 ohms below 5,000 cps with attenuator at zero. †Internal, non-operating controls permit precise calibration of each band. ‡0.5%, 50 cps to 20 KC at 1 watt output. 1.0% over full range at 3 watts output. §Above 5 cps. ¶Measured with respect to full rated output.

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.

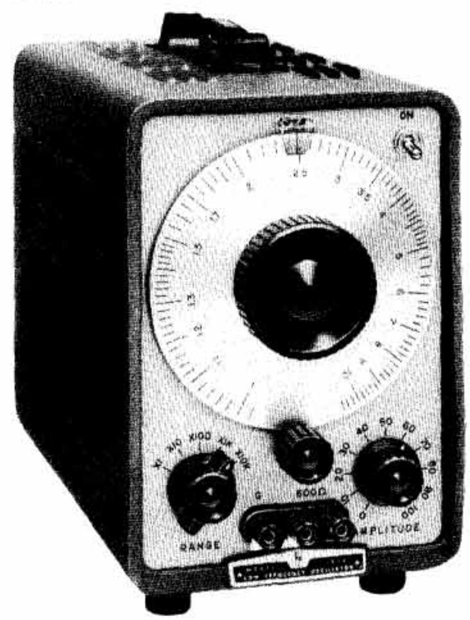
Power Source: 115 or 230 volts ± 10% at 50 to 1,000 cps.

Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50; AC-60A/B Line Matching Transformers, see page 192.

Data subject to change without notice.

hp 201C Audio Oscillator High Power, 20 cps to 20 KC

Particularly designed for amplifier testing, transmission line measurements, loud speaker 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 above 50 cps is less than 0.5%. hp 201C, $250.00 (cabinet); hp 201CR, $255.00 (rack mount).



hp 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, $300.00 (cabinet); hp 202CR, $305.00 (rack mount).

hp 202A LOW FREQUENCY FUNCTION GENERATOR

Transient-Free Voltages to 0.008 cps; Sine-Square-Triangular Waveforms

Advantages:

No transients

Range 0.008 to 1,200 cps

Sine, square, triangular waves

Continuously variable

High stability

Flat frequency response

Distortion less than 1%

Versatile, multi-purpose

Use It For:

Vibration studies

Servo applications

Medical research

Geophysical problems

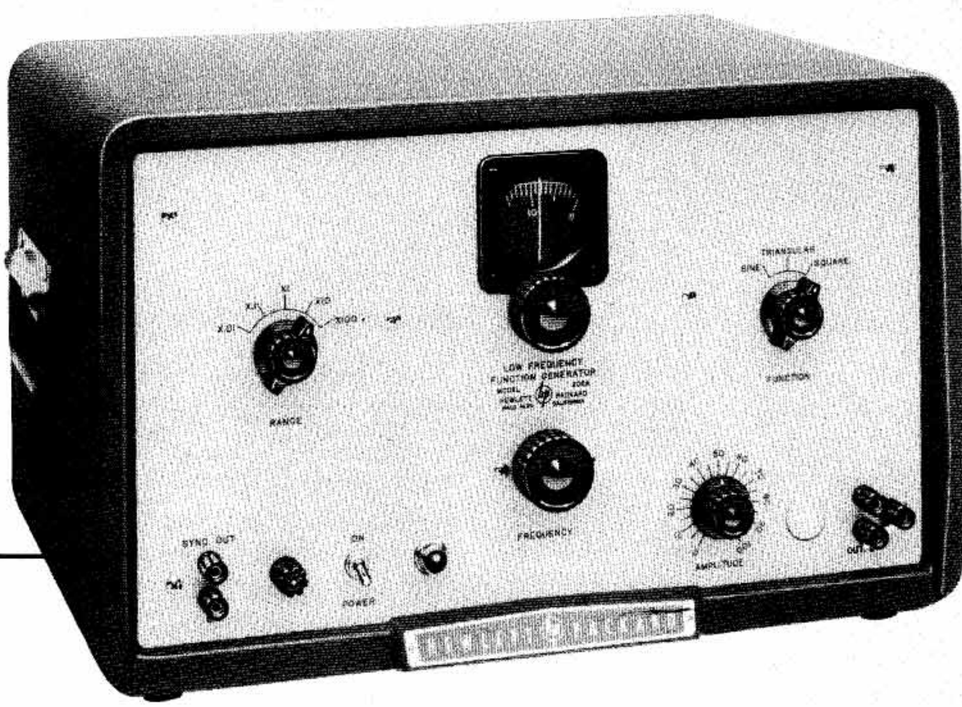
Subsonic, audio testing

The hp 202A Low Frequency Function Generator is a compact, convenient, multi-purpose source of transient-free test voltages, particularly useful for testing servo, geophysical and medical equipment, and for the electrical simulation of mechanical phenomena.

The instrument is continuously variable through 5 bands covering all frequencies from 0.008 cps to 1,200 cps. It 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 instantly 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.

Description

hp 202A differs from conventional low-frequency oscillators in that the sine wave is electronically synthesized. A con-



trolled bi-stable circuit generates a rectangular wave. This wave is passed through a special integrator providing a true triangular wave. *(See Figure 2A.)*

The triangular wave then enters a shaping circuit designed by ⓗ exclusively for this equipment. In this circuit, 12 crystal diodes modify or "shape" the peaks of the wave and provide a true sine wave. *(See Figure 2B.)* 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 of time 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.

Special Features

The output system of ⓗ 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 4,000 ohms or greater. Throughout, internal impedance is only 40 ohms. There are no coupling capacitors in the output system, and a high degree of dc balance is achieved by the special circuitry.

The instrument is ruggedly constructed of quality components; it is unusually simple to operate; and it is adapted to the widest possible variety of low-frequency field or laboratory work. It is available in a cabinet, as illustrated, for relay rack mounting or with end frames for table use.

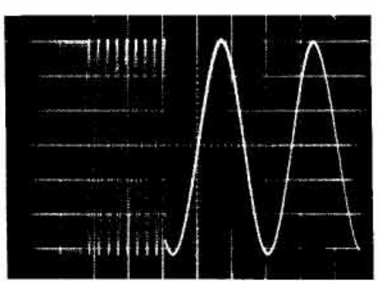


Figure 1. Oscillogram shows freedom from transients as output frequency is rapidly changed.

Specifications

Frequency Range: 0.008 to 1,200 cps in five decade ranges.

Dial Accuracy: 2% from 1.2 to 12; 3% from 0.8 to 1.2.

Frequency Stability: Within 1% including warmup drift.

Output Waveforms: Sinusoidal, square, and triangular.

Maximum Output Voltage: At least 30 volts peak-to-peak across rated load (4,000 ohms) for all three waveforms.

Internal Impedance: Approximately 40 ohms over the entire range.

Sinewave Distortion: Less than 1% on x .01, x .1, x 1, and x 10 ranges; less than 2% on x 100 range.

Output System: Output is isolated from ground and either side may be 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: 115/230 v ± 10%, 50/1,000 cps, approx. 150 watts.

Dimensions: Cabinet Mount: 20¾″ wide, 12¾″ high, 14⅝″ deep. Rack Mount: 19″ wide, 10½″ high, 13″ deep. Also can be used with ⓗ AC-17 End Frames.

Weight: Net 42 lbs. Shipping 53 lbs. (cabinet mount). Net 37 lbs. Shipping 52 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.50, AC-16B Cable Assembly, $5.50.

Price: ⓗ 202A, $550.00 (cabinet); ⓗ 202AR, $535.00 (rack mount).

Data subject to change without notice.

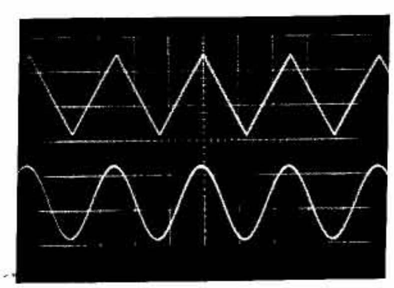


Figure 2. Oscillogram of (A) triangular wave applied to special ⓗ developed shaping circuit and (B) resulting true sine wave.

hp 650A TEST OSCILLATOR

Fast, Accurate Tests 10 cps to 10 MC

Advantages:

- No zero set
- Wide frequency range
- No adjustments during operation
- Output voltage attenuator
- Self-contained vacuum tube voltmeter
- High stability
- Ease of operation

Use It For:

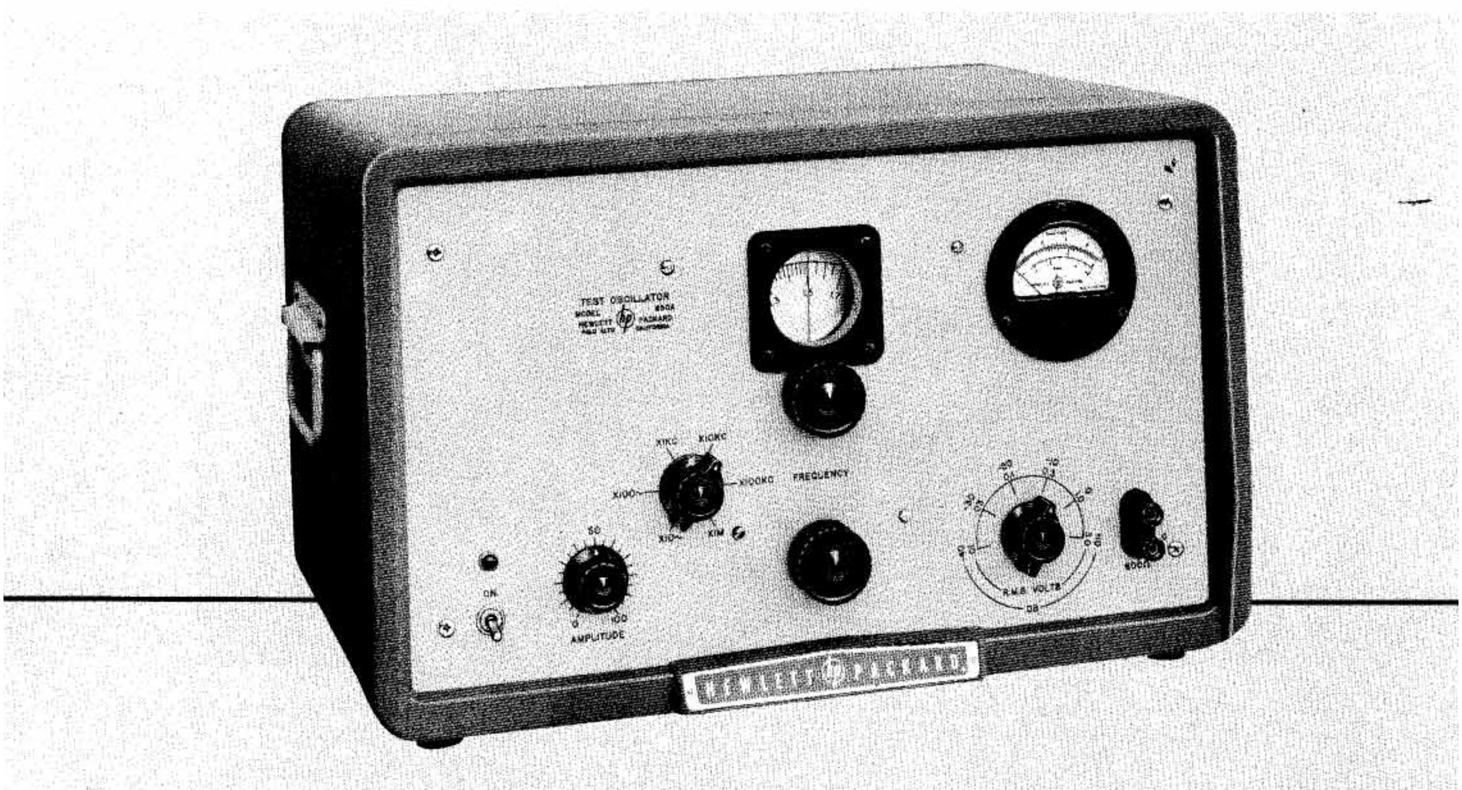
- Testing television amplifiers
- Wide-band systems
- Filter transmission characteristics
- Tuned circuit response
- Determining receiver alignment
- Telephone carrier measurements
- Bridge measurements

The hp Model 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. It is a wide-band highly-stable precision instrument which provides output flat within 1 db throughout its frequency range. Its voltage range is 0.00003 volts to 3 volts. Output impedance is 600 ohms, and, for measurements where low source impedance is desired, a 6 ohm impedance is provided by means of an output voltage divider.

Decade Ranges, Output Voltmeter

Like other hp resistance-capacitance oscillators, Model 650A is fast and easy to operate. 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. Frequencies are read through a no-parallax illuminated window.

The output voltage is monitored by a vacuum tube voltmeter which measures the voltage at the input to the atten-



uator 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. The voltage applied to the vacuum tube voltmeter and thus to the output attenuator is set by means of an amplitude control. The attenuated output voltage is correct only when the output terminals are loaded with 600 ohms, resistive.

Output Voltage Divider

Where small test signals or a low source impedance is required, a voltage divider is provided (shown connected to instrument in Figure 1). The divider consists of a cable and terminating connector which may be extended to the actual point of measurement. Two sets of voltages are obtainable from this divider. One voltage is one one-hundredth of the normal output voltage from the 650A and is delivered from a source impedance of only 6 ohms. True voltage is obtained at these terminals when they are connected to a load resistance large compared to 6 ohms. The second voltage is the actual output voltage of the Model 650A and is delivered from a source impedance of 300 ohms. Proper voltage is obtained at these terminals when working into a load resistance large compared to 300 ohms.

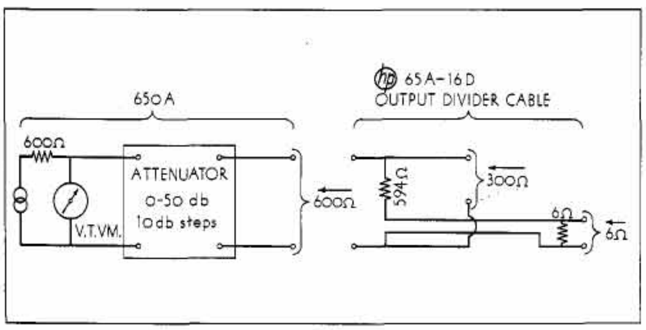


Figure 1

Circuits of the hp Model 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.

Uses

Employing essentially the same resistance-capacitance circuit as hp audio oscillators *(see pages 33, 34, 35 for description of hp resistance-capacitance principle)* this wide-band, stable hp Model 650A is ideally suited for laboratory and production jobs where fast, accurate wide band measurements are required. It is specifically designed for the testing of television amplifiers, audio amplifiers, filter networks, tuned circuits and telephonic and telegraphic carrier equipment. It serves admirably as a power supply for af and rf bridge 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 warmup, and ±10% line voltage variation.

Output: 15 milliwatts or 3 volts into 600 ohm resistive load. Open circuit voltage is at least 6 volts.

Source Impedance: 600 ohms; 300 ohms or 6 ohms when using 65A-16D Output Divider Cable.

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: Output level attenuated 50 db in 10 db steps, providing continuously variable output voltage from +12 dbm to −50 dbm, 3 volts to 3 millivolts, or down to 30 microvolts with voltage divider. Accuracy ±1 db, into resistive load of 600 ohms.

Hum Voltage: Less than 0.5% of output voltage with meter at full scale.

Power: 115/230 v ±10%, 50/1,000 cps, 165 watts.

Dimensions: Cabinet Mount: 20¾″ wide, 12¾″ high, 15″ deep. Rack Mount: 19″ wide, 10½″ high, 15″ deep behind panel. Also can be used with hp AC-17 End Frames.

Weight: Net 46 lbs. Shipping 55 lbs. (cabinet mount). Net 37 lbs. Shipping 52 lbs. (rack mount).

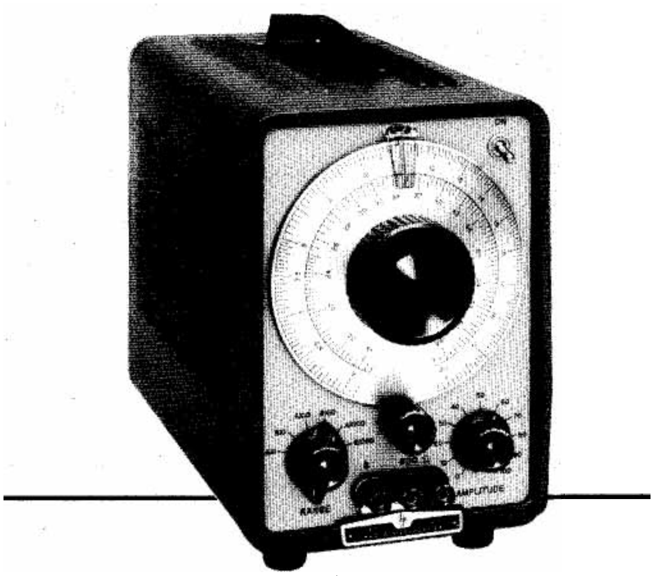
Accessories Furnished: 1 65A-16D Output Divider Cable.

Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50.

Price: hp 650A, $550.00 (cabinet); hp 650AR, $535.00 (rack mount).

Data subject to change without notice.

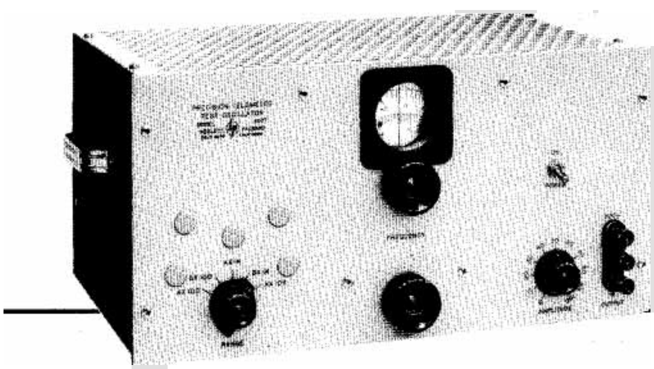
hp 200J, 200T, 233A SPECIAL PURPOSE OSCILLATORS



hp 200J

hp 200J Interpolation Oscillator Maximum Band Spread, 6 cps to 6 KC

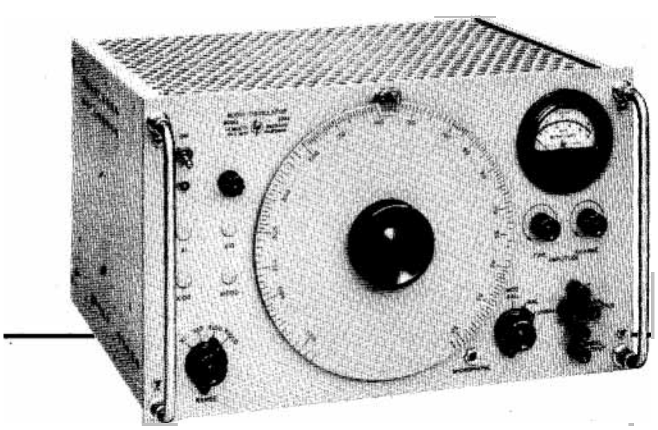
This ultra-precision instrument is engineered for interpolation and frequency measurements where frequencies must be known with extreme accuracy. Covering the range 6 cps to 6 KC, Model 200J offers an output of 160 mw or 10 volts into 600 ohms, or 20 volts open circuit, balanced to ground. Distortion is less than 0.5%, and frequency stability is ±2.0% 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 ±1.0%, and frequency response is 1 db full range. Hum voltage is less than 0.1% of output, 115/230 v ±10%, 50/1,000 cps, 110 watts. Cabinet mount, 7⅜″ wide, 11½″ high, 14¼″ deep. Rack mount, 19″ wide, 7″ high, 12⅞″ deep behind panel. Weight: cabinet mount, net 22 lbs., shipping 27 lbs.; rack mount, net 27 lbs., shipping 37 lbs. hp 200J, $350.00 (cabinet); hp 200JR, $355.00 (rack mount).



hp 200T

hp 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 circuits, 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. 115/230 v ±10%, 50/1,000 cps, approx. 160 watts. Cabinet mount 18¾″ wide, 9-3/16″ high, 11¾″ deep. Rack mount 19″ wide, 8¾″ high, 10-15/16″ deep behind panel. Weight: cabinet mount, net 27 lbs.; shipping 36 lbs.; rack mount, net 28 lbs., shipping 36 lbs. The instrument is compact, versatile, simple to operate and available in either cabinet or rack mounting. It covers IRIG (RDB) channels 1 through 18 and no channel is split by bandswitching. hp 200T, $500.00 (cabinet); hp 200TR, $505.00 (rack mount).



hp 233A

hp 233A Carrier Test Oscillator Checks Systems, 50 cps to 500 KC

This hp oscillator was designed specifically for checking carrier current systems, and covers frequencies 50 cps to 500 KC in 4 bands. It provides a high power output of 3 watts into a 600 ohm balanced load, making possible tests over loops 100 to 200 miles long. A second output of 6 volts into 600 ohms is available for audio tests (one terminal to ground). The instrument contains a voltmeter which monitors output power. Provisions are made for modulating the carrier so that communications are available on the carrier to facilitate tests. Frequency stability is ±2% including warmup; frequency response (3 w output) ±1 db, 5 to 500 KC; (6 v output) ±1 db, 50 cps to 500 KC. Distortion less than 1% to 100 KC; hum voltage less than 0.1% at full output. 115/230 v ±10%, 50/1,000 cps, approx. 185 watts. Cabinet mount, 17¼″ wide, 11″ high, 15″ deep. Weight: net 39 lbs., shipping 59 lbs. Price, hp 233A, $650.00.

Data subject to change without notice.

hp 204B PORTABLE OSCILLATOR

Transistorized, Battery-Operated, 5 cps to 500 KC, Floating Output

Fully transistorized and battery-operated, hp 204B Oscillator is extremely useful for both field and laboratory work. Internal heat production is small, resulting in unusually low warmup drift. Stable, accurate signals are instantly available over a frequency range from 5 cps to 500 KC.

Balanced and unbalanced loads, and loads referenced either above or below ground, can be driven by the versatile Model 204B. Its output is fully floating, isolated from power line ground and instrument chassis. 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.

Flat frequency response of Model 204B provides further convenience of operation. At all settings of the dial and range switch the output is flat within ± 3%.

The small size, light weight and battery operation make hp 204B a portable oscillator which can easily be carried in one hand. This oscillator is an excellent companion for hp 403A, a battery-operated voltmeter. In Model 204B the famous hp RC oscillator bridge is tuned by a variable resistance; range switching employs precision fixed capacitors.

The new modular hp cabinet allows easy access to the instrument chassis and makes an attractive, practical unit for portable or bench use. A rack mount adapter *(see page 194)* holds three Model 204B Oscillators or other instruments of the new hp modular design.

Specifications

Frequency Range: 5 cps to 500 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 milliwatts (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%, when battery operated.

Power Source: 4 battery cells at 6.75 volts each, 7 ma drain, life at least 300 hours.

Dimensions: Module 6-3/32″ high, 5⅛″ wide, 8″ deep.

Weight: Net 6 lbs. Shipping 9 lbs.

Accessory Available: AC power supply can be installed in place of batteries. Optional at extra cost.

Price: hp 204B, $275.00.

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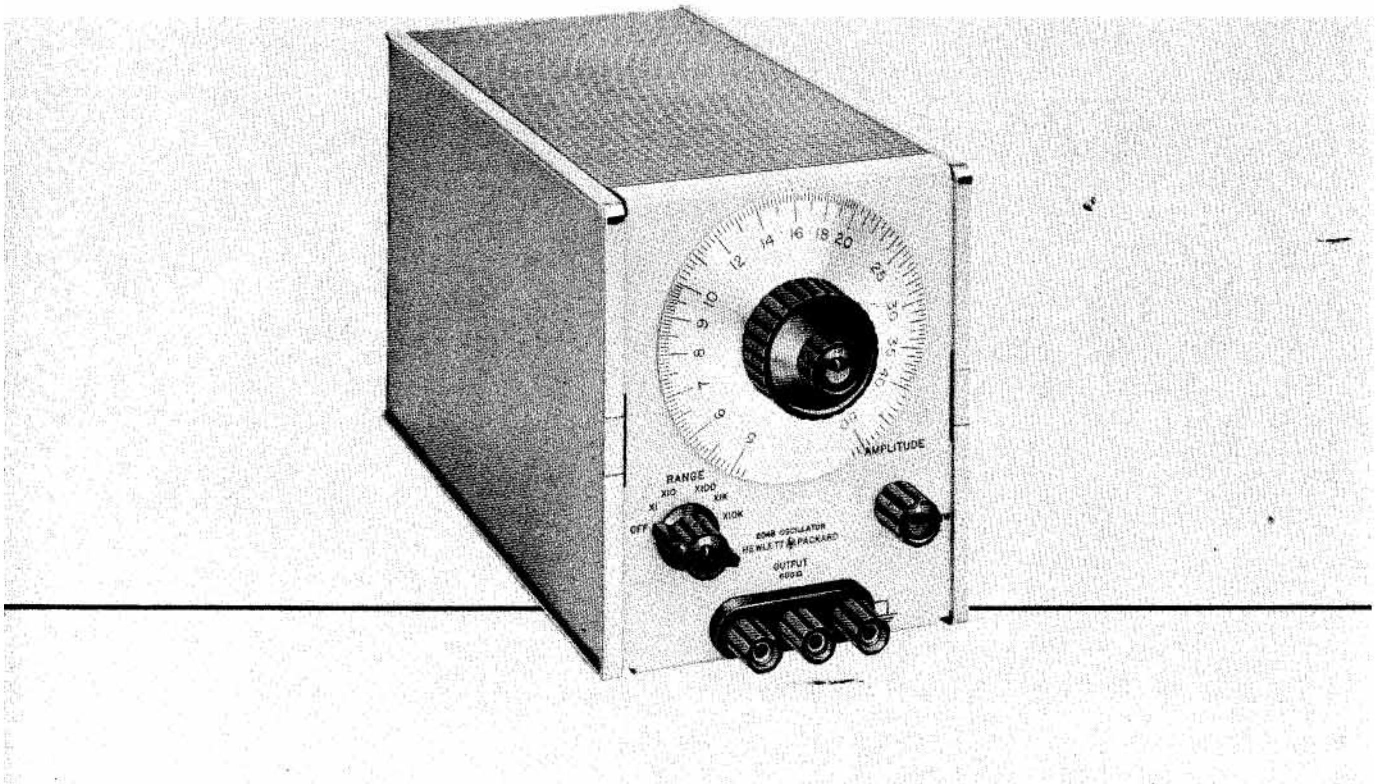



GENERATORS
AUDIO SIGNAL
SQUARE WAVE
PULSE
DIGITAL DELAY
POWER SUPPLIES
MODEL
HEWLETT PACKARD
PALO ALTO CALIFORNIA
OUTER CONTROLS
INNER CONTROLS
PULSE GENERATOR B
AMPLITUDE VOLTS
WIDTH μ SEC
DUTY LIMIT
OUTPUT
-POLARITY+
SEP
COM

AUDIO SIGNAL AND SQUARE WAVE GENERATORS, PULSE AND DIGITAL DELAY GENERATORS; POWER SUPPLIES

Hewlett-Packard offers a broad variety of signal, square wave and pulse generators for basic testing and investigation of circuits ranging from audio through the fast circuits employed in radar, DME, Tacan, computers, etc.

Audio Signal Generators

One basic instrument for audio research, development, production and maintenance is an audio signal generator.

Hewlett-Packard audio signal generators provide exact voltages across specific impedances at precisely known frequencies. They differ from audio oscillators in their ability to supply accurately known power even at low audio levels. Besides, hum is always maintained at a very low level.

-hp- audio signal generators are useful in making amplifier gain measurements, determining network or transmitter frequency response; as signal sources for distortion measurements, in production testing or general laboratory work and in other applications where an accurate signal is desired.

Circuit Description

An audio signal generator comprises an oscillator section, amplifier section, a vacuum tube voltmeter, an attenuator, and a line matching transformer. *(See Figure 1.)* The output transformer makes several commonly used output impedances available for matching the device under test.

-hp- 205AG Audio Signal Generator is a high-power, all-purpose instrument. It has a variable frequency between 20 and 20,000 cps at any voltage, 50 microvolts to 150 volts (5 watts), with less than 1% distortion.

-hp- 205AG includes an additional vacuum tube voltmeter to measure the output of the device under test. The instrument will determine complete gain and frequency response of an amplifier — no additional equipment is required. *(Figure 2.)*

-hp- 206A Audio Signal Generator is a precision-built test instrument designed to provide highly accurate test signals from 20 cps to 20 KC. The power output of this unit can be varied in 0.1 db steps, and it will deliver an output level of +15 db above 1 mw into rated load or approximately 10 volts open circuit. -hp- 206A includes a selective amplifier which is automatically tracked with the oscillator. With such an arrangement it is possible to reduce the harmonic distortion level to less than 0.1%. These features make -hp- 206A the finest and most accurate low distortion source for checking distortion in networks, for bridge and transmission measurements, for maintenance of high fidelity audio systems, for checking broadcast station performance and for other applications requiring low power, low distortion, accurately known test signals.

Operating Techniques

When making measurements requiring specific steps of output level, a good technique is to set the amplitude control at maximum value and use the attenuator knobs for varying the output level. This procedure insures the highest possible purity of output waveform and greatest attenuation accuracy.

A panel switch is provided to place a 600 ohm impedance across the output transformer of the -hp- 205AG when it is to be used with a high impedance load. This serves to match the impedance of the attenuators, so that the output voltmeter together with these attenuators will give the proper indication of output voltage.

With an attenuator setting of zero, the source impedance of -hp- 205AG is very low in order to permit maximum voltage at the load. In applications where a matched source impedance is required one of two procedures should be employed.

(1) For maximum power output, a resistor should be placed between the 205AG and the load to pad out the generator impedance to line impedance.

(2) When lower level output is sufficient, use an attenuator setting of 20 db or more for matched source impedance.

In the case of -hp- 206A, special design eliminates any variation in source impedance.

Square Wave Generator

The square wave generator is a useful and convenient instrument for testing amplifiers and networks, modulating signal generators, measuring time constants, checking cathode ray sweep circuits and generating harmonics for frequency multiplication.

Hewlett-Packard 211A Square Wave Generator is specifically designed to perform these functions quickly and accurately. This compact, wide range instrument is also useful in testing video and audio amplifier performance and checking oscilloscope performance. Further, it offers a simple means of controlling an electronic switch, and is extremely useful in phase shift, frequency response or transient measurements.

The 211A *(page 50)* provides complete coverage of all frequencies from 1 cps to 1 MC, and has a rise time of 0.02 μsec. It offers two separate outputs — a 7 volt peak-to-peak 75 ohm impedance circuit for television measurement, and a 55 volt peak-to-peak 600 ohm output for high level work.

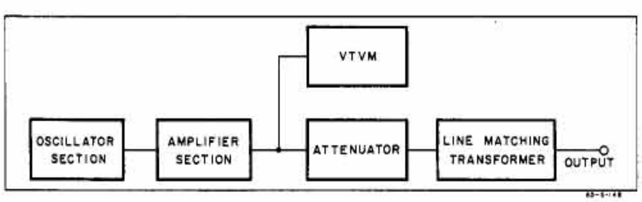


Figure 1. Elements of an audio signal generator.

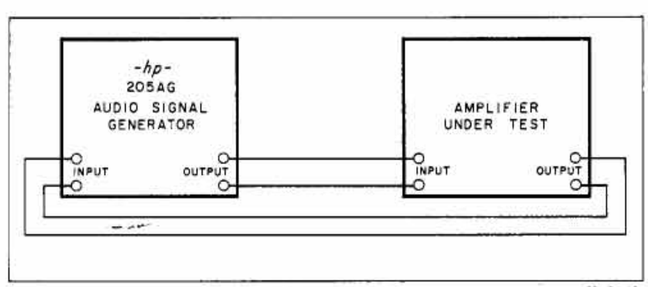


Figure 2. Typical test set-up.

Pulse Generator

Pulse generators are basic instruments for developing and testing radar, television, nuclear and similar "fast" circuits. They are also useful in testing response of rf amplifiers, filters, band pass circuits and oscilloscopes; may further be used to modulate rf carriers, pulse modulate uhf signal generators and to check performance of peak measuring equipment.

The widely-used hp 212A Pulse Generator *(page 51)* is deliberately designed for speeding and simplifying all of these measurements. It has a direct-reading pulse length control, and 50 watts of peak pulse power. Rise time is 0.02 μsec, pulses have a "flat" top with minimum overshoot. Either positive or negative pulses may be synchronized to other equipment through built-in delay and advance sync-out circuits; accurate pulses may also be delivered at the end of a long transmission line.

Double pulses, useful in checking resolution time of pulse counters, can be obtained by connecting a stub line across the 212's output.

Digital Delay Generators

The hp 218A Digital Delay Generator is a unique instrument providing two independent delays adjustable from 1 microsecond to 10,000 microseconds in steps of 1 microsecond. Vernier controls permit interpolation to 0.1 microsecond. With circuitry which eliminates the usual ± 1 count error, the accuracy of the 1 microsecond steps is determined only by the internal standard frequency. Figure 3 is a block diagram of this versatile instrument.

Produced initially to meet requirements for generation of precise digital delays, the 218A has since proven to offer many advantages as a general purpose laboratory pulse generator. By using the appropriate plug-in unit, a 218A can often take the place of several special-purpose pulse generators.

Some of the instruments which the 218A becomes are:

(1) Precision dual time interval generator, digitally calibrated from 1 to 10,000 microseconds, with synchronized time marker outputs preset to accuracy of ±0.1 microsecond, ± 0.001%. A special version of the 218A is available, providing time intervals up to 40,000 microseconds. Longer time intervals can also be generated with the standard 218A, by using an external counted frequency.

(2) Double pulser, with amplitude, width, polarity, and position of each pulse individually adjustable. Complex pulses (one pulse superimposed on the other) can be obtained.

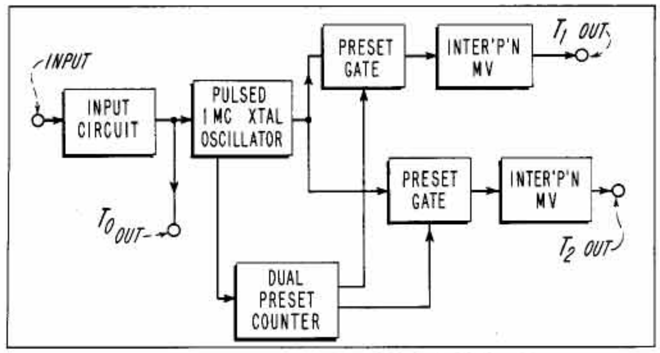


Figure 3. Block diagram, hp 218A Digital Delay Generator

(3) Single pulser, providing simultaneous, adjustable-amplitude positive and negative pulses, with pulse position and width variable over the complete time range of 1 to 10,000 microseconds.

(4) Precision pulse generator, with digitally controlled pulse length and repetition rate.

(5) Two independent preset counters; operating from a common start trigger.

Many users have found it more economical and convenient to have a versatile 218A in the laboratory than to have the several other instruments which would otherwise be needed to do similar jobs.

A more complete description of the hp 218A Digital Delay Generator, the 219A Dual Trigger Unit, the 219B Dual Pulse Unit, and the model 219C Digital Pulse-Duration Unit appears on pages 52 and 53. hp Application Note 48 also contains detailed information on this instrument.

Power Supplies

Highly regulated, ripple-free, temperature-stable power supplies are an everyday necessity in research and development laboratories. Required outputs are widely diverse, ranging from the typical high voltage, low current demands of microwave oscillators to the heavy current, low voltage requirements of power transistors. In its design of laboratory-quality power supplies, Hewlett-Packard attempts to give each unit sufficient versatility to cover a broad category of these requirements.

Conventional tube circuits are the most practical means of building high voltage supplies, because of the high inverse signals encountered. Tubes are used throughout hp power supplies which have output voltages higher than 100 volts. The inherent advantages of the transistor are utilized

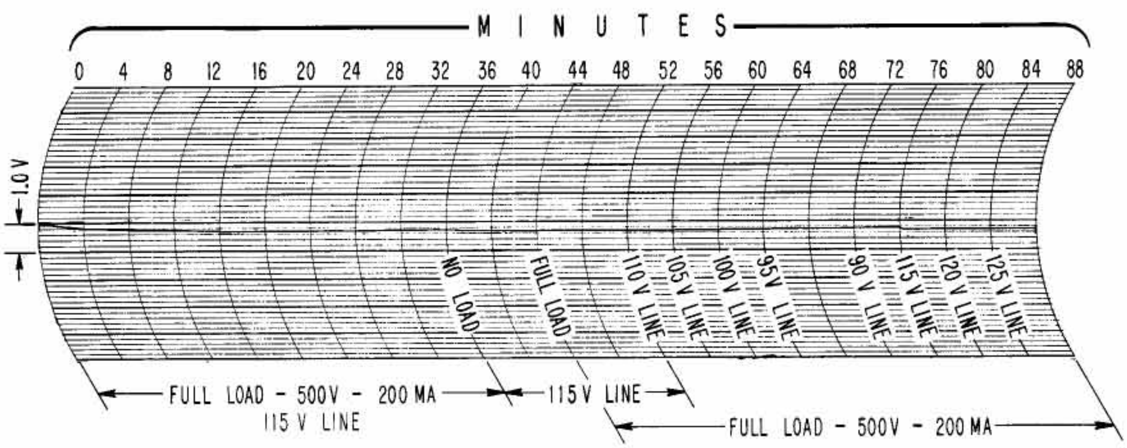


Figure 4. Record of main output voltage, hp 712B, while instrument is subjected to wide variations in line voltage and output current.

in lower voltage supplies where transistors yield top efficiency, high current ratings, reliability and freedom from filament hum. Transistor power ratings are very carefully observed and the design of each supply is sufficiently conservative to allow high performance operation in ambient temperatures as high as 55°C.

Performance Data

One of the most important design goals in a power supply is a high degree of voltage regulation. Not only must the dc output resistance be kept low, but the reactive impedance component must also be minimized to achieve fast transient response and proper regulation in high-frequency circuit use. Low output impedance is achieved in two ways. First the regulating circuitry is designed with considerable bandwidth, bringing about rapid compensation for voltage changes. This, in effect, gives very low dc resistance and low-frequency ac impedance. Second, a large capacitor is placed at the output terminals. Since this capacitor shunts a very small low-frequency impedance, its regulating effect is felt mainly at frequencies above several kilocycles. Typical transient response of hp Model 712B is shown in Figure 4.

The high current, low voltage transistor power supplies require even lower output impedance to achieve good regulation. Figure 5 shows output impedance vs. frequency for the hp 722AR.

The high order of regulation becomes difficult to utilize because of the resistance of the connecting leads. To achieve improved regulation at the load, a remote sensing feature is included in the hp 722AR which regulates the voltage directly at the point of use. This connection is shown in Figure 6.

External circuit protection is a feature of every hp power supply. The tube type units use either fuses or overload relays. The transistor types use electronic protection circuits which automatically raise the series impedance when a preselected current level is reached, thus limiting the current that can flow. Typical curves for this feature are shown in Figure 7. The hp 721A, which uses four switch-selected current limits, is illustrated.

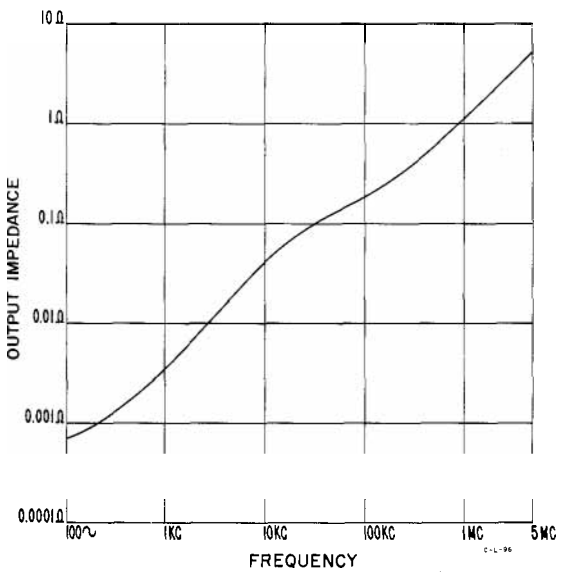


Figure 5. Output impedance vs. frequency, hp 722AR.

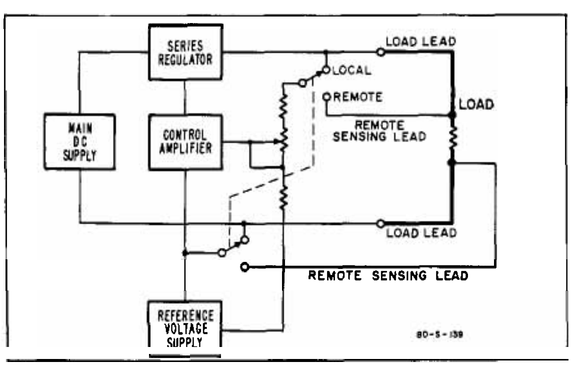


Figure 6. Remote sensing arrangement, hp 722AR.

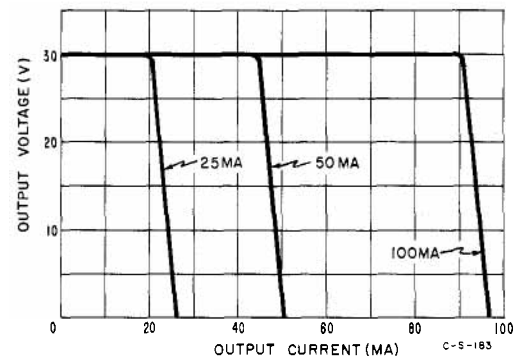


Figure 7. Output voltage vs. current, hp 721A.

In some applications a high degree of time stability becomes important. The more refined designs incorporate careful balancing of components with critical temperature coefficients, and close attention to the stability of voltage reference and comparison circuits. Figure 8 illustrates the result of such design in the hp 722AR.

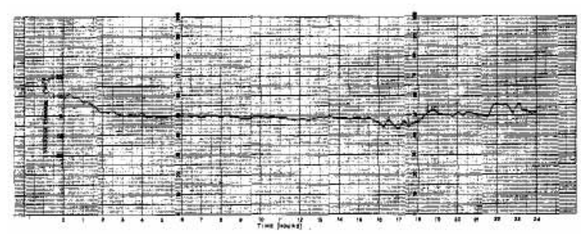


Figure 8. Long term stability of hp 722AR.

Summary of hp Power Supplies

Tube Types	Main Features	Special Comments
Model 711A	DC output 0 to 500 v; 100 ma max. AC output 6.3 v; 6 amps or 12.6 v, 3 amps. DC regulation 0.5%.	Inexpensive versatile high voltage, low current power supply. Metered voltage and current.
Model 712B	DC output 0 to 500 v; 200 ma max. Regulation 0.01% at 500 v Bias supply 0 to —150 v; 5 ma max. AC —6.3 v; 10 amps. max.	High quality, high voltage supply; particularly good transient response, regulation and stability.
Model 715A	Beam supply —250 v to —400 v, 50 ma max. Reflector supply 0 to —900 volts below beam supply, 10 μamp max. AC 6.3 v; 1.3 amps. Modulation capabilities	Klystron supply, inexpensive general purpose instrument.
Transistor Types		
Model 721A	DC output 0 to 30 v; 150 ma max.; metered voltage or current. Current limit feature regulation 0.3%.	Inexpensive general purpose, low voltage, low current power supply. Very low ripple and noise output.
Model 722AR	DC output 0 to 60 v; 2 amps max. Regulation 0.01% at 60 v continuously adjustable current limit	High quality, high power particularly good regulation, stability, low ripple and noise. Remote sensing.
Model 723A	DC output 0 to 40 v; 500 ma max. Metered voltage or current Current limit feature regulation 0.1%	General purpose, medium power low voltage supply can be programmed remotely.

205AG AUDIO SIGNAL GENERATOR

Six Basic Instruments Combined to Speed Gain Measurements

This 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.

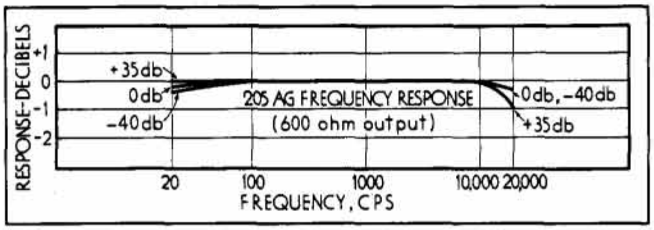


Figure 1. Typical frequency response of 205AG output section. (Response of attenuator and line matching transformer.)

Specifications

Frequency Range: 20 cps to 20 KC in three decade ranges.

Calibration Accuracy: ±2% under normal temperature conditions.

Output: Five watts maximum into loads of 50, 200, 600 and 5,000 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 at +37 db; ±1.5 db, 20 cps to 20 KC at output levels above +30 dbm with output meter reading held at +37 db (reference 1,000 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: The hum level is 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: 0-65 volts, db scale +20 to +37 dbm.

Input Meter: Calibrated in dbm from −5 to +8 dbm and in volts from 0 to 2 volts rms. Voltage accuracy is ±5% of full scale.

Input Attenuator: Extends meter range to +48 dbm and to 200 volts rms in 5 db steps. Accuracy ±0.1 db. Input impedance 5,000 ohms.

Output Attenuator: 110 db in 1 db steps.

Power: 115/230 v ±10%, 50/1,000 cps, 150 watts.

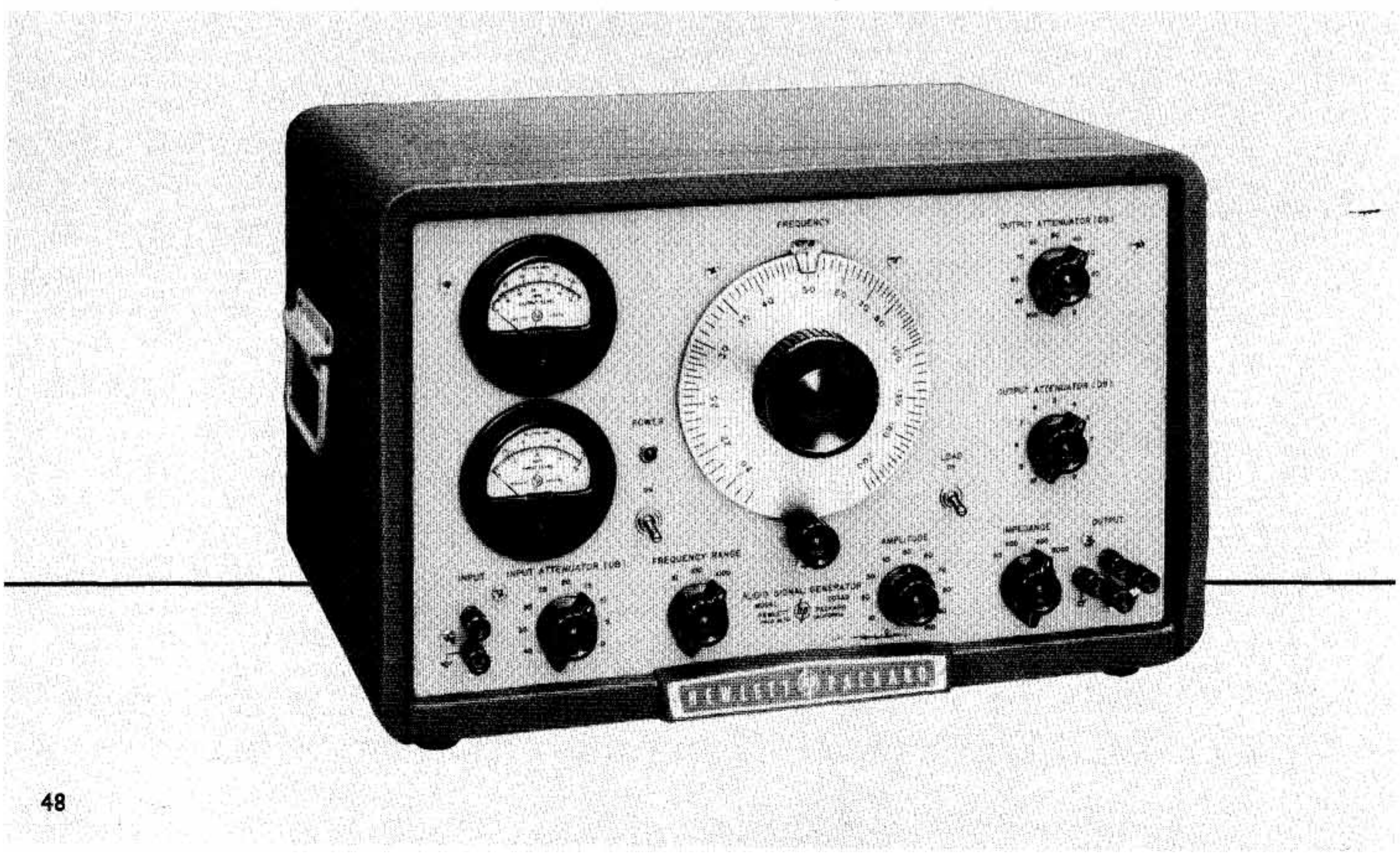
Dimensions: Cabinet Mount: 20¾″ wide, 12¾″ high, 15½″ deep. Rack Mount: 19″ wide, 10½″ high, 14″ deep behind panel. Also can be used with AC-17 End Frames.

Weight: Net 56 lbs. Shipping 67 lbs. (cabinet mount). Net 49 lbs. Shipping 64 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50.

Price: 205AG, $600.00 (cabinet); 205AGR, $585.00 (rack mount).

Data subject to change without notice.



206A AUDIO SIGNAL GENERATOR

Continuously Variable Audio Signals Less Than 0.1% Distortion

The hp Model 206A Audio Signal Generator provides a source of continuously variable audio frequency voltage at a total distortion level of less than 0.1%. This unusually low distortion, coupled with simple, straightforward circuitry, rugged construction and typical hp ease of operation, makes this signal generator ideal for use in the maintenance of FM broadcasting units and high fidelity audio systems.

The oscillator section is followed by a tuned amplifier, automatically tracked with the oscillator. High selectivity of the amplifier reduces the harmonic voltages generated by the oscillator section.

The output of the amplifier is measured by a voltmeter. Indications can be read in either volts or dbm to an accuracy of 0.2 db. Following the vacuum tube voltmeter is a 111 db attenuator which allows the power output to be varied in 0.1 db steps.

Uses

This instrument is suitable for FM transmitter maintenance, studio amplifier and console testing, as a low distortion source for bridge measurements, and as a transmission measuring set.

Data subject to change without notice.

Specifications

Frequency Range: 20 cps to 20 KC in three decade ranges.
Calibration Accuracy: ± 2% including warmup 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 the 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. Accuracy approximately ±0.1 db.
Power: 115/230 v ±10%, 50/1,000 cps, 140 watts.
Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14" deep. Rack Mount: 19" wide, 10½" high, 14" deep behind panel. Also can be used with hp AC-17 End Frames.
Weight: Net 57 lbs. Shipping 68 lbs. (cabinet mount). Net: 50 lbs. Shipping 65 lbs. (rack mount).
Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50.
Price: hp 206A, $800.00 (cabinet); hp 206AR, $785.00 (rack mount).

211A SQUARE WAVE GENERATOR

Convenient Audio, Video Testing 1 cps to 1 MC

Specifications

Frequency Range: 1 cps to 1 MC, continuous coverage.

Low Impedance Output: Negative 3.5 v peak across 75 ohm impedance; negative 7.0 v peak open circuit, zero level clamped to chassis. Rise time less than 0.02 μsec. BNC connector.

High Impedance Output: Negative 27 v peak across 600 ohm impedance; negative 55 v peak open circuit, zero level clamped to chassis. Rise time less than 0.1 μsec. Dual banana jacks—3/4" centers.

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. BNC connector.

Power: 115/230 v $\pm$ 10%, 50/60 cps, 225 watts.

Dimensions: Cabinet Mount: 9 3/4" wide, 15 1/4" high, 14 5/8" deep. Rack Mount: 19" wide, 8 3/4" high, 13 3/8" deep behind panel.

Weight: Net 26 lbs. Shipping 38 lbs. (cabinet mount). Net 25 lbs. Shipping 34 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50; AC-16D Cable Assembly, $3.50.

Price: hp 211A, $325.00 (cabinet); hp 211AR, $330.00 (rack mount).

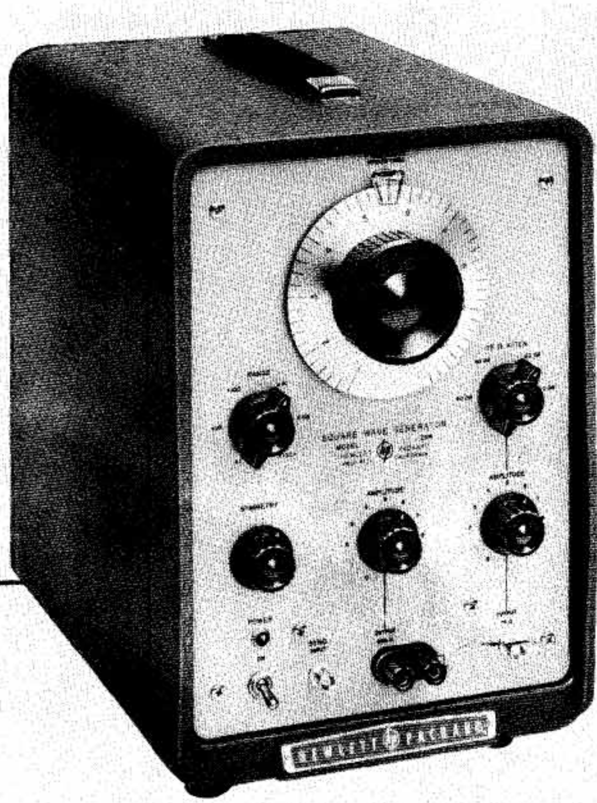
Data subject to change without notice.

The hp Model 211A Square Wave Generator is a versatile, wide range instrument particularly designed for testing video and audio amplifier performance,[1] or checking oscilloscope operation. It provides complete coverage of all frequencies from 1 cps to 1 MC, and has a rise time of 0.02 microseconds. There are two separate outputs — a 3.5 volt peak 75 ohm impedance circuit for television measurement, and a 27 volt peak 600 ohm output for high level work. The positive excursions of the output signals are clamped to chassis. Full amplitude variation is available on either output. The generator may be operated free-running or externally synchronized with either a positive going pulse or a sine wave signal of 5 volts peak minimum amplitude.

Uses

Model 211A is ideal for testing amplifiers and networks and 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. The generator is also a convenient instrument for indicating phase shift, frequency response, transient effects or deflection polarity of oscilloscopes.

[1]See Hewlett-Packard Application Note 17, "Square Wave and Pulse Testing."



212A PULSE GENERATOR

Basic Test Instrument for Radar, TV and Other Fast Circuits

Popular 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. The instrument permits accurate pulses to be delivered to the end of a long transmission line. If the line is correctly terminated, pulse shape is independent of line length, sync conditions, input voltage or output attenuator setting.

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, band pass circuits, oscilloscopes; and in checking peak measuring equipment, modulating rf carriers or pulse modulating uhf signal generators.

Data subject to change without notice.

Specifications

Pulse: Length continuously variable 0.07 to 10 μsec. Amplitude 50 v peak positive or negative into 50 ohm load (50 watt peak).

Amplitude Control: 50 db attenuator, variable in 10 db steps. Continuously variable amplitude control, 10 db range.

Pulse Shape: Rise and decay time approximately 0.02 μsec. Crest variation less than $\pm 5\%$.

Jitter: Less than 0.01 microsecond.

Internal Impedance: 50 ohms or less, either pulse polarity.

Repetition Rate: Internal sync, 50 to 5,000 pps. External sync, approx. 2 to 5,000 pps.

Sync In: Pos. or Neg., 5 v peak minimum.

Sync Out: 25 v pos, 15 v neg into 2,000 ohms 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 2,500 pps) 0 to 50 μsec (to 5,000 pps). Advance, 0 to 10 μsec (to 5,000 pps).

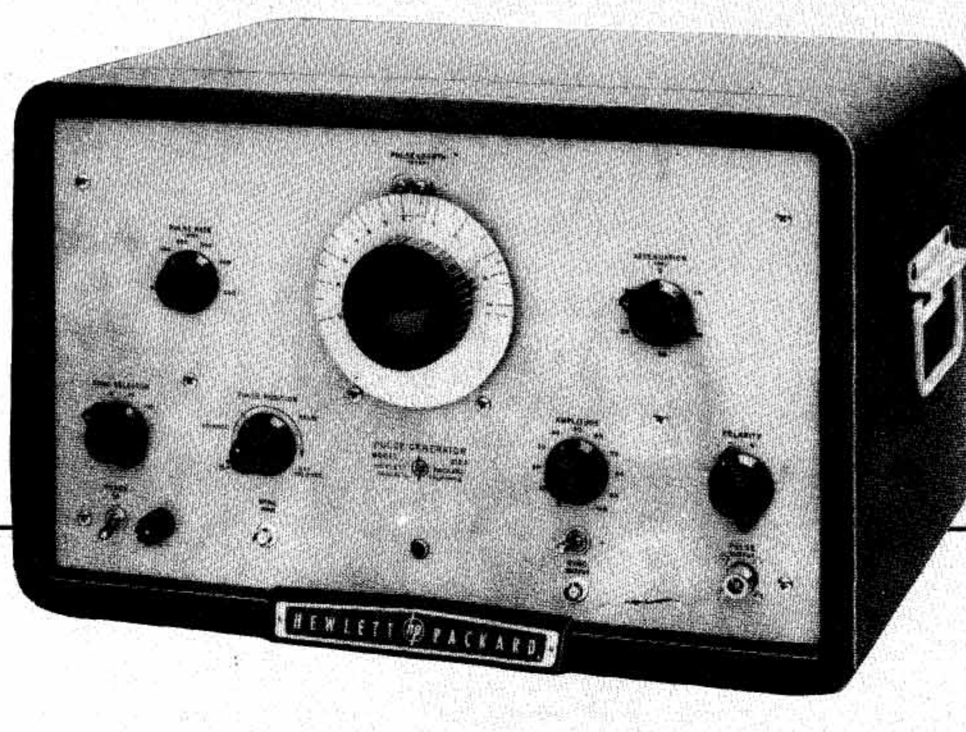
Power: 115/230 v $\pm 10\%$, 50/60 cps, 380 watts.

Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14-3/16" deep. Rack Mount: 19" wide, 10½" high, 13⅝" deep behind panel. Also use with hp AC-17 End Frames.

Weight: Net 56 lbs. Shipping 67 lbs. (cabinet mount); net 50 lbs. Shipping 65 lbs. (rack mount).

Accessories Available: AC-16K BNC Cable Assembly, \$6.50; AC-16F Type N Cable Assembly, \$15.00.

Price: hp 212A, \$600.00 (cabinet); hp 212AR, \$585.00 (rack mount).



218AR DIGITAL DELAY GENERATOR

± 1 Count Ambiguity Eliminated in Time Interval, Pulse Generation

Advantages:

Generates time intervals 1 — 10,000 μsec

Variety of adjustable output pulses

±0.1 μsec ±0.001% accuracy

Crystal oscillator, dual-preset counter controls delays

Perfect slave to start pulses; no ±1 count error

New ease, speed, dependability

Uses:

Precision time interval generator for calibrating time bases, delay lines, radar ranges and precision sweep delays

1 MC dual preset counter for digital computer work

Precision variable gate generator for work with digital computers, counters

Precision double-pulse generator for pulse code modulation, resolution measurements on high speed circuits

Based on a unique approach, the hp 218AR Digital Delay Generator is designed to generate precise time intervals and single, double or superimposed pulses.[1] Its accuracy and flexibility make it ideally suited to pulse simulation and time measurement in radar, loran, Tacan, DME, and pulse code systems, as well as oscilloscopes and computers.

Produced initially to meet requirements for generation of precise digital delays, the 218A has since proven to offer many advantages as a general purpose laboratory pulse generator. By using the appropriate plug-in unit, a 218A can often take the place of several special-purpose pulse generators.

Engineered to meet military performance requirements, the hp 218AR consists of three main parts: (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.

Two Independent Pulses

The hp 218AR generates independent pulses, one at the end of each preset time interval, at times T_1 and T_2. A sync pulse is available at the time of the start pulse, T_0 or at T_1 or T_2.

[1]See "Applications of the hp Model 218A, a Versatile General Purpose Pulse and Delay Generator." Application Note 48, available from Hewlett-Packard Company.

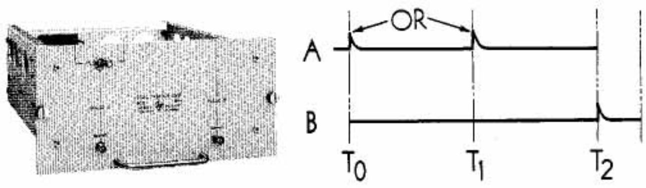
hp 218A with hp 219B

The time intervals are independently adjustable, with directly calibrated front panel controls, in 1 μsec steps from 1 to 10,000 μsec with interpolation between steps. Either T_1 or T_2 may occur first, and accuracy is $\pm$ 0.1 μsec $\pm$0.001% of the delay selected.

Plug-ins Increase Versatility

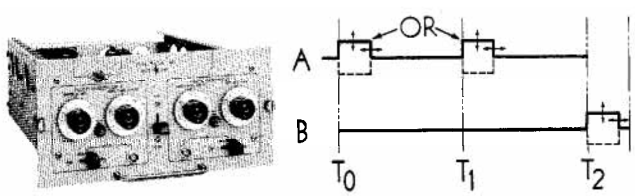
For maximum flexibility, output pulses are generated in the -hp- 219 series plug-in units. The units and the pulse options they provide are described below.

-hp- 219A Dual Trigger Unit



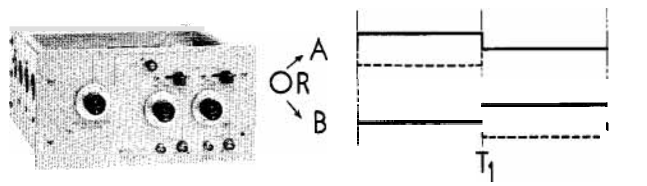
Model 219A Dual Trigger Unit contains two blocking oscillators supplying positive polarity trigger pulses to control auxiliary equipment. Pulse A is available at T_0 or T_1, and pulse B at T_2. Pulse characteristics are identical to the sync output pulse of the 218AR Digital Delay Generator — approximately 50 volts positive, into an open circuit with a rise time of 0.1 μsec from a 50 ohm source. $100.00.

-hp- 219B Dual Pulse Unit



Model 219B Dual Pulse Unit contains two pulse generators providing digitally delayed, fast rise time, high power pulses. The leading edge of pulse A occurs simultaneously either with T_0 or T_1 (as selected by a panel switch) and the leading edge of pulse B occurs at time T_2. Either positive or negative polarity is available, amplitude is variable from 0 to 50 volts into an open circuit, pulse width is variable from 0.2 to 5 μsec, and rise time is 0.06 μsec. The pulses may be delivered separately on individual cables, or on the same cable from either output connector. Output impedance and voltage are not affected by the setting of a "separate-common" switch governing the pulse outputs. Internal impedance is 50 ohms. $450.00.

-hp- 219C Digital Pulse Duration Unit



Model 219C Digital Pulse Duration Unit produces a high power output pulse with digitally controlled delay and duration. Pulses may be started at T_0 and ended at T_1, or the pulse may be digitally delayed from T_0 to T_1 with duration digitally controlled from T_1 to T_2. Both polarities are available simultaneously and are continuously adjustable from 0 to 15 volts into an open circuit (from 90 ohms impedance) or 90 volts into an open circuit (from 500 ohms impedance). Rise or decay time is 0.03 μsec at 90 ohms. $350.00.

Specifications

-hp- 218AR Digital Delay Generator

(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 $\pm$ 0.1 μsec $\pm$ 0.001% of time interval selected.

Digital Adjustment: 1 to 10,000 μsec in 1 μsec steps.

Interpolation: Continuously adjustable. Adds 0–1 μsec to digital setting.

Input Trigger: Internal: 10 cps to 10 KC, 3 decade ranges. External: Sine wave, 5 v rms, 10 to 100 cps; 2 v rms, 100 cps to 10 KC. 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 0.25 μsec $\pm$0.05 μsec. Manual: Pushbutton operation.

Jitter: 0.02 μsec or less.

Recovery Time: 50 μsec or 10% of selected interval, whichever is larger.

Sync Output: 50 v positive pulse into an open circuit, 0.1 μsec rise time (from 50 ohm source). Available at T_0, T_1 or T_2.

1 MC Output: 1 v, 1 MC pulses (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, 2 v rms, 10 cps–1 MC and pulses, periodic or random, 2 v peak, 0–1 MC can be counted instead of internal standard. Time interval range becomes 1–10,000 periods in 1 period steps and accuracy is $\pm$ 0.1 μsec $\pm$ 1 period.

Power: 115/230 v $\pm$ 10%, 50/60 cps, 555 watts.

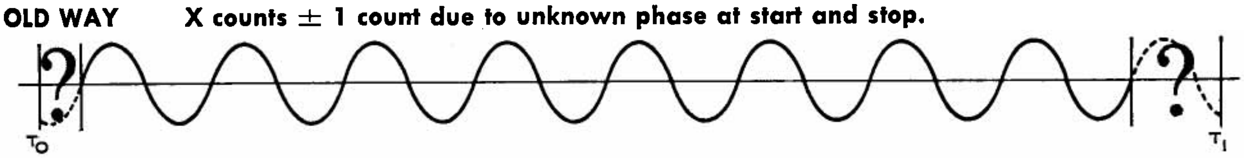
Size: 14" high, 19" wide, 21¾" deep behind panel. Weight 75 lbs.

Price: -hp- 218AR (rack mount), $2,000.00.

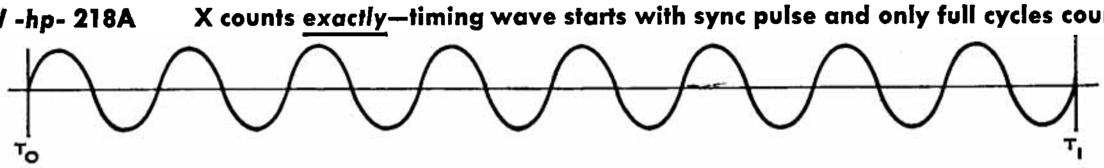
Data subject to change without notice.

± 1 COUNT AMBIGUITY ELIMINATED!

OLD WAY **X counts ± 1 count due to unknown phase at start and stop.**



NEW -hp- 218A **X counts <u>exactly</u>—timing wave starts with sync pulse and only full cycles counted!**



hp 711A LABORATORY POWER SUPPLY

High Regulation, 0 to 500 Volts, Separate Meters

Specifications

Output Voltages:
DC Regulated High Voltage: 0 to 500 volts (without switching), 100 ma maximum load.
AC Unregulated: 6.3 volts, 6 amps maximum load or 12.6 volts CT, 3 amps maximum load.

Regulation: For line voltage 115/230 volts $\pm$ 10%, less than 0.5% change or 1.0 volt change, whichever is greater; from no load to full load, change of less than 0.5% or 1.0 volt, (whichever is greater).

Ripple: Less than 1.0 mv.

Metering:
Current Meter: 0 to 100 ma; 0 to 10 ma with push-button.
Voltage Meter: 0 to +500 volts; 0 to +50 volts with push-button.

Terminals: Either positive or negative dc regulated high voltage terminal may be grounded.

Overload Protection: AC line fused. Output relay prevents dc output from greatly exceeding current rating of output milliammeter thus protecting instrument from overload conditions including short circuit of output.

Power: 115 volts $\pm$ 10%, 50/1,000 cps. Approximately 145 watts depending on load and line voltage.

Dimensions: Cabinet Mount: $7\frac{3}{8}''$ wide, $11\frac{1}{2}''$ high, $14\frac{1}{4}''$ deep. Rack Mount: 19" wide, 7" high, 13-1/16" deep behind panel.

Weight: 20 lbs. Shipping weight, 26 lbs.
Net 24 lbs. Shipping 35 lbs. (rack mount).

Price: hp 711A, $250.00 (cabinet); hp 711AR, $255.00 (rack mount).

The hp 711A is an easy-to-use, general purpose low power laboratory supply particularly suited to powering experimental setups and other basic bench applications. It offers very high regulation, and a wide, variable voltage range extending from 0 to 500 volts. There are separate current and voltage meters with two ranges each to permit accurate measurement of small power outputs. Full overload protection is provided to protect the instrument even under short-circuit output conditions.

Uses

Model 711A can be used to power a wide variety of equipment. It is particularly useful in driving low level amplifiers, constant frequency oscillators and other instruments or setups requiring a highly stable source of voltage. Model 711A is extremely compact, mounted in a rugged but lightweight cabinet. Its moderate price makes it an exceptional value in the power supply field.

Data subject to change without notice.

hp 712B REGULATED POWER SUPPLY

0.01% Regulation at 500 Volts, 200 Milliamperes

The hp 712B Power Supply is deliberately designed to give you the finest performance obtainable plus broadest usefulness and the lowest price consistent with quality.

Model 712B provides four outputs for maximum applicability and has less than 50 millivolts change (no load to full load) at any regulated output voltage. Internal impedance is 0.1 ohm in series with 25 μh maximum. Transient recovery is 0.1 milliseconds upon application of full load.

Uses

This power supply meets the most demanding requirements of heavy duty laboratory or production work. It is particularly useful in powering pulse circuitry and other systems such as radar modulators having high instantaneous current demands; and in powering oscillators, small transmitters, complex systems and certain klystrons.

To insure long, trouble-free operation, the instrument uses sealed transformers and chokes, oil-filled capacitors and is fully fused. Only the highest quality components are used, and no electrolytic capacitors are employed.

Specifications

Output Voltages:
- **DC Regulated High Voltage:** 0 to +500 v (without switching), 200 ma max. load.
- **DC Regulated Fixed Bias:** −300 v, 50 ma max. load.
- **DC Variable Bias:** 0 to −150 v, 5 ma max. load.
- **AC Unregulated:** 6.3 v, CT, 10 amps max. load.

Regulation: (For constant line voltage.)
- **DC Regulated High Voltage:** Less than 50 millivolts change no-load to full load at any output voltage. Less than 100 mv change at any voltage or current condition for ±10% line voltage variations.
- **DC Regulated Fixed Bias:** Less than 50 millivolts change no-load to full-load.
- **DC Variable Bias:** Regulated against line voltage changes. Internal impedance 0 to 10,000 ohms depending on bias control setting.

Line Voltage Regulation: Less than ±100 mv change in dc output for ±10% change from 115 v.

Ripple: Less than 500 microvolts.

Internal Impedance:
- **DC Regulated High Voltage:** (For frequencies above 20 cps.) Full-load: 0.1 ohm in series with 25 μh max. No load: 1 ohm in series with 50 μh max.

Recovery Time: Upon application of full-load: 0.1 millisecond max. Upon decrease from full load to: (a) 0 ma, 0.5 millisecond max.; (b) 25 ma, 0.1 millisecond max. Maximum transient voltage, 1 volt.

Metering:
- **Current Meter:** 0 to 200 ma (high voltage only).
- **Voltmeter:** Three ranges, 0 to +500, 0 to +150 volts and 0 to −150 volts. Panel switch connects meter to dc regulated high voltage or dc variable bias and selects range.

Terminals: Either positive or negative dc regulated high voltage terminal may be grounded. Positive terminals of both bias supplies and negative terminal of dc regulated high voltage are common.

Overload Protection: AC line, dc regulated high voltage, dc regulated fixed bias and filament supply are separately fused. DC regulated high voltage drops to a safe value if bias fuse blows.

Power: 115 v ± 10 v, 50/60 cps. Approx. 120 to 450 watts depending on load and line conditions.

Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13⅝" deep behind panel. Also can be used with hp AC-17 End Frames.

Weight: Net 70 lbs. Shipping 81 lbs. (cabinet mount). Net 62 lbs. Shipping 77 lbs. (rack mount).

Price: hp 712B, $390.00 (cabinet); hp 712BR, $375.00 (rack mount).

Data subject to change without notice.

721A Transistor Power Supply

0 to 30 Volts, 150 ma Output, Positive Overload Protection

Inexpensive, highly versatile, less than 5″ high Model 721A is finding increasingly broad applications in research and development laboratories, particularly in semiconductor circuit design.

721A provides fully regulated output voltages from 0 to 30 volts. With the three terminal output connector, either the positive or negative terminal may be grounded, or the supply may be stacked on another voltage. A front panel meter monitors either voltage or current to the load.

The high stability of output voltage for variations in both line voltage and load current and the extremely low ripple (less than 150 microvolts) aid in assuring the accuracy of experimental results. The small size, low power consumption and simple controls save time and space and give real convenience in an inexpensive transistor power supply.

Specifications

Regulated Output: 0 to 30 volts dc; 0 to 150 ma dc.
Load Regulation: Less than 0.3% or 30 mv (whichever is greater) change from 0 to 150 ma.
Line Regulation: Less than 0.3% or 15 mv (whichever is greater) for ±10% line voltage change.
Noise and Ripple: Less than 150 μv.
Output Impedance: Less than 0.2 ohms in series with 30 μh.
Output Meter: Full scale indications of: 10 ma, 30 ma, 100 ma, 300 ma; 10 volts, and 30 volts.
Output Protection: Four step selection of maximum current: 25, 50, 100 and 225 ma.
Power: 115/230 ±10%, 50/60 cps, 16 watts.
Weight: Net 4 lbs. Shipping 7 lbs.
Dimensions: 7″wide, 4⅜″ high, 5¼″ deep.
Price: 721A, $145.00

723A Power Supply

500 ma Output, 0 to 40 Volts, Remote Voltage Programming

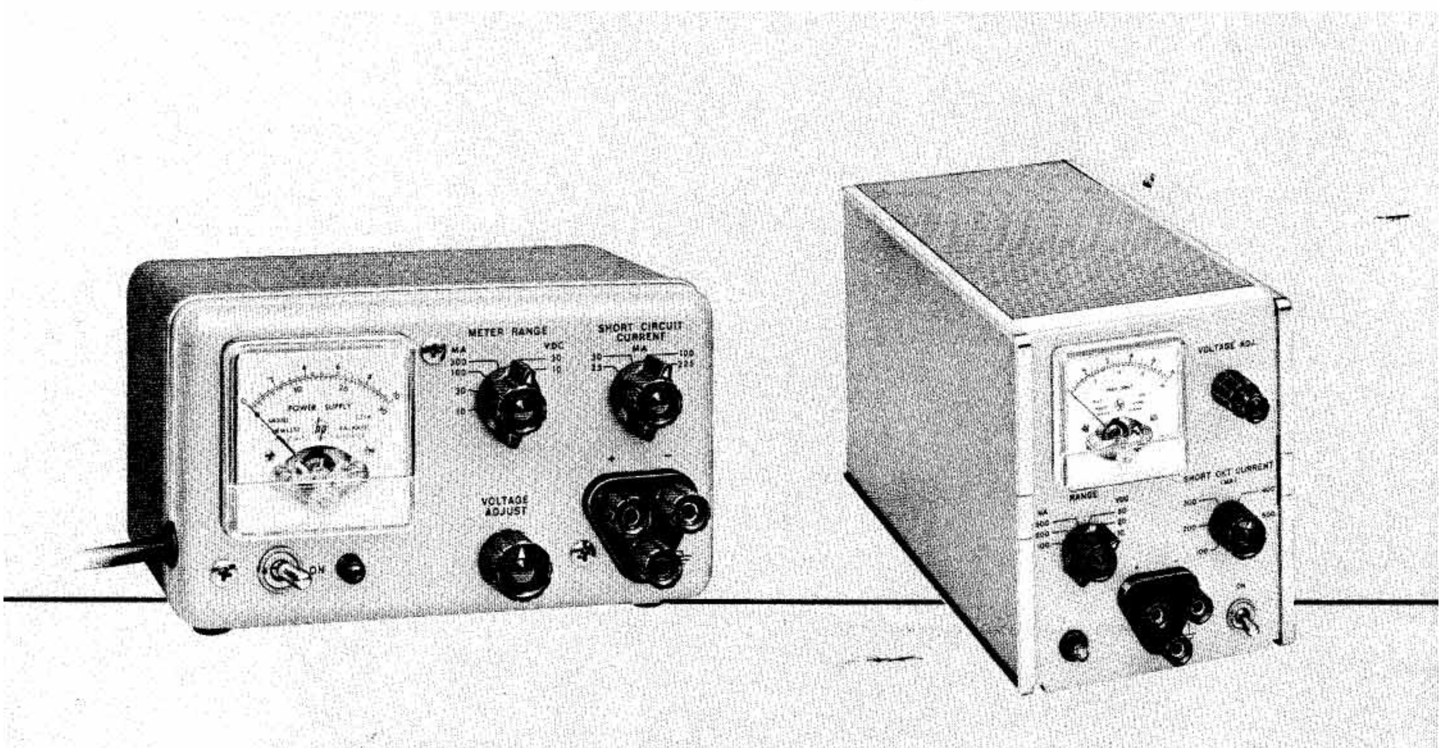
Compact new 723A is an ideal dc power supply for systems applications where a number of tests or measurements are made automatically at different voltages. Output voltage of Model 723A may be changed simply by changing the value of an external resistor. Thus, output voltage may be programmed remotely by using stepping switches to change external resistor values in accordance with programmed tests.

Output terminals are isolated from the chassis and power line ground so either positive or negative terminals may be grounded, or several units operated in cascade.

Specifications

Regulated Output: 0 to 40 volts dc, 0 to 500 ma dc.
Load Regulation: Less than 20 mv change from 0 to 500 ma.
Line Regulation: Less than 10 mv change for ±10% line voltage change.
Noise and Ripple: Less than 150 μv.
Temperature Stability: Less than 0.05%/°C or 10 mv/°C, whichever is greater.
Temperature Range: 0 to 55°C for operation within specifications.
Remote Programming: External resistance can control output voltage at the rate of 50 ohms/volt.
Output Impedance: Less than 40 milliohms in series with 20 μh.
Current Limiter: Continuously adjustable from approximately 60 to 600 ma.
Power: 115/230 v ±10%, 50/60 cycles.
Weight: Net, 12 lbs. Shipping 21 lbs.
Dimensions: 6-3/32″ high, 5-1/16″ wide, 11″ deep.
Price: 723A, $225.00.

Data subject to change without notice.



721A   723A

2 Amperes and 60 Volts Output; Precise Regulation

New transistorized (hp) 722AR meets today's most demanding requirements for a well regulated dc power supply in investigations where high stability output under varying line and load conditions is essential. Model 722AR is particularly useful in applications which require high current at low voltage because it regulates over its full voltage range. For example, Model 722AR is an ideal source for furnishing power to banks of tunnel diodes.

The low noise and ripple of the output voltage aid materially in increasing the accuracy of measurements, and the high stability of the output voltage assures that voltage sensitive parameters will remain constant.

Remote Sensing

By means of two extra wires, output voltage may be sensed directly at the load, making regulation nearly independent of voltage drop in the main current-carrying leads. A terminal board is provided at the rear of the instrument for remote sensing leads, and a slide switch selects either local or remote sensing. This circuit can compensate for up to 0.6 volts IR drop in the main leads.

Other Features

Separate meters measure current and voltage continuously, permitting convenient monitoring of output without external equipment. Furthermore, the 722AR has a continuously variable control which limits output current, and may be used safely with low power transistors and other low current devices. Model 722AR is also useful wherever high stability at moderate voltage and current is required and is an excellent laboratory source of regulated voltage for vacuum tube heaters.

Specifications

Regulated Output: 0 to 60 volts, dc; 0 to 2 amperes, dc.

Load Regulation: Less than 5 mv change for 0 to 2 amperes change.

Line Regulation: Less than 2.5 mv change for ± 10% line voltage change.

Noise and Ripple: Less than 250 µv.

Temperature Stability: Better than 0.02%/°C or 5 mv/°C, whichever is greater.

Temperature Range: 0 to 55°C for operation within specifications.

Output Impedance: DC: less than 2.5 milliohms.
AC: less than 5 milliohms in series with 4 µh.

Transient Recovery Time: Less than 200 µsec for recovery within 5 mv for change from 0 to full load or full load to 0 at any rated output or line voltage.

Output Meters: Voltage: 0 to 60 volts, one range.
Current: 0 to 2.5 amperes, one range.

Output Protection: Output current limiter continuously adjustable from approximately 100 ma to 2.1 amperes.

Cooling: Forced air.

Power: 115/230 v ±10%, 50/60 cps, 260 watts.

Weight: Net 34 lbs. Shipping 46 lbs.

Dimensions: 19" wide, 5¼" high, 12" deep.

Price: (hp) 722AR, $525.00 (rack mount).

Data subject to change without notice.

722AR POWER SUPPLY

2 Amperes and 60 Volts Output; Precise Regulation

New transistorized hp 722AR meets today's most demanding requirements for a well regulated dc power supply in investigations where high stability output under varying line and load conditions is essential. Model 722AR is particularly useful in applications which require high current at low voltage because it regulates over its full voltage range. For example, Model 722AR is an ideal source for furnishing power to banks of tunnel diodes.

The low noise and ripple of the output voltage aid materially in increasing the accuracy of measurements, and the high stability of the output voltage assures that voltage sensitive parameters will remain constant.

Remote Sensing

By means of two extra wires, output voltage may be sensed directly at the load, making regulation nearly independent of voltage drop in the main current-carrying leads. A terminal board is provided at the rear of the instrument for remote sensing leads, and a slide switch selects either local or remote sensing. This circuit can compensate for up to 0.6 volts IR drop in the main leads.

Other Features

Separate meters measure current and voltage continuously, permitting convenient monitoring of output without external equipment. Furthermore, the 722AR has a continuously variable control which limits output current, and may be used safely with low power transistors and other low current devices. Model 722AR is also useful wherever high stability at moderate voltage and current is required and is an excellent laboratory source of regulated voltage for vacuum tube heaters.

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Load Regulation: Less than 5 mv change for 0 to 2 amperes change.

Line Regulation: Less than 2.5 mv change for ± 10% line voltage change.

Noise and Ripple: Less than 250 μv.

Temperature Stability: Better than 0.02%/°C or 5 mv/°C, whichever is greater.

Temperature Range: 0 to 55°C for operation within specifications.

Output Impedance: DC: less than 2.5 milliohms.
AC: less than 5 milliohms in series with 4 μh.

Transient Recovery Time: Less than 200 μsec for recovery within 5 mv for change from 0 to full load or full load to 0 at any rated output or line voltage.

Output Meters: Voltage: 0 to 60 volts, one range.
Current: 0 to 2.5 amperes, one range.

Output Protection: Output current limiter continuously adjustable from approximately 100 ma to 2.1 amperes.

Cooling: Forced air.

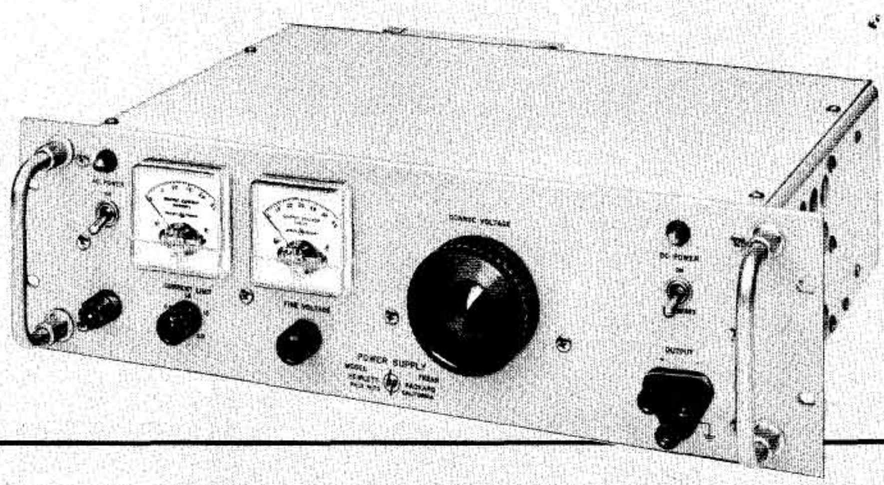
Power: 115/230 v ±10%, 50/60 cps, 260 watts.

Weight: Net 34 lbs. Shipping 46 lbs.

Dimensions: 19" wide, 5¼" high, 12" deep.

Price: hp 722AR, $525.00 (rack mount).

Data subject to change without notice.



715A KLYSTRON POWER SUPPLY

Versatile Power Source for Low-Power Klystrons

Specifications

Supply No. 1: (Beam supply) Voltage range −250 to −400 volts; Max. current, 30 ma at 250 volts, 50 ma at 400 volts; regulation, less than 1% from no load to full load or for line voltage variations of 115 v ± 10%; ripple, less than 7 mv; calibrated voltage controls provided.

Supply No. 2: (Reflector supply) Voltage range 0 to −900 volts, with respect to Supply No. 1; max. current, 10 microamperes; regulation, within 1% for line voltages of 115 v ± 10% for fixed currents; ripple, less than 10 mv; calibrated voltage controls provided.

Filament Supply: Provides 1.5 amperes max. at 6.3 volts, ac.

Modulation: Square wave modulation provided on supply No. 2; amplitude adjustable from 0 to 110 volts peak-to-peak. Square wave rise and decay times less than 10 microseconds each; square wave frequency adjustable over ± 100-cycle range from nominal 1,000 cps center frequency. Supply No. 2 also includes 60 cps sine wave modulation adjustable 0 to 350 volts peak-to-peak for reflector (FM) modulation.

External Modulation: Terminals and circuit provided for modulation from external source. Input impedance at external modulation terminals is approximately 100,000 ohms.

Power: 115/230 v ± 10%, 50/60 cps, 200 watts.

Dimensions: Cabinet Mount: 7⅜" wide, 11½" high, 13¾" deep.

Weight: Net 19 lbs. Shipping 24 lbs. (cabinet mount).

Accessories Furnished: 1 715A-16C Cable Assembly (for connection to Klystron).

Accessories Available: AC-16A Cable Assembly, $4.50. AC-16B Cable Assembly, $5.50.

Price: hp 715A, $325.00.

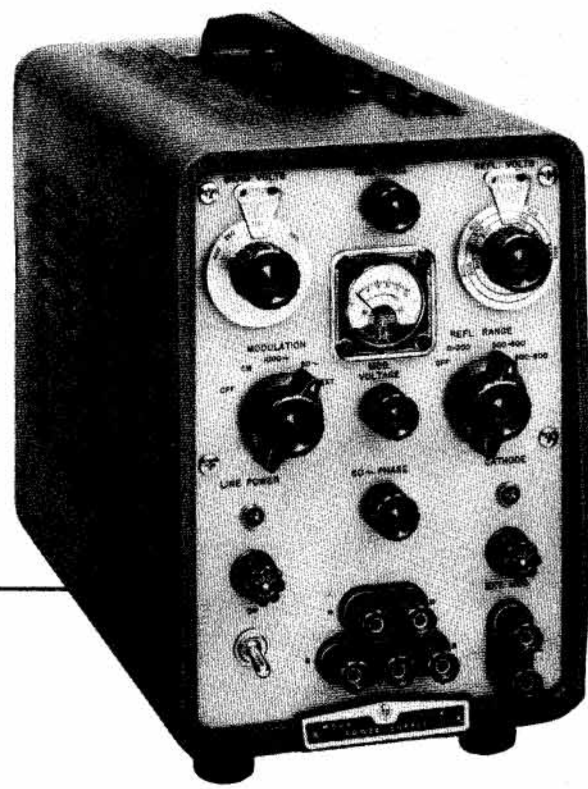
Data subject to change without notice.

The hp 715A Power Supply was designed to meet the need for a compact, portable bench supply capable of operating many different types of low-power klystrons.

The Supply offers a regulated 250 to 400 volt beam voltage (continuously variable), a 0 to 900 volt regulated and continuously variable 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 1,000 cps, externally modulated or sine wave modulated at the power line frequency.

To minimize the chance of accidental damage to a klystron, the instrument's reflector supply is arranged with a protective circuit preventing the reflector from becoming appreciably more positive than the cathode.

The unit is provided with a plug-in output cable that is shielded to minimize hum pick-up. Direct-reading controls set the regulated voltages and a meter monitors the beam current.



Fast, convenient measurement of harmonic distortion is of great value not only in the laboratory, but in the manufacturing and testing of electronic, electrical and mechanical equipment.

Distortion in a network may be defined as the presence of harmonics along with the fundamental. This harmonic distortion is the result of nonlinear transfer characteristics of a network, and may be expressed:

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

(In this expression A_1 is the amplitude of the fundamental, A_2 is the second harmonic, A_3 is the third harmonic, etc.)

Distortion Measuring Methods

Two procedures are commonly followed in determining distortion. One of these is the "fundamental" method. In this method, a single pure frequency is fed to a device and each frequency appearing at the output is measured with a frequency-selective voltmeter or a wave analyzer. The measured values are substituted in the expression given above and percent distortion may be calculated.

A second method is known as "total" distortion measuring. A single pure frequency is again fed to the device. Here the amplitude of the output voltage containing harmonics is first measured. Then the fundamental frequency is filtered out and the rms value of the combined harmonics is measured. The ratio of the two values expressed in percent is the distortion in the circuit.

ⓗⓟ Wave Analyzer

For measuring distortion by the "fundamental" method, the ⓗⓟ 302A Wave Analyzer *(pages 60, 61)* is ideal. This compact, completely transistorized, essentially hum-free instrument is highly selective, requires no tedious calibration or stabilization, and provides direct, accurate readings.

Use of the heterodyne technique gives a constant bandwidth over its frequency range, and the use of crystal filters has resulted in a particularly narrow pass-band of only 6 cps at the 3 db points. These features are combined with a carefully designed system for achieving a linear frequency dial, so that the narrow pass band can be very accurately positioned within a few cycles, even at frequencies as high as 50 KC. The dynamic range of about 70 db provides additional measuring versatility. For example, a hum (60 cps) sideband of a very high harmonic of a square wave can be measured with ease, even though this sideband may be only a few microvolts in amplitude.

Automatic Harmonic Analysis

A new accessory, ⓗⓟ AC-97C Sweep Drive Unit, when coupled with the ⓗⓟ 302A and an X-Y recorder, permits automatic plotting of the frequency spectrum of a signal. The AC-97C has two sweep speeds compatible with the ⓗⓟ 302A bandwidth, and it also has adjustable limits so that the sweep range will cover any portion of the band from 20 cps to 50 KC. A typical recording from these instruments is shown below in Figure 2.

ⓗⓟ Distortion Analyzers

ⓗⓟ 330 series Distortion Analyzers are basically selective amplifiers whose frequency of rejection is tunable. *(See Figure 1.)* They are designed for measuring distortion by the "total" method between 20 and 20,000 cps. These instruments are extremely simple to use, and are particularly useful in measuring total audio distortion or hum and noise level in audio amplifiers. They are also convenient for measuring voltage levels, power output, amplifier gain; and may be used as high-gain, wide-band stabilized amplifiers. The 330D includes a linear rf detector for determining distortion in amplitude modulated broadcast carriers.

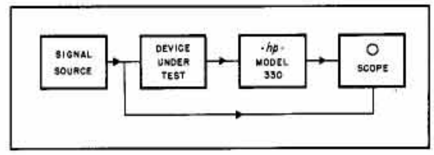


Figure 3. Recommended setup for distortion measurement using ⓗⓟ 330 Analyzers.

A typical setup utilizing ⓗⓟ 330 series analyzers for measuring by the "total" distortion method is shown in Figure 3. The combination of distortion analyzer and oscilloscope is an ideal arrangement and provides a great deal of information. With this setup, transient oscillations caused by saturation of iron in the circuit can be easily detected, as can continuous oscillations caused by unfavorable gain-shift characteristics. Such oscillations indicate an unstable system and are often unstable themselves. However, they are frequently non-detectable unless an oscilloscope is used.

The analyzer-oscilloscope combination is also useful for determining the nature of distortion, the presence of excessive noise and hum; or for detecting distortion caused by grid current on driving peaks.

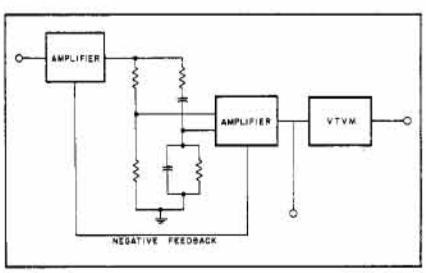


Figure 1. Block diagram of ⓗⓟ 330B Distortion Analyzer.

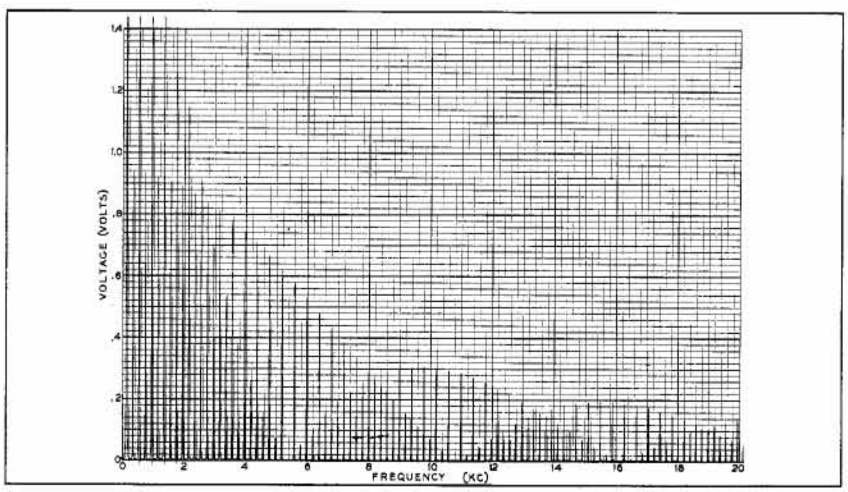


Figure 2. Harmonic analysis of slightly unsymmetrical square wave. Several harmonics were allowed to run off scale so the smaller, higher order harmonics are clearly visible.

302A WAVE ANALYZER

New, Highly Selective, Transistorized, Measures Wave Components Directly

Advantages:

No calibration or stabilization needed

Direct readings; accurate

Measures frequencies 20 cps to 50 KC

Completely transistorized

Battery or ac powered; hum free

Low power consumption; no warmup needed

Very sharp acceptance circuits

AFC; also frequency restorer circuit

Compact, rugged, versatile

Oscillator-tuned voltmeter

Uses:

Measures and analyzes fundamentals, harmonics, and intermodulation products in telemetering, carrier and vibration systems as well as audio circuits. Speeds analysis of noise and broadcast amplifier characteristics; modulation amplifier, film sound track and recording distortion; hum, network characteristics, etc.

New Model 302A Wave Analyzer represents a significant improvement in wave analyzer design.

Completely transistorized, sophisticated in design, highly selective, free of tedious calibration and stabilization before use—these are but a few of the important convenience and accuracy features in the new 302A.

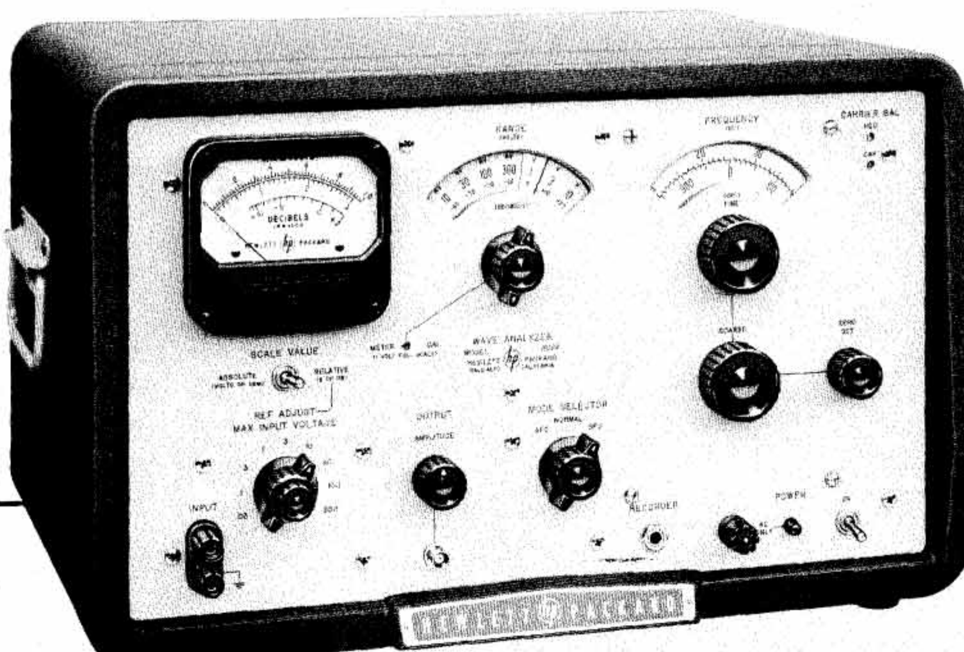
Other exceptional features are extremely narrow bandwidth, automatic frequency control, automatic tracking when used as an oscillator tuned-voltmeter, provision for battery operation (18 to 28 volts) as well as ac line power, and elimination of warmup time.

Simple Operation

In operation the instrument functions as a highly selective tuned voltmeter. A front panel control selects the frequency to be measured and voltage is then read directly on the front panel meter.

Model 302A separates 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. When the mode selector switch is in the normal or AFC position, the signal appears at the output terminals if the meter is indicating.

Model 302A is also 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 is enhanced by a linearly calibrated tuning control giving the same "tuning feel" throughout range.

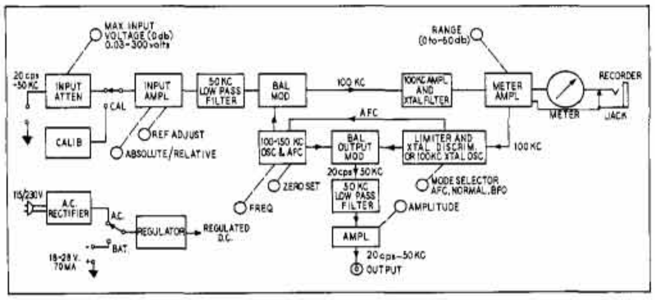


Figure 1. Block diagram, Model 302A Harmonic Wave Analyzer.

Specifications ⓗⓟ 302A

Frequency Range: 20 cps to 50 KC.

Frequency Calibration: Linear graduation 1 division per 10 cycles. Accuracy $\pm$ (1% + 5 cps).

Voltage Range: 30 μv to 300 v full scale in a 30, 100, 300 sequence. Steps of 1:3 or 10 db. Meter range indicated by a dial mechanically linked to input attenuator. An absolute-relative switch provides for adjustment of intermediate values.

Warmup-Time: None.

Voltage Accuracy: $\pm$ 5% 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: $\pm$ 3½ cycle b.w.—at least 3 db down
$\pm$ 25 cycle b.w.—at least 50 db down
$\pm$ 70 cycle b.w.—at least 80 db down
beyond $\pm$ 70 cycle b.w.—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 v across 600 ohms at output terminals for full scale meter deflection. Output level control provided. Frequency response $\pm$ 2%, 20 cycles to 50 KC. Output impedance approximately 600 ohms.

Oscillator Output: 1 v across 600 ohms at output terminals (mode selector in B.F.O.). Output level control provided. Frequency response $\pm$ 2%, 20 cps to 50 KC. Output impedance approximately 600 ohms.

Recorder Output: 1 ma dc into 1,500 ohms or less at full scale meter indication, for ungrounded recorders only.

Automatic Frequency Control: Range of frequency holdin is $\pm$ 100 cycles minimum.

Power: 115/230 v $\pm$ 10%, 50/1600 cycles, 3 watts (approximately). Terminals provided for powering instrument from external battery source. Battery supply range 28 v to 18 v.

Weight: Net 43 lbs. Shipping 54 lbs. (cabinet mount). Net 35 lbs. Shipping 50 lbs. (rack mount).

Dimensions: Cabinet Mount: 20¾″ wide; 12½″ high; 14½″ deep. Rack Mount: 19″ wide; 10½″ high; 13 13/16″ deep behind panel.

Price: ⓗⓟ 302A, $1,800.00 (cabinet); ⓗⓟ 302AR, $1,785.00 (rack mount).

AC-97C Sweep Drive

The AC-97C is a motor drive unit designed to enhance the usefulness of the ⓗⓟ 302A. With the AC-97C you may sweep through all or any part of the 302A range. Because the AC-97C produces an X-axis output, you may easily make automatic plots of harmonics and intermodulation products. When the ⓗⓟ 302A is used as an oscillator tuned-voltmeter the AC-97C permits automatic frequency response measurements of networks, amplifiers and filters even in the presence of high noise.

The AC-97C, although designed for use with the ⓗⓟ 302A, also may be used to drive oscillators and other tunable devices through their ranges. A stand which allows the shaft height to be adjusted from 4 inches to 12 inches is available for adapting the AC-97C to other equipment.

Specifications ⓗⓟ AC-97C

Sweep Range: 50 revolutions.

Sweep Limits: Any interval from 50 revolutions to 10 degrees.

Sweep Speed: With ⓗⓟ 302A: 170 cps per second and 17 cps per second.

Shaft Speed: 10 rpm, 1 rpm, and neutral; quick change speed transfer without stopping. Neutral permits manual operation.

Sweep Output: 15 volts maximum. Change of output proportional to change in shaft position and zero output may be set for any shaft position. Full output may be obtained with 2½ revolutions or with 50 revolutions of the output shaft.

Motor: Reversible synchronous capacitor type reluctance motor; may be stalled indefinitely.

Output Shaft: ¼ inch diameter with adapter to 7/16 inch for ⓗⓟ Model 302A.

Power: 115 volts $\pm$ 10%, 50 to 60 cps, 12 watts, running or stalled.

Mount: Mounts on front panel of ⓗⓟ Model 302A or bench stand.

Dimensions: 3½″ high, 7″ wide, 5¼″ deep, shaft extends 13/16″ behind case.

Price: ⓗⓟ AC-97C, $275.00.

Data subject to change without notice.

hp 330B/C/D DISTORTION ANALYZER

Accurate Distortion Readings 20 cps to 20,000 cps

Advantages:

Blankets audio spectrum

Measures noise as small as 100 μv

High sensitivity, high stability

Measures distortion as low as 0.1%

Wide-band 20 db gain amplifier

Oscilloscope terminals, built-in VTVM

High-gain, wide-band amplification

Use It To Determine:

Total audio distortion

Voltage level, power output, gain

Total distortion of AM rf carrier

Noise and hum level directly

Audio signal frequency

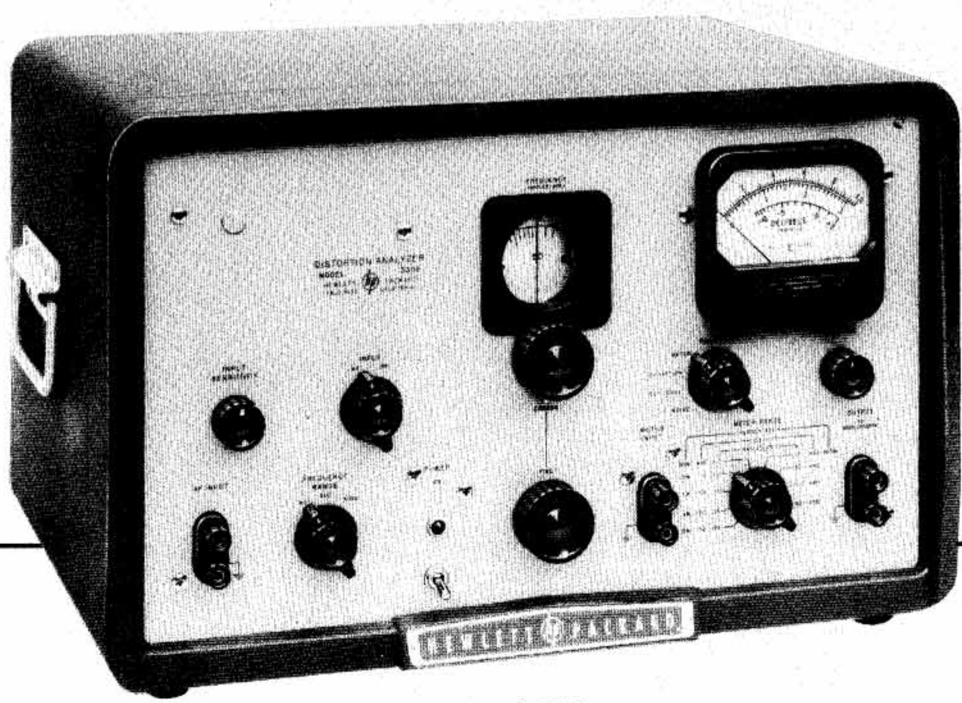
The hp Model 330B Distortion Analyzer will give you quick, accurate measurements of distortion as low as 0.1% at any frequency from 20 cps to 20,000 cps. It will make noise measurements of voltages as small as 100 microvolts. The analyzer has high sensitivity and high stability. Its circuit includes a 20 db amplifier, oscilloscope terminals and a precision vacuum tube voltmeter which is usable separately.

These many features give the instrument exceptional usefulness for all kinds of audio measurements in recording and motion picture facilities, broadcast studios, research laboratories and in maintaining quality of audio production.

Model 330B Distortion Analyzer

Basically, hp 330B Distortion Analyzer consists of a flat amplifier with slot rejection, a regulated power supply and a vacuum tube voltmeter.

The 20 db amplifier operates in conjunction with the hp R-C tuned rejection circuit to provide nearly infinite attenuation at one frequency while allowing all other frequencies



hp 330B

to be passed at the amplifier's normal gain. *(See Figure 1.)* Negative feedback is employed in the amplifier to minimize distortion, to give a uniform response over a wide range of frequencies and to provide high stability. Frequency response is flat from 10 cps to 100,000 cps; thus even the 5th harmonic of 20,000 cps is passed by the amplifier without appreciable attenuation.

The voltmeter section of the equipment consists of a two-stage, high-gain amplifier, a rectifier and an indicating meter. A large amount of negative feedback is again employed to insure stability and uniform response from 10 cps to 100,000 cps. The voltmeter—which may be used as a separate instrument—responds to the average value of the applied voltage wave and is calibrated in the rms value of a sine wave.

Model 330C Distortion Analyzer

For FM broadcasters, the ⓗ 330C Distortion Analyzer is offered. It is identical in all respects with ⓗ 330B, except that the voltmeter frequency range is 10 cps to 60 KC and the indicating meter movement is provided with VU ballistic characteristics to meet F.C.C. requirements for FM Broadcasting. Like the 330B, Model 330C provides nearly infinite attenuation at any one frequency and makes possible total audio distortion measurements at any frequency from 20 to 20,000 cps.

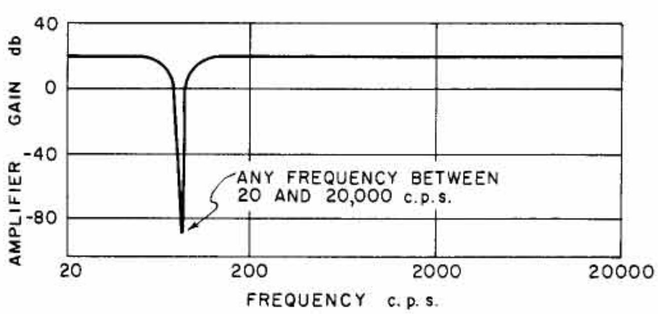


Figure 1

Model 330D Distortion Analyzer

The 330D is identical to the 330C except that an AM detector has been included. This detector permits the measurement of envelope distortion of an amplitude-modulated carrier. The detector covers a range of 500 KC to 60 MC and is varied by a tuning capacitor and range switch which selects one of five bands. (Detector may be switched out of circuit when audio frequencies are used.) Model 330D also includes the special VU meter employed in Model 330C. Other specifications are similar to Model 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 KC 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, 0.10, 0.30, 1.00, 3.00, 10.0, 30.0, 100 and 300 volts. Nine ranges spaced exactly 10 db. Db scale: −12 db to +2 db, calibrated on zero level = 1 milliwatt 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 volts to 126 volts), Model 330B within ±3%, 10 cps to 100 KC: Models 330C and 330D within ±3%, 10 cps to 20 KC and ±6%, 10 cps to 60 KC.

Voltmeter Input Impedance: Approximately one 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.

Oscilloscope Terminals: Maximum gain from AF input to oscilloscope terminals is 75 db.

Meter Movement: Models 330C and 330D: VU ballistic characteristics to meet F.C.C. 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: 115/230 v ±10%, 50/1,000 cps, approximately 90 watts.

Dimensions: Cabinet Mount: 20¾″ wide, 12¾″ high, 14¼″ deep. Rack Mount: 19″ wide, 10½″ high, 13⅝″ deep behind panel. Also can be used with ⓗ AC-17 End Frames.

Weight: Net 38 lbs. Shipping 49 lbs. (cabinet mount). Net 30 lbs. Shipping 45 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.50; AC-16B Cable Assembly, $5.50. AC-60B Transformer (for bridging input), $80.00.

Price: ⓗ 330B, $450.00 (cabinet); ⓗ 330BR, $435.00 (rack mount). ⓗ 330C, $475.00 (cabinet); ⓗ 330CR, $460.00 (rack mount). ⓗ 330D, $525.00 (cabinet); ⓗ 330DR, $510.00 (rack mount).

Data subject to change without notice.

hp 350A/B Attenuators

Model 350A/B are basic bridged-T instruments for use when high accuracy, wide frequency response and large 5 watt power handling capacity are required. The instruments are ideal for attenuating output of audio and supersonic oscillators, measuring gain and frequency response of amplifiers, measuring transmission loss and increasing the utility of other laboratory equipment.

Specifications

hp 350A, matches 500 ohm impedance.
hp 350B, matches 600 ohm impedance.

(Following apply to hp 350A and 350B)

Attenuation: 110 db in 1 db steps.
Accuracy, 0 to 100 KC: 10 db attenuator section: error less than ±0.125 db, any step. 100 db attenuator section: error less than ±0.25 db to 80 db, less than ±0.5 db on 90 and 100 db steps.
Power Capacity: 5 watts continuous duty.
Dimensions: Cabinet Mount: 8¼" wide, 5⅝" high, 5-5/16" deep. Rack Mount: 19" wide, 5¼" high 3⅞" deep.
Weight: Net 3 lbs. Shipping 7 lbs. (cabinet mount). Net 3 lbs. Shipping 10 lbs. (rack mount).
Price: hp 350A or 350B, $110.00 (cabinet); hp 350AR or 350BR, $115.00 (rack mount).

Data subject to change without notice.

NOTE: hp also offers a wide variety of waveguide attenuators. Please see pages 180, 181.

hp 355A/B Precision Attenuators

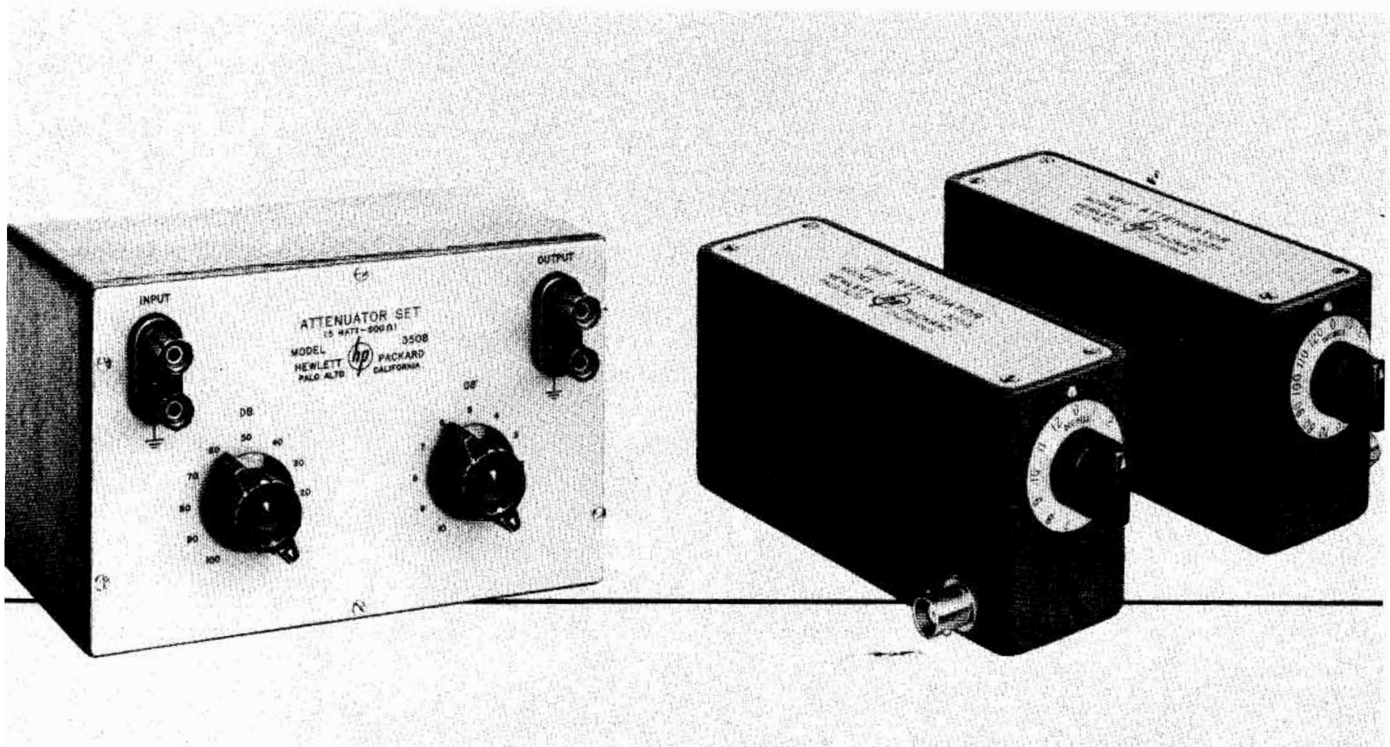
Model 355A and 355B are precision attenuators useful as components or laboratory instruments. Together the hp 355A and 355B provide 0 to 132 db attenuation in 1 db steps from dc to 500 MC. Accuracy and performance derives from a new design using balanced capacities, complete shielding of sections, and cam-driven microswitches to insert or remove attenuator sections.

Specifications hp 355A

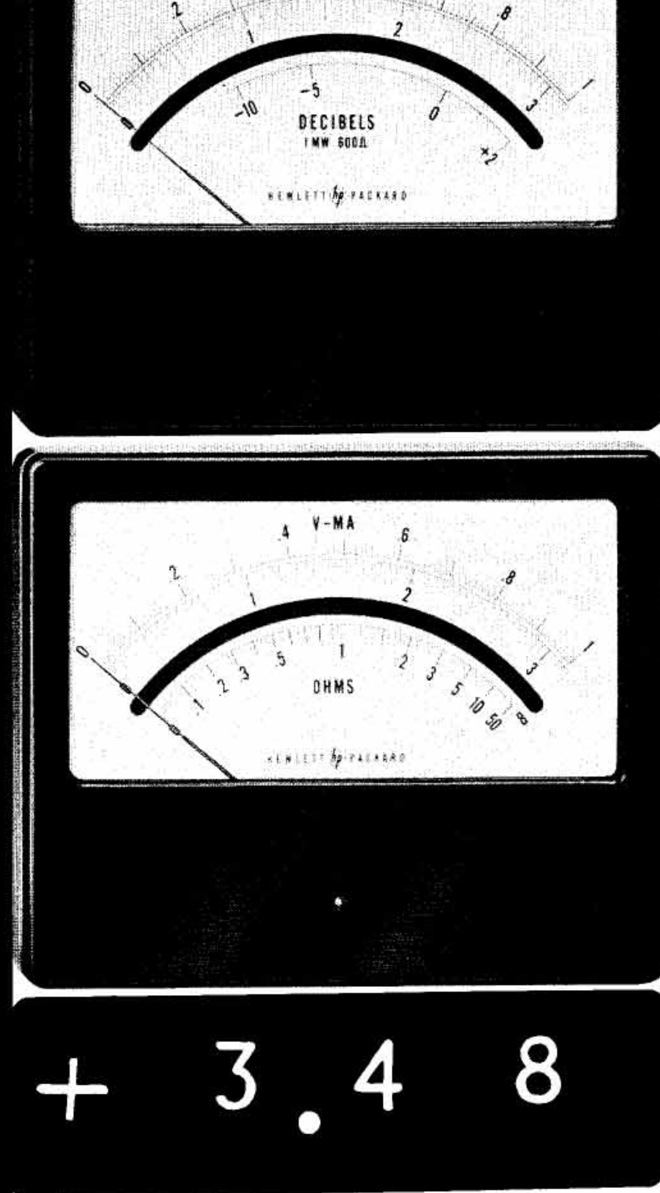
Attenuation: 12 db in 1 db steps.
Frequency Range: DC to 500 MC.
Overall Accuracy: ±0.1 db at 1000 cps, ±0.25 db, full range.
Impedance: 50 ohms.
Maximum SWR: 1.2 below 250 MC, 1.5 below 500 MC.
Max. Insertion Loss: 0 at dc; 0.4 db at 60 MC; 1.0 db at 250 MC; 1.5 db at 500 MC.
Power Dissipation: 0.5 watts average, 350 v peak.
Connectors: BNC.
Dimensions: 2¾" wide, 6" long, 2⅝" high.
Weight: Net 1½ lbs. Shipping 3 lbs.
Price: hp 355A or 355B, $125.00.

hp 355B same as 355A except:

Attenuation: 120 db in 10 db steps.
Overall Accuracy: ±0.3 db to 120 db at 1000 cps, ±1 db to 60 db below 250 MC, ±2 db to 120 db below 500 MC.



hp 350B   hp 355A   hp 355B



VOLTAGE CURRENT and RESISTANCE MEASURING

Measurement of the basic electrical quantities of voltage, current and resistance is required daily in practically every facility applying electronics. Electronic measuring instruments also are often used to facilitate mechanical and medical measurements. To fill all of these needs, Hewlett-Packard has developed many precise, easy to use instruments to make electrical measurements under a wide range of conditions. Dependability and versatility are important hp design objectives, so that hp instruments can be applied with confidence even by personnel inexperienced with electronic circuits.

Some of the operating principles of hp measuring instruments are briefly outlined below to help in selection of the proper instrument for a specific job.

AC Voltage Measurement

Average Responding Meters. The most widely used technique for ac voltage measurement is to amplify the signal with a high-gain, broad-band amplifier, and apply the amplifier output to a bridge rectifier circuit. The resulting dc current, which drives the meter, is proportional to the average level of the incoming signal. Average responding meters are usually calibrated in terms of rms for a sine wave. This yields an answer remarkably close to the rms reading even with considerable amounts of distortion in the measured signal. *(See Table 1.)*

% Harmonic	True Rms Value	Model 400D Indication	Peak Meter Indication
0	100	100	100
10% 2nd	100.5	100	90 to 110
20% 2nd	102	100 - 102	80 to 120
50% 2nd	112	100 - 110	75 to 150
10% 3rd	100.5	96 - 104	90 to 110
20% 3rd	102	94 - 108	88 to 120
50% 3rd	112	90 - 116	108 to 150

Table 1. Measurement errors from harmonic or other spurious voltages.

Careful amplifier design makes possible sensitivity of 1 mv full scale on such instruments, and suitable attenuators are used to measure signals as high as 300 volts full scale. High input impedance is a necessary requirement, so that circuit conditions are not upset when the voltmeter is placed in the circuit. Input shunt capacity also is important *(see Figure1)* because this will considerably modify the input impedance at high frequencies and may even be reason to use capacitive dividers *(see voltmeter accessories, page 84)* or a voltmeter employing another principle. Since input circuits of all hp ac voltmeters are single ended, bridging transformers AC-60A and AC-60B are used for balanced line measurements.

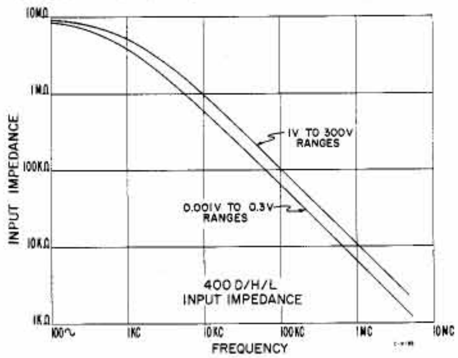


Figure 1.

hp 400D, 400H, 400L and 403A are high impedance, average responding ac voltmeters. Each model offers some particularly useful advantage. The 400D is an inexpensive, yet versatile and stable instrument with bandwidth of 10 cps to 4 MC. Measurement ranges are from 1 mv to 300 volts full scale, and input impedance is 10 megohms shunted by 15 pf or 25 pf depending on voltage range. hp 400H is similar to hp 400D but accuracy is increased to 1% over the middle frequency range. Model 400L is also a high accuracy instrument with the added feature of a logarithmic meter movement giving considerable expansion of the lower portion of the scale. The resulting linear db scale spreads 12 db over more than 3 inches of scale length and is easily readable within 0.1 db. The db scale covers from —70 to +52 in 12 ranges.

Peak Responding Voltmeters. A second method of measuring voltage is to use a single diode detector in a high impedance probe to rectify the signal at the point of measurement and then amplify the resulting dc. This technique offers particularly high frequency response since the ac signals travel a very short path to the rectifying diode. The peak responding circuit has the added advantage of very low input capacity, usually 1 to 3 pf, which makes the instrument useful in capacity-sensitive circuits. A peak rectifier is more sensitive to distortion, however, so the waveform should be studied with an oscilloscope if voltage accuracy is important. Meter scales are calibrated in rms value of a sine wave for maximum convenience. A peak responding instrument may be used to measure even short pulses if suitable corrections are applied to the reading.

hp 410B is a general purpose peak responding instrument. Its frequency coverage is 20 cps to 700 MC and voltage range is from 1 volt to 300 volts full scale. Since the unit contains a dc amplifier it has the added versatility of measuring both dc voltage and resistance.

hp 411A RF Millivoltmeter uses the peak responding principle to measure much lower voltages than the 410B. The obvious extension of the principle, that of further amplification of the dc signal, is impractical because at low voltage, diode rectifiers are non-linear, and a different meter scale would be needed on each voltage range. This problem is overcome in the hp 411A by using a new type of measuring circuit. The rf signal is rectified and converted to dc in the probe (as in the 410B), but in the 411A this signal is fed to one input of a differential amplifier. The amplitude of a 100 KC oscillator is controlled by the dc output of this amplifier. A feedback diode identical to the rf detector rectifies the 100 KC which is then fed to the other side of the differential amplifier. The circuit then acts as a servo loop. Rectified rf causes the amplitude of the 100 KC signal to vary until its rectified output is equal to the rectified rf. Then a simple meter circuit reads amplitude of the 100 KC which equals the rf voltage.

The meter scale problem is overcome by the 411A circuit because the feedback diode compensates for the non-linear response of the rf diode. The result is a truly linear scale. The range of measurements possible with the 411A is from 500 KC to 1,000 megacycles with a full scale sensitivity of 10 mv to 10 volts. The 411A has input capacity of only 2.5 pf to permit accurate low level measurements where low capacity is necessary.

DC Voltage Measurements

DC voltmeters also require high input impedance and high sensitivity but, in addition, they must not respond to ac voltages, and they are more difficult to stabilize in terms of zero drift.

hp 410B uses a straightforward dc-coupled amplifier approach to provide high input impedance with moderate sensitivity.

DC signals lower than 1 volt are usually converted into ac with a mechanical chopper so that they can be amplified by ac techniques. This avoids the problem of dc drift. Mechanical choppers, however, have the disadvantages of relatively short life, high replacement cost, and occasional noisy contacts. To overcome the mechanical chopper problem, hp developed a photoconductor chopper which accomplishes switching by shining light on the cells at the proper time. This yields a quiet, low-noise chopper with high impedance and the long life associated with semiconductors.

The hp photoconductor chopper was first employed in a very high sensitivity dc voltmeter, hp 425A, which has a range from 1 volt to 10 microvolts end scale. Careful attention to small sources of thermocouple voltages and galvanic action gives the very low drift of less than 4 microvolts per day. Very high input impedance is obtained by using feedback to increase the already high chopper impedance. Heavy ac filtering makes the 425A reading insensitive to ac signals as high as 100 times the dc being measured. Calibrated shunt resistors make possible current measurements down to 10^{-12} amperes.

A second photochopper instrument is hp 412A, a general purpose, high accuracy unit for measuring voltage, current and resistance. Voltage accuracy is 1% of full scale even on the most sensitive 1 mv range. Current ranges with suitable shunt resistors yield a current accuracy of 2% of full scale. Zero drift is negligible in the 412A; no zero control is required. This allows great simplicity of operation, and is a measure of the inherent design stability of Model 412A.

Where extremely high measurement accuracy and resolution are needed, a digital voltmeter is logically employed. An added advantage of digital metering is the ease of permanent recording, with equipment such as hp 560A or hp 561B Digital Recorders. With coupling equipment manufactured by Dymec, a division of Hewlett-Packard, digital measurements can also be recorded on punched cards or tape.

hp 405BR and 405CR Digital Voltmeters were designed to provide digital measurement at a reasonable price. Remarkable simplicity of operation is an outstanding feature of these instruments. When a dc voltage is applied, the 405 is automatically zero set, the range and polarity are automatically selected, and the reading appears in a three-digit numeric tube display. These digital voltmeters also provide 11 megohm input impedance, and freedom from the effects of ac signals. A low-pass filter in the input circuit attenuates power line frequencies by over 40 db.

hp 405 type digital voltmeters employ a ramp technique in which the input dc voltage is compared with a linearly rising ramp voltage. At the instant the ramp begins, a signal gate is opened and the decade counter units begin to totalize clock pulses. When the ramp voltage reaches the external voltage, the gate is closed and the readout indicates the number of clock pulses counted. By choosing a clock rate of 50 KC and a ramp slope which produces 1 volt in 20 milliseconds, 1,000 counts will accumulate for a 1 volt input. Since the ramp is linear, the accumulated count will always directly indicate the input voltage. The indicated voltage is that existing at the instant of coincidence.

The hp 405 digital voltmeter is very useful in detecting small increments in a large voltage. A change of 1 millivolt in a 1 volt signal is very apparent on such an instrument, but would be extremely difficult to detect on a meter face. A suitable ac to dc converter such as the hp 457A will extend the digital voltmeter advantages to ac measurement.

The hp Dymec division also manufactures a high-resolution digital voltmeter. *(See page 201.)*

Resistance Measurement

A frequently used ohmmeter circuit is based on the principle shown in Figure 2. If the source voltage (E) is one volt and R_x is infinite, the voltmeter will deflect to full scale on its one volt range. A short circuit at R_x would show no deflection. If R_x were equal to R_i, a mid-scale reading would occur. Thus the ohms scale is calibrated with "zero" at no deflection, "infinity" at full deflection, and the value of R_i at midscale. Such an ohmmeter is included in hp 410B, which has mid-scale resistance readings ranging from 10 ohms to 10 megohms in seven ranges.

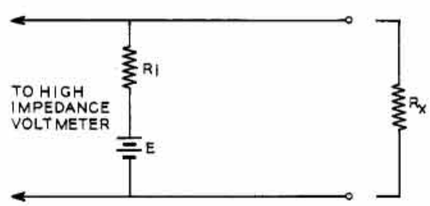


Figure 2

hp 412A covers an extremely wide range of resistance measurements, ranging from 1 ohm to 100 megohms, center scale. The smallest calibration mark represents just 20 milliohms on the lowest range. With such sensitivity the resistance of the ohmmeter leads could contribute considerable error. To meet this problem a more refined circuit is used in hp 412A. *(See Figure 3.)* The four-wire probe allows the resistance of the current-carrying leads to be calibrated as a part of R_i. The resistance in the voltmeter leads becomes insignificant when compared to the input impedance of the metering circuit.

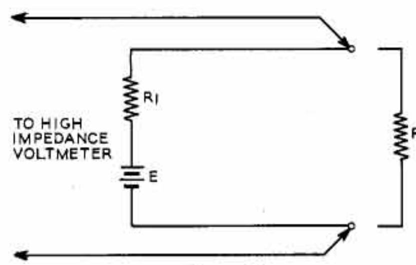


Figure 3

On the very high resistance ranges of the 412A, the input impedance of the voltmeter becomes a significant factor. On the 100 megohm scale, for example, R_i is actually chosen as 200 megohms. The parallel 200 megohm input impedance of the meter gives an effective internal impedance of 100 megohms.

To measure extremely low resistances such as would be found in short lengths of large wire or relay contacts, a constant current source and sensitive dc voltmeter may be employed. The hp 722AR 2-ampere power supply and 425A sensitive voltmeter, for example, could be used for resistance measurements as low as 1 micro-ohm.

The use of a constant current source makes the voltage reading directly proportional to the resistance value ($R = E/I$). By taking the voltage readings with the hp 405 series digital voltmeters, highly accurate resistance information is obtained in digital form. With the proper selection of current, the instrument can be made direct-reading.

Extremely high resistances can be measured by applying a high voltage and measuring the current flow on a sensitive instrument such as hp 412A or 425A. Using a 500 volt supply (hp 711A) and the most sensitive current range of the 425A, resistances as high as 5×10^{14} ohms can be measured.

Current Measurement

Classical current measurements are made by passing the current flow through a precisely calibrated resistor and measuring the IR drop. hp calibrated shunt resistors, Models 470A through 470F, are designed to shunt the input of the 400 series voltmeters, making the instruments direct-reading in current units. hp 412A and 425A are internally equipped with calibrated shunt resistors, reading dc currents directly. Together they cover the range from 10^{-12} amperes to 1 ampere, full scale.

Current measurements of this type have the obvious disadvantage of interrupting the circuit under test. While in-convenient, the IR drop method still achieves very accurate results in many cases. In some applications, however, insertion of a resistance in the line of current flow may alter the current being measured. With the increased importance of current measurements in transistor work an obvious need developed for more versatile current measuring instruments.

The ⓗ 456A Current Probe meets this need in ac measurements. This inexpensive instrument is, in effect, a transformer which *clips around* the current-carrying wire, making the wire a one-turn primary. A transistor amplifier follows the transformer and produces an output voltage proportional to the current flowing in the original wire. When connected to an ac voltmeter or an oscilloscope, the ⓗ 456A acts as a one-ohm current-to-voltage converter. Voltage scales can then be read directly in current units.

The probe transformer design provides an unusually wide passband of 20 MC. The problem of impedance inserted into the measured circuit is minimized with the 456A. The reflected impedance of the secondary is reduced by the square of the turns ratio of the transformer. The ⓗ 456A specifies an impedance insertion of less than 0.05 ohms in series with 0.05 μh.

A similar ac clip-on current probe has been designed specifically for use with the ⓗ 150A Oscilloscope. *(See pages 22 and 23.)*

Extending clip-on convenience to dc current measurements represented a somewhat more challenging problem for ⓗ design engineers. By employing the second harmonic flux gate principle, however, the ⓗ 428A and 428B have been made to respond to the magnetic field surrounding a wire carrying direct current. The advantages shown for the ⓗ 456A also occur in these dc clip-on instruments. The reflected impedance is extremely low, making possible even the direct measurement of circulating dc ground currents.

Model 428B has an output monitoring terminal which may be used for oscilloscope observations, taking advantage of a bandwidth of dc to 300 cps. This makes possible the measurement of power line frequency ground loops.

Model 428A measures dc current from 3 ma full scale to 1 ampere; Model 428B covers a range extending from 1 ma full scale to 10 amperes. Many interesting applications for these instruments arise from the possibility of adding or subtracting currents by enclosing several wires within the jaws of the probe.

Table 2. ⓗ voltage, current and resistance measuring instruments.

Instrument	AC Voltage (full scale)	DC Voltage (full scale)	Resistance (center scale)	Current (full scale)	Frequency Range	Max. Accuracy	Special Features
400D	1 mv - 300 v	—	—	—	10 cps - 4 MC	2% F.S.	High sensitivity, wide range
400H	1 mv - 300 v	—	—	—	10 cps - 4 MC	1% F.S.	High readability, high accuracy, wide range
400L	1 mv - 300 v	—	—	—	10 cps - 4 MC	1% F.S. 2% of reading	Logarithmic voltage scale, linear db scale
403A	1 mv - 300 v	—	—	—	1 cps - 1 MC	3% F.S.	Portable, battery operated, low frequency
405BR/CR	—	1 v - 1,000 v	—	—	—	0.2% of reading ± 1 digit	Digital VM, automatic range and polarity
410B	1 v - 300 v	1 v - 1,000 v	10 ohms to 10 Megohms	—	20 cps - 700 MC	3% F.S.	Multipurpose test equipment
411A	10 mv - 10 v	—	—	—	500 KC - 1 GC	3% F.S.	Linear scales temperature stabilized
412A	—	1 mv - 1,000 v	1 ohm to 100 Megohms	1 μa to 1 amp	—	1% F.S.	High accuracy general purpose dc
413A	—	1 mv - 1,000 v (End Scale)	—	—	—	2% (End Scale)	High accuracy DC null meter
425A	—	10 μv - 1 v (End Scale)	—	10 $\mu\mu$amp - 3 ma (End Scale)	—	3% (End Scale)	High sensitivity center scale zero
428A	—	—	—	3 ma - 1 amp	—	3% F.S.	Clip-on dc current measurement
428B	—	—	—	1 ma - 10 amp	—	3% F.S.	Clip-on dc current measurement
456A	—	—	—	1 ma - 1 amp	25 cps - 20 MC	2%	Clip-on ac current measurement. Use with VTVM or scope
457A	1 v - 300 v	—	—	—	50 cps - 500 KC	0.3% of reading, ± 0.002 volts	AC converter for use with digital dc voltmeters

hp 403A TRANSISTORIZED AC VOLTMETER

Compact, Battery-Operated, 1 cps to 1 MC, Portable

Weighing less than 5 pounds and compact enough to hold in your hand, this hp transistorized ac voltmeter measures from 100 microvolts to 300 volts over frequencies from 1 cps to 1 MC. (Maximum full scale sensitivity is 1 millivolt.)

The instrument's frequency coverage means it is useful in measuring sub-audio voltages in medical and geophysical instruments, servomechanisms, amplifiers and other instruments in the broadcast region.

The battery powered Model 403A is completely free of internal hum and provides accurate measurements at power line frequencies or harmonics without beat effects. Similarly, the meter is ideal for ungrounded measurements or those where ground loops create problems. Further, turnover and waveform effects are minimized because the meter responds to the average value of the input signal.

Battery life of Model 403A is 400 hours, more than 6 months normal use. Battery charge may be checked instantly by a front panel switch.

Data subject to change without notice.

Specifications

Range: 0.001 to 300 volts rms full scale (12 ranges) in a 1, 3, 10 sequence.

Frequency Range: 1 cps to 1 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.

Nominal Input Impedance:
2 megohms shunted by approx. 40 pf, 0.001 volt to 0.1 volt ranges. 20 pf shunt on 0.3 to 10 volt ranges, 15 pf shunt on 30 to 300 volt ranges.

Overload Capacity: 600 volts peak on 0.3 volt and higher ranges. 25 volts rms on 0.1 volt and lower ranges (fuse protection for greater than 25 volts).

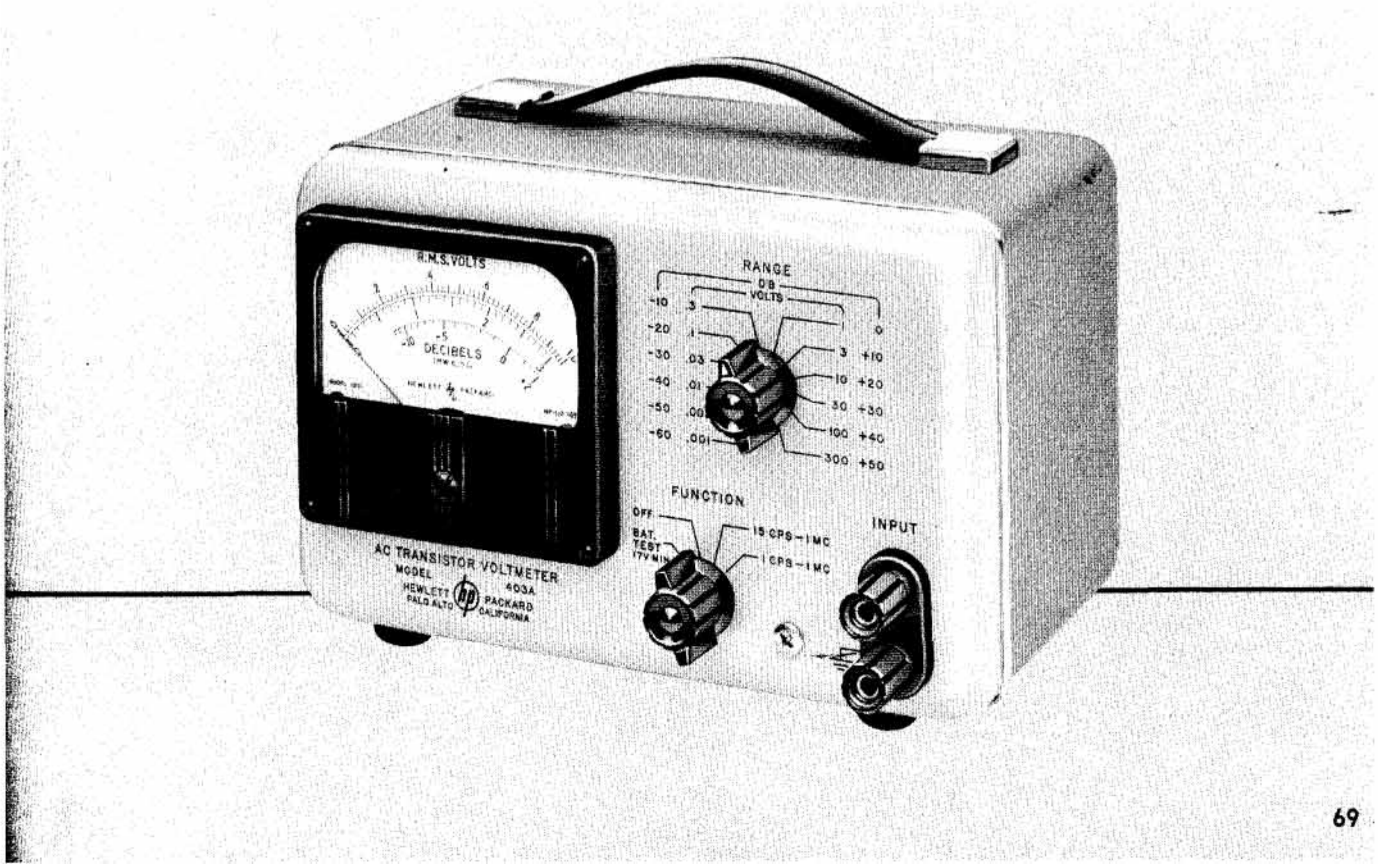
Power Supply: 5 standard radio type mercury cells (furnished with instrument). Battery life: Approximately 400 hours.

Noise: Less than 6% of full scale when terminated in 100,000 ohms or less on 0.001 volt range. Less than 3% of full scale on all other ranges.

Dimensions: 8¼" wide, 5½" high, 6⅜" deep.

Weight: Net 4¾ lbs. Shipping 9 lbs.

Price: hp 403A, $275.00.



ⓗⓟ 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
- Two models individually calibrated to eliminate tracking error
- 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

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.

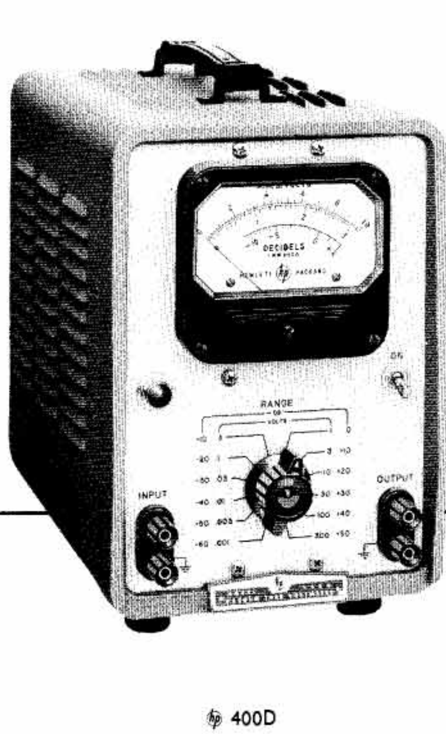
Model 400D is essentially a low-priced precision voltmeter offering wide voltage range, 2% accuracy and the broad frequency coverage 10 cps to 4 MC.

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.

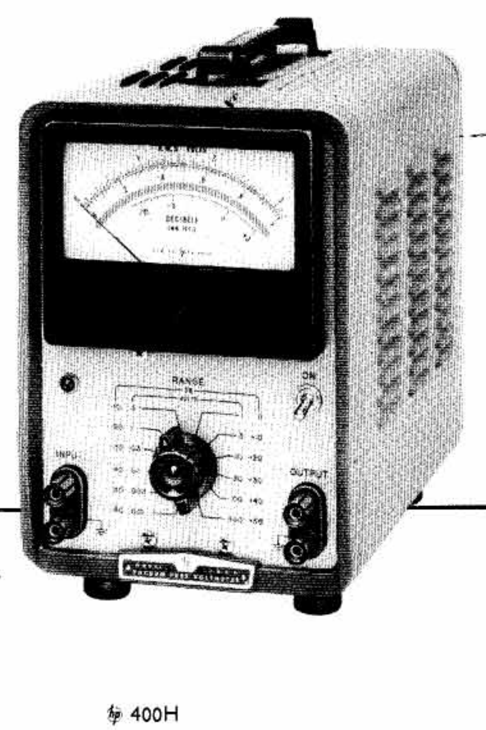
Model 400L is a logarithmic version of Model 400D, again offering individual meter face calibration and very high accuracy, ±2% *constant percentage of reading*. The 5″ mirror-scale meter is included.

Individual Calibration

As indicated above, Models 400H and 400L are individually 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 two precision ⓗⓟ



ⓗⓟ 400D



ⓗⓟ 400H

instruments. The result is maximum accuracy for the indicating meter itself, and maximum accuracy for the instrument itself—the combination of the meter and its driving circuitry. The meter on each ⓗⓟ 400H and 400L is precisely and individually calibrated to the circuitry of that specific instrument.

General Description

Models 400D, H, and L are deliberately engineered to give you the best possible combination of measuring accuracy, frequency and voltage range, and the trouble-free service life you expect from ⓗⓟ; in short, perhaps the best multipurpose voltmeters available.

An important feature of each is the ⓗⓟ-developed amplifier providing approximately 56 db of feedback at mid-range. This assures highest stability and freedom from calibration change due to external conditions.

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 MC.

And even line voltage variations as high as $\pm$ 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.

1% Accuracy Model 400H

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 below.

Logarithmic Model 400L

Designed specifically for acoustical and communications engineers, and men working with decibel measurements, Model 400L incorporates a special logarithmic meter movement. The log voltage scale plus unusually long scale length provide an instrument of maximum readability and accuracy which is a *constant percentage ($\pm$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, together with the 12 db scale, provides the wide overlap desirable in decibel level measurements.

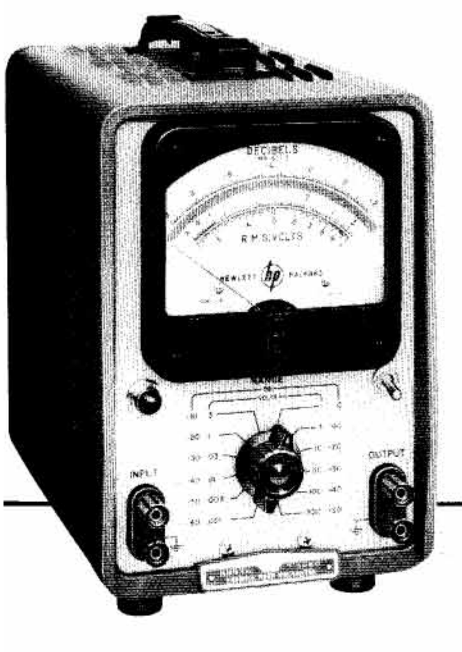
Special db-Measuring 400D and 400H

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-db and 400H-db ($12.50 extra) with the db meter scale uppermost.

Accessories

See page 192 for line matching and bridging transformers. Capacitive voltage dividers and other useful accessories for ⓗⓟ vacuum tube voltmeters are listed on page 84. A voltmeter calibration system is described on page 83.

Data subject to change without notice.



ⓗⓟ 400L

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:	$\pm$ 2% full scale, 20 cps to 1 MC; $\pm$3%, 20 cps to 2 MC; $\pm$ 5%, 10 cps to 4 MC	$\pm$ 1%, 50 cps to 500 KC; $\pm$ 2%, 20 cps to 1 MC; $\pm$ 3%, 20 cps to 2 MC; $\pm$ 5%, 10 cps to 4 MC	$\pm$ 2% of reading or $\pm$ 1% of full scale whichever is more accurate, 50 cps to 500 KC. $\pm$ 3% of reading or $\pm$ 2% of full scale, 20 cps to 1 MC; $\pm$ 4% of reading or $\pm$ 3% of full scale, 20 cps to 2 MC; $\pm$ 5% of reading, 10 cps to 4 MC
Long Term Stability:	Reduction in Gm 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.		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:	115/230 volts $\pm$ 10%, 50/1000 cps, approx. 80 watts		
Dimensions:	Cabinet Mount: 7½″ wide, 11½″ high, 12″ deep. Rack Mount: 19″ wide, 7″ high, 10⅞″ deep behind panel.		
Weight:	Net 18 lbs. Shipping 23 lbs. (cabinet mount). Net 21 lbs. Shipping 33 lbs. (rack mount)		
Price:	-*hp*- 400D $250.00* -*hp*- 400DR $255.00**	-*hp*- 400H $325.00* -*hp*- 400HR $330.00**	-*hp*- 400L $325.00* -*hp*- 400LR $330.00**

* Cabinet ** Rack Mount

(hp) 405BR/CR AUTOMATIC DC DIGITAL VOLTMETERS

Touch and Read Convenience, Automatic Range and Polarity Selection

Specifications

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 seconds to 2 seconds, depending on range change required.

Input Impedance: 11 megohms to dc on all ranges.

Sample Rate: Internal: Maximum, between 4 and 5 per second. Minimum, one every 5 seconds.
External (405CR only): Controlled by 20 volt positive pulse, maximum rate five per second.

Response Time: Less than 1 second 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 (hp) Model 561B Digital Recorder or K05-405A remote indicator.

(2) Single-line voltage coded decimal (staircase), for operating (hp) Model 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: 115/230 volts ± 10%, 50/60 cps, 180 watts.

Dimensions: 7" high, 19" wide, 13⅞" deep behind panel.

Weight: Net 26 lbs. Shipping 38 lbs.

Accessories Available: (hp) 457A AC-to-DC Converter, see next page.

Price: (hp) 405BR, $850.00. (hp) 405CR, $925.00. (Both rack mount.)

Data subject to change without notice.

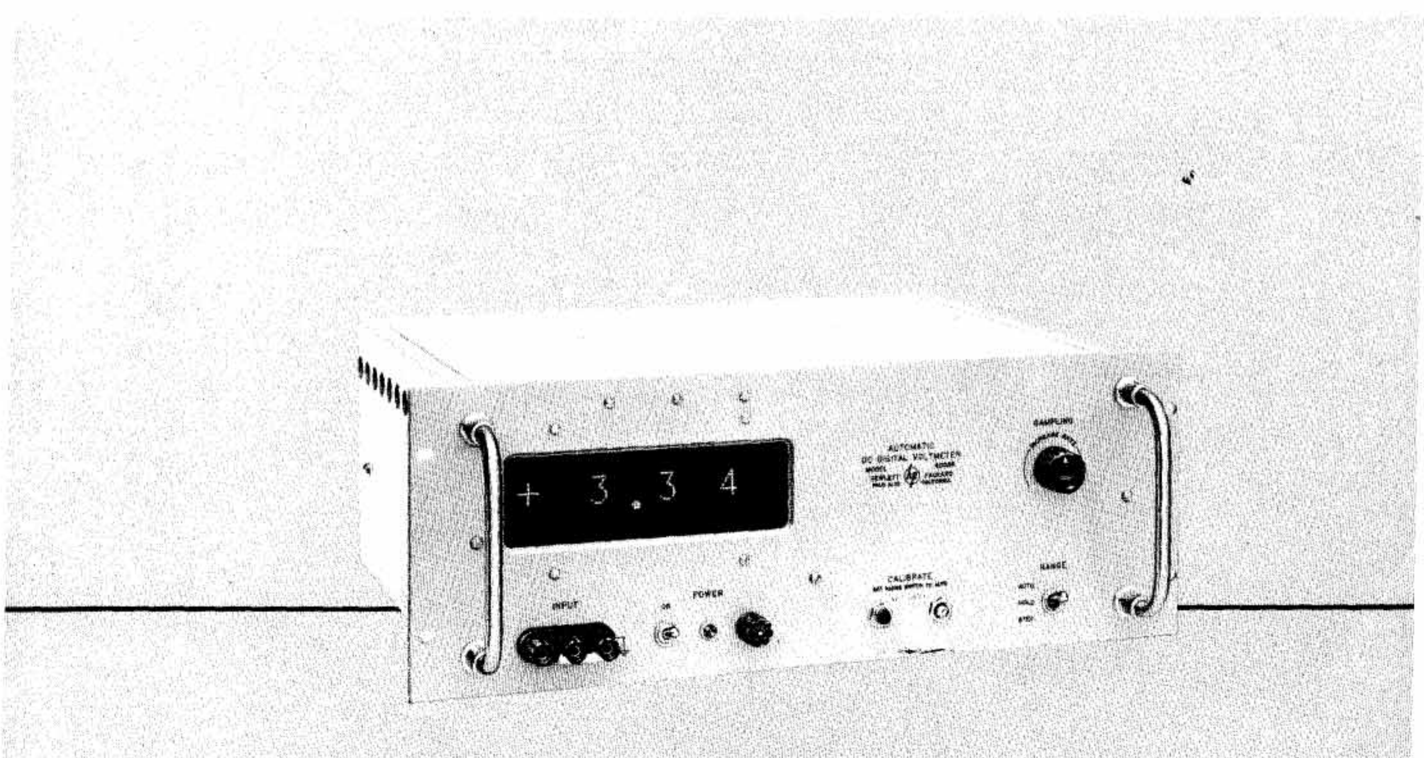
Remarkable simplicity of use is an outstanding feature of the (hp) 405BR/CR Digital Voltmeters. Just touch the probe to the voltage to be measured, and the 405BR/CR automatically zero-sets itself, chooses the proper voltage range and polarity, and displays the result in bright, clear numerals, complete even to the polarity sign and decimal point. Operator errors are reduced to the vanishing point!

For repeated readings in the same voltage range, the automatic feature can be disabled and the decimal can be positioned manually.

Three digit resolution on all voltages between 1 and 1,000 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 (hp) 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/561B Digital Recorders.

Versatility, operating simplicity and reasonable price make (hp) 405BR/CR Automatic DC Digital Voltmeters solid investments for the laboratory, production line, or systems console.



(hp) 405BR

High Accuracy AC Measurements to 500 KC With Digital Voltmeter

With a dc digital voltmeter ㊌ 457A is the ideal converter for many digital systems requiring that ac voltages be presented in digital form for entry into card punches or automatic testing systems. It can also be used with ㊌ 405CR Digital Voltmeter and an ㊌ 560 series Digital Recorder to provide a permanent record in printed digital form.

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 Model 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 cps to 500 KC. From 50 cps to 50 KC accuracy is 0.5% ± 2 counts.

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.

Ranging is accomplished by input attenuation so that the output dc voltage is always between 0 and 1 volt dc. Attenuation ratios are 1:1, 10:1, 100:1, and 1,000:1 with highest rated input of 300 volts rms.

A new modular cabinet design provides easy access to the instrument chassis. The modular design facilitates stacking of instruments on the test bench. Or, if rack mounting is desired, two end brackets supplied with the instrument may be attached quickly.

Specifications

Input Range: 0 to 300 volts rms, in 4 decade ranges corresponding to 1, 10, 100, and 1,000 v rms full scale.

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.

Output: 0 to 1.0 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 1,000.

Output Impedance: 10,000 ohms.

Input Impedance: 1 megohm, shunted by 30 pf.

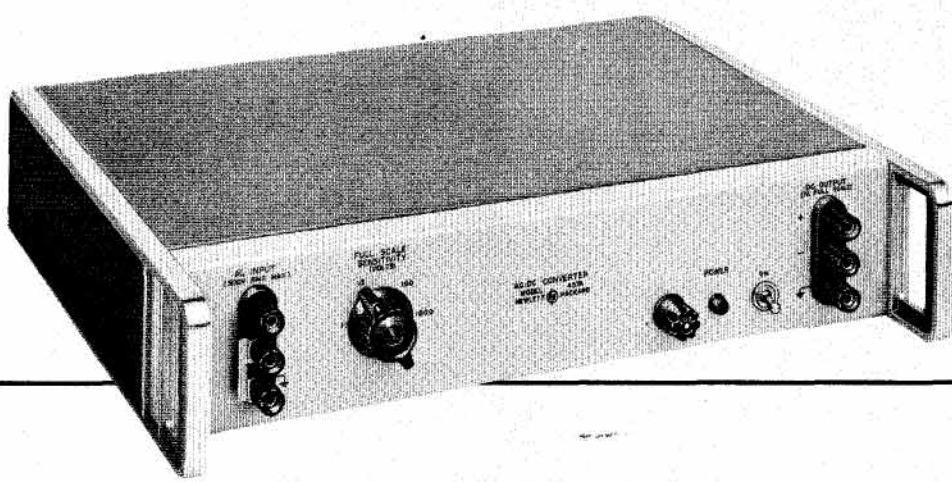
Power: 115/230 volts ± 10%, 50/1,000 cps, approximately 31 watts.

Dimensions. 16¾" wide, 3⅜" high, 13¼" deep.

Weight: Net: 12 lbs. Shipping 20 lbs.

Price: ㊌ 457A, price on request.

Data subject to change without notice.



411A RF MILLIVOLTMETER

"Touch and Read" Measurement, 3 mv to 10 v, 500 KC to 1,000 MC!

Advantages:

- More measurements with a single instrument
- Reads rf voltage, 500 KC to 1,000 MC
- Measures millivolts at 1 GC (KMC)
- Full scale ranges 10 mv to 10 v
- Versatile probe tips for wide application
- High resolution on linear scale
- Reads in volts, decibels
- Eliminates annoying thermal drift
- Probe diodes protected against burnout

Uses:

- Laboratory, broadcast, production test department
- Measurements on coaxial lines
- Measurements in terminated coaxial circuits
- Accurate low-level measurements in IF strips
- Low-level measurements at vhf frequencies

Millivolt sensitivity from 0.5 to 1,000 MC, linear voltage scales and low thermal drift make the ⓗⓟ 411A RF Millivoltmeter unique among instruments of its kind.

Although Model 411A measures voltages in the region where detector characteristics are square-law, the meter scales are linear without resorting to complex, difficult to adjust, compensating networks. Two voltage scales in a 1:3 ratio are provided so that you may make most measurements in the more accurate upper two-thirds of the scales. The 1:3 ratio between voltage scales also permits a high-resolution db scale with 10 db between ranges.

Temperature compensation in Model 411A is so effective that rated performance is obtained in an ambient temperature range of 10 to 40°C, even when measuring signals as low as 3 mv.

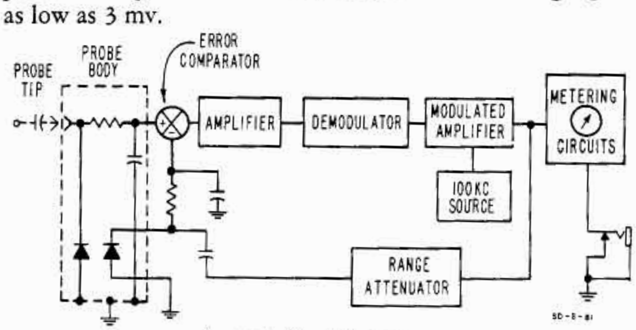
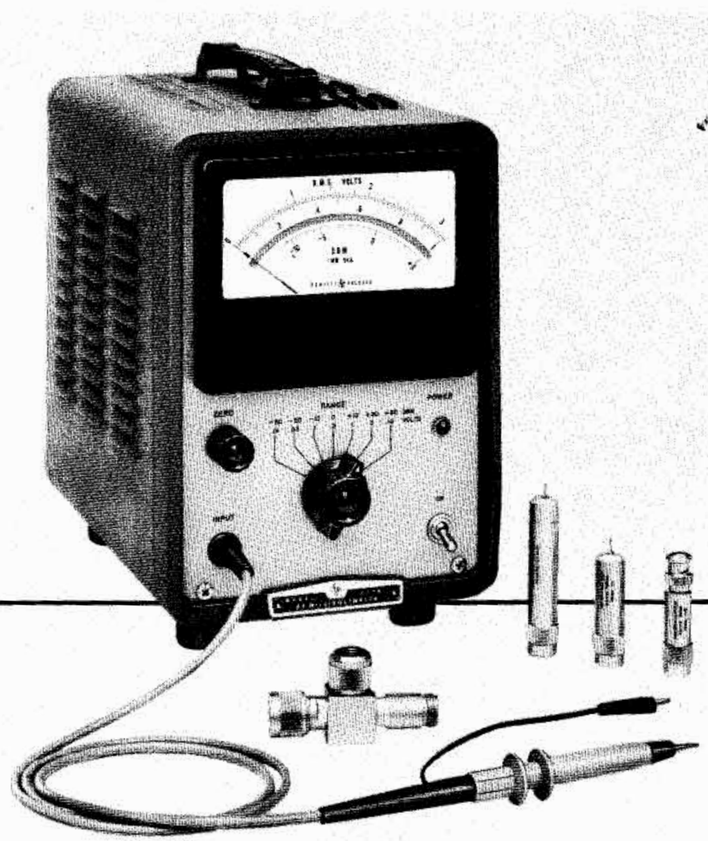


Figure 1. ⓗⓟ 411A Simplified Block Diagram.



Circuit Description

Utilizing a new approach, hp 411A generates, by use of feedback, a low frequency sine wave whose amplitude is equivalent to that of the rf signal input. This low frequency signal is metered, indicating the magnitude of the input rf signal.

The general operation can be seen from the block diagram shown in Figure 1. The input rf is detected by a semiconductor diode, and the resulting dc signal is fed into an error detector. Any difference between it and the feedback reference is amplified and used to control the output of a modulator operating on a 100 KC carrier.

The magnitude of the 100 KC output is proportional to the magnitude of the error signal. The modulator output is fed back through the range attenuator to a second diode whose detection characteristics are closely matched to those of the rf detector. The resulting dc is used as the reference for the error detector. As long as the loop gain is high, the error will tend toward zero.

Since the two detected dc voltages are approximately equal and the detection characteristics of the diode detectors are the same, the effective amplitude of the low frequency feedback signal must be equal to that of the input rf. Thus, a measure of the amplitude of the feedback 100 KC is equivalent to a measure of the input rf regardless of any non-linearity in the detector characteristics.

Temperature compensation in Model 411A is accomplished by placing the two detector diodes in close thermal proximity in the rf probe. Even though their detection characteristics change with temperature, they change in the same manner. In this way the two diodes maintain their match over a wide temperature range.

Photoelectric Chopper

Other features offered in the 411A include an hp developed photoelectric chopper to eliminate contact noise, guarantee high sensitivity, and provide freedom from zero-drift; an output for galvanometer recording; accessory probe tips for use in a wide variety of circuits (for measuring *on* as well as *at the termination of* coax transmission lines), and a capacity divider increasing 411A voltage capability to 1,000 v. A coupling capacitor in the probe protects diodes from high-current transients when the probe is connected to potentials up to 300 v dc.

When measuring terminal voltages on coaxial lines it is often desirable to terminate the line with a low reflection load such as the hp Model 908A Coaxial Termination *(see page 189)*.

In this application the hp 411A-21D Type N Tee Probe Tip is used with the 908A. Model 908A terminates the line and the "T" makes a convenient connection for the voltmeter.

hp 411A-21G Accessory Probe Kit. Contains probe tips to meet all measurement requirements normally encountered. See specifications for details.

Specifications

Voltage Range: 10 mv rms full scale to 10 v rms full scale in seven 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(KMC) with accessory probe tips. Usable indications to 4 GC.

Accuracy: 1 MC to 50 MC, ± 3% of full scale; 50 MC to 150 MC, ± 6% of full scale; 500 KC to 1 GC, 1 db.

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 *(see Figure 2)*; typically 200 K ohms at 1 MC and 1 volt.

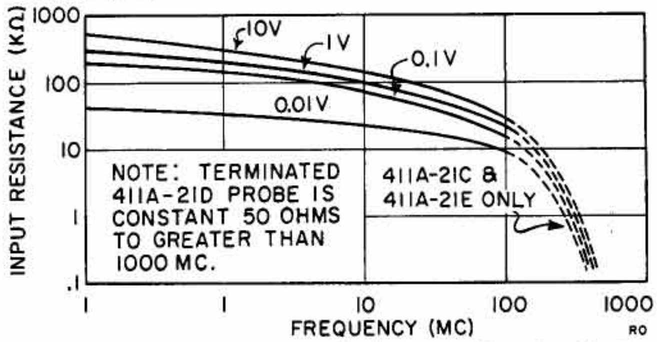


Figure 2. Typical input resistance for hp 411A-21B, 21C, 21E. For 21F, multiply 21E x 100.

Probe Tip Furnished: *411A-21E* BNC Open Circuit Probe Tip, 500 KC to 500 MC. Maximum input: 300 v dc.

Accessories available at additional cost:

Probe Tips: *411A-21B* Pen Type Probe Tip, 500 KC to 50 MC. Shunt capacity: less than 4 pf. Maximum input: 300 v dc. Price, $25.00. *411A-21C* VHF Probe Tip, 500 KC to 250 MC. Shunt capacity: less than 2 pf. Maximum input: 300 v dc. Price, $20.00.

411A-21D Type N "Tee" Probe Tip, 500 KC to 1 GC. SWR is less than 1.15 when terminated in 50 ohms. Maximum input: 10 v dc. Price, $40.00.

411A-21F 100:1 Capacity Divider Probe Tip, 500 KC to 250 MC. Division accuracy: ± 1%; Shunt capacity: 2 pf. Maximum input: 1,000 v pk (dc + pk ac). Price, $35.00.

Probe Kit: *411A-21G* Accessory Probe Kit. This kit includes the 411A-21B, 411A-21C, 411A-21D, 411A-21F Probe Tips and a replacement diode cartridge, 411A-21-5, in a convenient storage case. Price, $152.50.

50-ohm Termination: hp Model 908A Coaxial Termination. *(See page 189.)*

Galvanometer Recorder Output: Proportional to meter deflection, 1 ma into 1,000 ohms at full scale deflection.

Power: 115/230 v ± 10%, 50 to 60 cps, 35 watts.

Dimensions: Cabinet Mount: 11¾" high, 7½" wide, 12" deep. Rack Mount: 6 - 31/32" high, 19" wide, 10⅜" deep behind panel.

Weight: Net 12 lbs. (cabinet); 15 lbs. (rack). Shipping, 18 lbs. (cabinet); 28 lbs (rack).

Price: hp 411A, $450.00 (cabinet); hp 411AR, $455.00 (rack mount).

Data subject to change without notice.

410B VACUUM TUBE VOLTMETER

All-Purpose Test Instrument Measures to 700 MC

Specifications

AC Voltmeter:

Range: 1 to 300 v full scale.

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 3,000 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 1,000 v full scale.

Input Resistance: More than 100 megohms, all ranges.

Ohmmeter:

Range: 0.2 ohm to 500 megohms in 7 ranges. Midscale readings of 10, 100, 1,000, 10,000, 100,000 ohms, 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: 115/230 v ±10%, 50/1,000 cps, 40 watts.

Dimensions: Cabinet Mount: 7½″ wide, 11½″ high, 8¼″ deep. Rack Mount: 19″ wide, 7″ high, 6″ deep behind panel.

Weight: Net 12 lbs. Shipping 17 lbs. (cabinet mount). Net 12 lbs. Shipping 26 lbs. (rack mount).

Price: ⓗⓟ 410B, $245.00 (cabinet); ⓗⓟ 410BR, $265.00 (rack mount).

Audio, ultrasonic, rf and vhf voltages, antenna voltage, dc voltage in high impedance circuits—these are some of the measuring jobs the universally-known ⓗⓟ 410B can perform swiftly and dependably. This one compact instrument combines an ac voltmeter covering 20 cps to 700 MC, a dc voltmeter with more than 100 megohms input resistance, and an ohmmeter measuring from 0.2 ohms to 500 megohms.

An important reason for the 410B's perennial 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.

Data subject to change without notice.

Read Directly 1 μμa and 1 μv with Compact, Portable Instrument

Hewlett-Packard 425A DC Microvolt-Ammeter makes measurements of extremely small dc voltages and currents without requiring expensive arrays of complex equipment, even in the presence of relatively strong ac signals.

No Mechanical Vibrator

Two important circuit aspects include very heavy ac filtering and the substitution of a photoelectric chopper developed by hp to replace the conventional error-inducing mechanical vibrator. Every known assurance of safety, accuracy and dependability has been incorporated; momentary overloads of 1,000 volts cause no damage; the pickup probe minimizes thermocouple and triboelectric effects.

To assure that unwanted ac on the dc input does not disturb the meter indication, frequency response is down about 3 db at 0.2 cps, down 50 db at 30 cps, and down approximately 60 db at 60 cps.

Drift-Free Amplifier

The amplifier provides a 1 volt output for end scale deflection or a 1 ma output into 1,000 ohms to drive a potentiometer or galvanometer recorder. For driving sensitive potentiometer recorders, the 425A includes a built-in potentiometer for reducing output voltage.

Model 425A has an inherent input impedance much higher than specified and a 1 megohm resistor directly across the input insures a constant input impedance. If an unusually high input impedance is required, the input resistor can be removed to provide greater than 200 megohms input impedance.

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 μμa end scale to 3 ma end scale, 18 steps, 1–3–10 sequence.
Input Impedance: Voltage Ranges: 1 megohm ± 3%. Current Ranges: 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%.

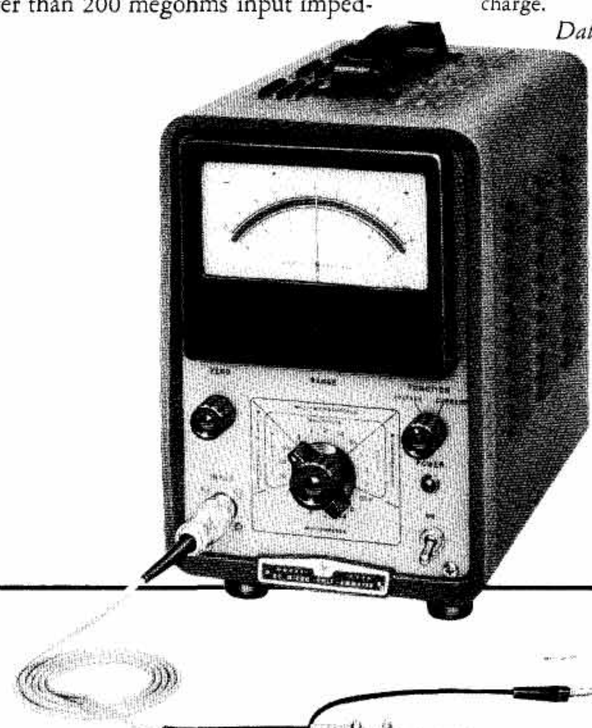
Amplifier

Gain: 100,000 maximum.
AC Rejection: At least 3 db at 0.2 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 (5,000 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 warmup drift is less than ± 4 μv per day referred to input.

General

Power: 115/230 v ± 10%, 60 cps, 40 watts. 50 cps operation on special order.
Dimensions: Cabinet Mount: 7½" wide, 11¾" high, 12" deep. Rack Mount: 19" wide, 7" high, 11" deep behind panel.
Weight: Net 17 lbs. Shipping 23 lbs. (cabinet mount). Net 21 lbs. Shipping 33 lbs. (rack mount).
Accessories Available: hp 425A-21B, 1,000:1 Divider Probe, increases range of 425A to 1,000 volts. Division accuracy ± 2%, input resistance 10 megohms. $55.00.
Price: hp 425A, $500.00 (cabinet); hp 425AR, $505.00 (rack mount).
For 50 cps power lines prefix Model No. with H02; no additional charge.

Data subject to change without notice.



ⓗ 412A PRECISION DC VOLTMETER-OHMMETER-AMMETER

1% Accuracy VTVM is Also Precision Ohmmeter, Ammeter

Specifications

Voltmeter:
Voltage Range: Pos. and neg. voltages from 1 mv to 1,000 v full scale. 13 ranges.
Accuracy: ±1% of full scale on any range.
Input Resistance: 10 megohms ±1% on 1 mv, and 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 1,000 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 5,000 megohms.

Amplifier:
Voltage Gain: 1,000 maximum.
AC Rejection: 3 db at 1 cps, approx. 80 db at 50 and 60 cps.
Output: Proportional to meter indication; 1 v at full scale; maximum current, 1 ma. (Full scale corresponds to 1.0 on upper scale.)
Output Impedance: Less than 2 ohms at dc.
Noise: Less than 0.1% of full scale on any range.
Drift: Negligible.

Power: 115/230 v ±10%, 50/60 cps, 35 watts.
Dimensions: Cabinet Mount: 11½" high, 7½" wide, 10" deep.
Rack Mount: 5¼" high, 19" wide, 7½" deep behind panel.
Weight: Net 12 lbs. Shipping 17 lbs. (cabinet mount). Net 14 lbs. Shipping 22 lbs. (rack mount).
Price: ⓗ 412A, $400.00 (cabinet); ⓗ 412AR, $405.00 (rack mount).

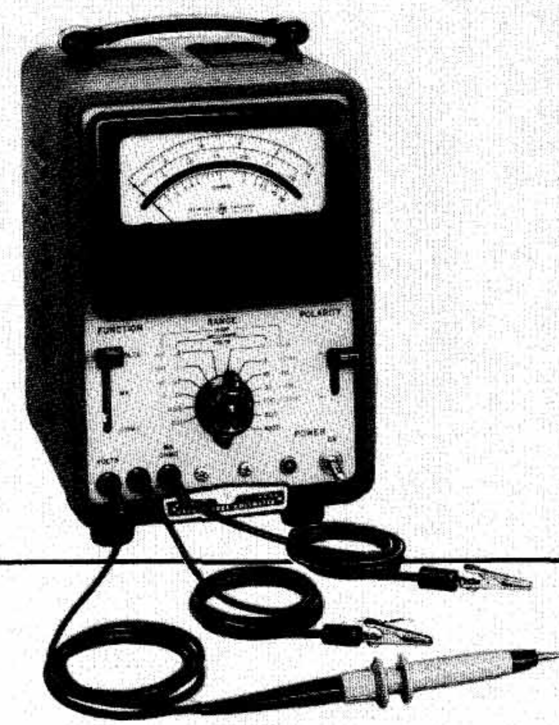
Here is one compact instrument that makes all normally used dc measurements with precision and simplicity.

The ⓗ 412A provides 1% voltage and 2% current measurement accuracy. The unusually wide ohmmeter range covers from 1 ohm center scale to 100 megohms center scale so that resistance measurements can be made on wire sections as short as 6 inches or across insulators as high as 5,000 megohms.

The sensitivity and precision of the 412A are due in part to fresh circuitry concepts. For example, an exclusive ⓗ developed photoconductor chopper virtually eliminates dc drift and offset. No zero set control is needed. The 412A is thus an ideal dc preamplifier for a recorder or other applications. Output terminals are provided.

The 412A insures accurate readings regardless of test conditions. Input is floating and input resistance is high, thereby avoiding errors due to loading circuits or insertion of ground connections. A very high degree of ac rejection insures that readings are accurate even in the presence of ac signals.

Data subject to change without notice.



ⓗ 413A DC NULL VOLTMETER

Floating, High Impedance Input; 1 mv End Scale Sensitivity

Model 413A uses the sensitive and precise circuitry of ⓗ 412A *(opposite page)* to provide a dc null voltmeter of outstanding stability and resolution. Model 413A has 13 zero-centered ranges, running from 1 mv to 1,000 volts end scale. The input terminals are isolated from ground, allowing operation up to 500 volts dc or 130 volts ac from ground potential.

High input impedance, (10 megohms on the most sensitive range, 200 megohms on 300 mv range and above) makes the Model 413A especially valuable in resistance bridge measurements. Accuracy of this instrument is within 2% of end scale; drift and noise are virtually imperceptible.

Because the dc null voltmeter provides an output proportional to meter deflection, ⓗ 413A is useful as an indicating and control device. For instance its high voltage gain (1,000 on the 1 mv range), high stability and low noise make the ⓗ 413A desirable for amplifying the output of a thermocouple in control systems. The Zero control may be used to set an arbitrary reference.

For dc voltmeter use, ⓗ 413A offers high input impedance, voltage ranges from 1 mv to 1,000 volts end scale, 2% accuracy and virtually drift-free operation.

Specifications

Voltmeter:

Ranges: Positive and negative voltages from 1 mv to 1,000 v end scale in thirteen zero-center ranges.

Accuracy: ± 2% of end scale value.

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 full scale affects reading less than 1%. Peak voltage must not exceed 1,500 v.

Limits of Zero Control: Approximately ± end scale value on any range.

Amplifier:

Voltage Gain: 0.001 to 1,000 in thirteen steps.

Gain Accuracy: ±1½%.

Gain Linearity: ± 0.2%.

Noise: Less than 0.1% (rms) of end scale on any range.

Output: 1 volt for end scale deflection, same polarity as input signal. End scale corresponds to 1.0 on upper scale. Maximum load current 1 ma.

Output Impedance: Less than 2 ohms at dc.

AC Rejection: Approximately 3 db at 1 cps, 80 db at 50 and 60 cps.

Input Terminals: Binding post.

Input Isolation: Greater than 100 megohms shunted by 0.1 μf to instrument case (power line ground).

Common Signal Rejection: May be operated up to 500 v dc, or 130 v ac above ground.

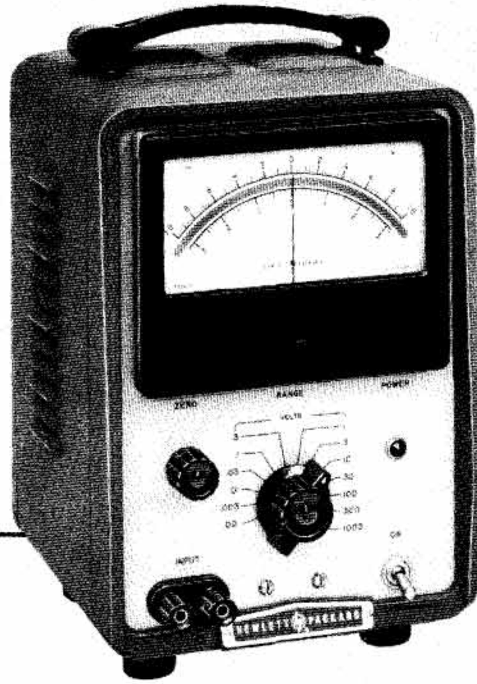
Power: 115/230 volts ± 10%, 50/60 cps, 35 watts.

Dimensions: Cabinet Mount: 11½" high, 7½" wide, 10" deep. Rack Mount: 5¼" high, 19" wide, 7½" deep behind panel.

Weight: Net 12 lbs. Shipping 17 lbs. (cabinet).

Price: ⓗ 413A, $350.00 (cabinet); ⓗ 413AR, $355.00 (rack mount).

Data subject to change without notice.



hp 428A/B CLIP-ON DC MILLIAMMETERS

Ultimate Measuring Ease, No Circuit Loading

Advantages:

No circuit interruption

No circuit loading

Measures dc in the presence of ac

A convenient dc amplifier completely isolated from circuit being measured.

Uses:

Computer testing: with quick clip-on convenience, current measurements can be made rapidly. This speed of measurement is a great advantage wherever multiple readings must be made.

Transistor circuit analysis: with virtually no loading of the circuit under test, Model 428A/B can usefully measure current even in a low impedance emitter circuit.

Combined measurements: by looping several wires through the jaws of the probe, the sum (or difference) of individual currents can be measured directly.

Low frequency ac current measurements: for external metering or recorder operation a front panel output on Model 428B provides a voltage proportional to the current being measured; bandwidth is dc to > 300 cps. Can be used as an isolated input dc current amplifier.

With the increased importance of current parameters in today's development activities, hp 428A/B Clip-on DC Milliammeters are instrumental in saving many expensive engineering manhours. Now direct current from 0.3 milliampere to 10 amperes can be measured without interruption to the circuits involved, and without the error-producing loading of conventional methods.

For any measurement of direct current within its range, simply clamp the jaws of the hp 428 probe around a wire, and read!

In any application where a large number of direct current measurements must be made, Models 428A and 428B are without equal for ease and speed of operation. Their wide current range 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.

hp 428A/B make fast, accurate measurements in circuits where the introduction of conventional current-measuring devices would alter conditions to such an extent that the desired measurement would no longer be accurate. In fact, there are some cases where conventional current-measuring methods would render the circuit inoperative. Here, too, hp 428A/B are fast and accurate.

hp 428B

Besides making current measurements directly, Models 428A/B are 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. In this way, the balancing of currents is easily accomplished by making their difference equal to zero.

Models 428A and 428B are almost identical except for current measurement range. Model 428B has three more ranges than the 428A to give it full scale readings from 1 ma to 10 amperes. Another important new feature of Model 428B is an output voltage proportional to meter deflection. This adjustable or calibrated output is available at the front panel for driving recorders or making low frequency current measurements over a dc to 300 cps bandwidth. It thus makes the instrument a convenient, completely isolated dc current amplifier.

Circuit Description

The core of the Model 428A/B probe tip is magnetically saturated by a high frequency current produced within the instrument. Without the high frequency saturation current the direct current being measured would induce a steady magnetic flux in the core. However, the magnetic saturation periodically changes the reluctance of the magnetic circuit and varies the strength of the dc-caused magnetic flux.

Varying the dc magnetic flux induces a periodic voltage in the output coil proportional to the dc being measured. This signal is amplified and demodulated, then returned to the probe as negative dc feedback. It is this feedback signal which is metered. By keeping loop gain high and including the probe as well as the signal amplifier in the feedback loop, high levels of stability and accuracy are attained.

Specifications

Current Range: ⓗ 428A: Full scale readings from 3 ma to 1 ampere in 6 ranges. ⓗ 428B: Full scale readings from 1 ma to 10 amperes in 9 ranges.

Accuracy: $\pm$ 3%, $\pm$0.1 ma.

Probe Inductance: Less than 0.5 μh will be introduced into measured circuit.

Probe Induced Voltage: Less than 15 mv peak into measured circuit.

AC Rejection: AC with peak value less than full scale affects meter accuracy less than 2% at frequencies above 5 cycles and different from the carrier (40 KC) and its harmonics. (On 428B 10 ampere range, ac is limited to 4 amperes, peak.)

Output: ⓗ 428B — Approx. 1.4 volts across 1400 ohms for full scale. Frequency response dc to 300 cps.

Probe Insulation: 300 volts, maximum.

Probe Tip Size: Approximately ½" by 9/32". Aperture diameter 3/16".

Dimensions: Cabinet Mount, 7½" wide, 11½" high, 14¼" deep. Rack Mount, 19" wide, 7" high, 13" deep behind panel.

Weight: Cabinet Mount: Net 19 lbs. Shipping 24 lbs. Rack Mount: Net 24 lbs. Shipping 35 lbs.

Price: ⓗ 428A, $500.00 (cabinet); ⓗ 428AR, $505.00 (rack mount). ⓗ 428B, $550.00 (cabinet); ⓗ 428BR, $555.00 (rack mount).

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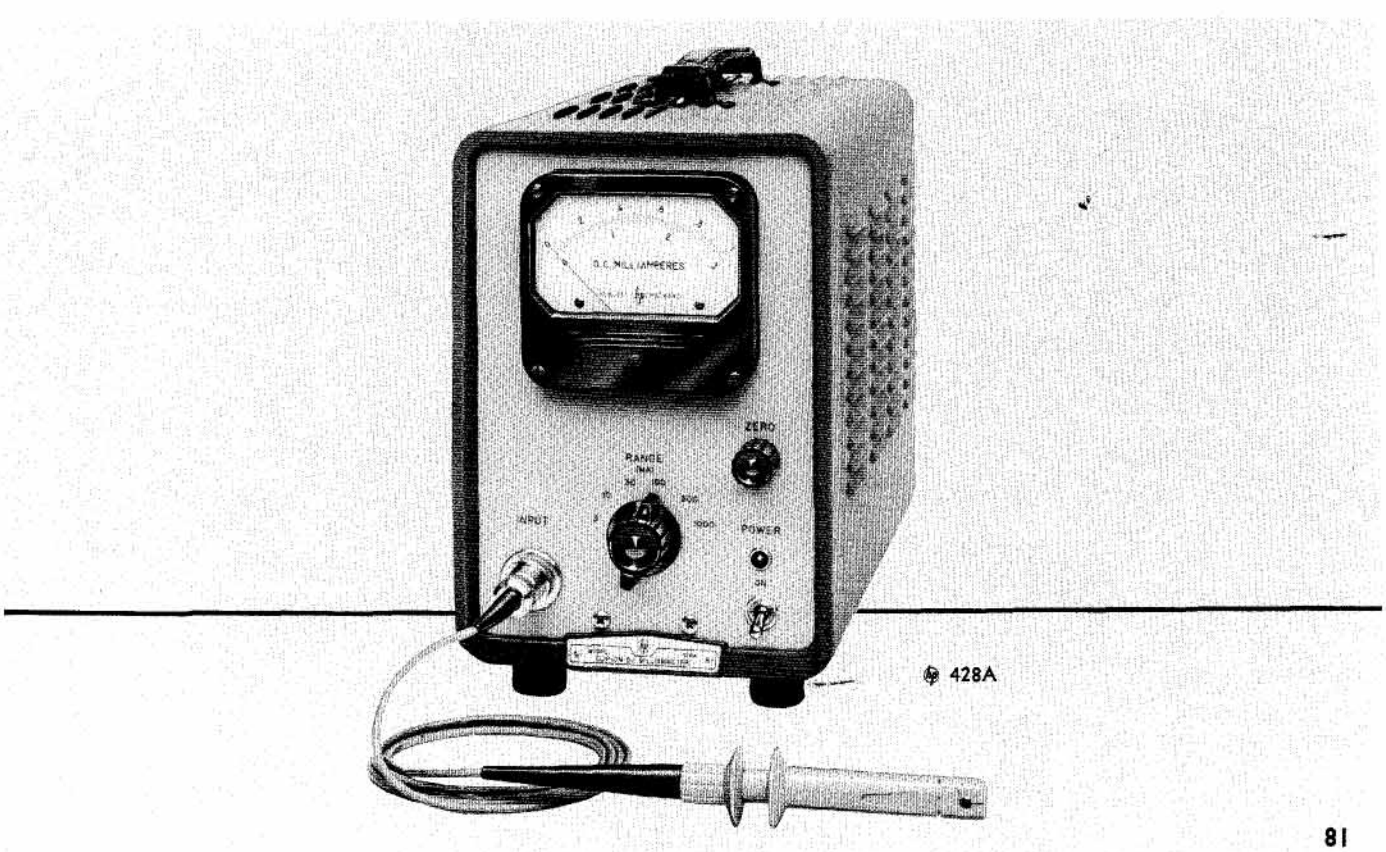

ⓗ 428A

ⓗ 456A AC CURRENT PROBE

Measures AC Current Without Direct Connection to Wire

Specifications

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 0.05μh. (This is approximately the inductance of 1½ in. of hookup wire.)

Probe Aperture: 3/16" dia.

Probe Shunt Capacity: Approximately 4 pf added from wire to ground.

Distortion at 1 KC: For ½ 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, 115/230 v ±10% 50 to 1,000 cps, approximately 1 watt.

Weight: Net 3 lbs. Shipping 4 lbs.

Dimensions: 5" wide, 6" deep, 1½" high. Probe cable is 5 ft. long; 2 ft. output cable terminated with dual banana plug.

Price: ⓗ 456A with batteries, $190.00.
ⓗ 456A with ac supply (456A-95A) installed in lieu of batteries, $210.00. ⓗ 456-95A AC Supply for field installation, $40.00.

Now 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 unique ⓗ 456A AC Current Probe clamps *around* the current-carrying wire, and provides a voltage output you read on a VTVM or scope. Model 456A's 1 ma to 1 mv unity conversion permits direct readings up to 1 ampere rms. Model 456A permits measurement of ac in logic circuits, transistors and vacuum tubes since even 0.5 ampere of dc has no appreciable effect on operation. The instrument also makes possible viewing on oscilloscopes complex current waveforms with rise times up to 20 nsec, or current signals ranging from 1 ma rms to 1 ampere rms.

The instrument can be relied upon for accurate measurements since it is virtually unaffected by stray fields or wire position in the aperture of the probe.

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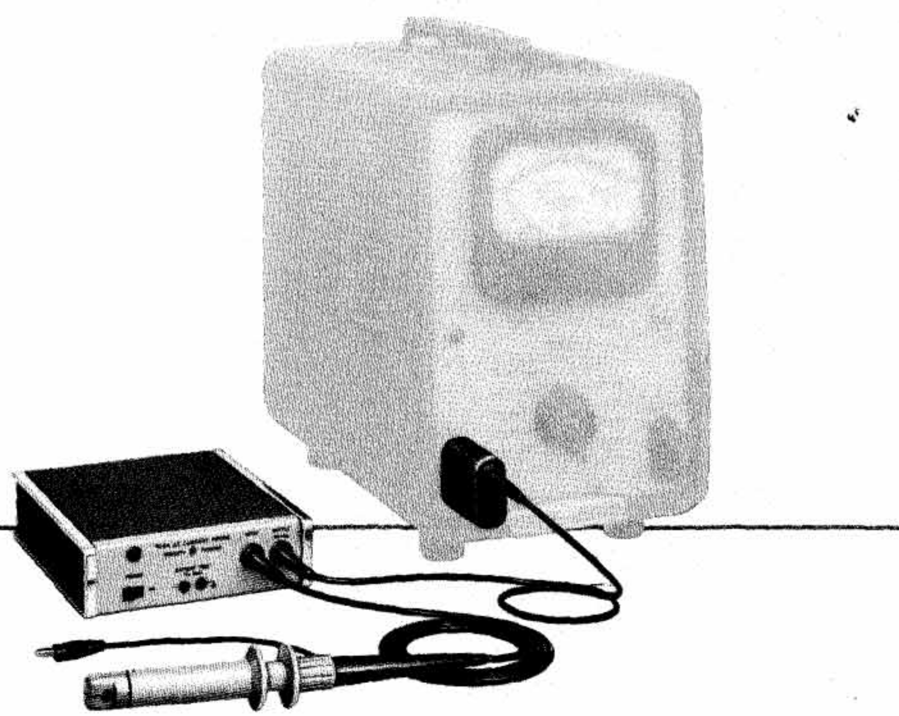


ⓗ 456A shown with ⓗ 400D

Highly accurate calibration of vacuum tube voltmeters or oscilloscopes is simple and fast with an hp VTVM Calibration System composed of Model 738AR Voltmeter Calibrator, Model 739AR Frequency Response Test Set and Model 200SR Oscillator.

hp 738AR Voltmeter Calibrator is a highly stable precision voltage source, expressly designed for calibration of high impedance electronic voltmeters and oscilloscopes. It provides accurate voltage levels from 300 microvolts to 300 volts in precise pre-selected steps. Drift of dc voltage is less than 0.1% per week and less than 0.25% per week for ac voltages.

hp 739AR Frequency Response Test Set provides a convenient constant-amplitude reference voltage of a variable frequency, is ideal for checking the frequency response of VTVM's, oscilloscopes, video amplifiers and filters. Frequency response is checked by applying a constant amplitude voltage at various frequencies and noting the response of the device under test with respect to response at a reference frequency. Internal oscillator, 300 KC to 10 MC.

hp 200SR Oscillator combines with the hp 739AR to extend the range to frequencies as low as 5 cps.

Data subject to change without notice.

Specifications

hp 738AR Voltmeter Calibrator

Voltage Range: 300 μv to 300 v, dc or ac (rms and peak-peak, 400 cps).
Levels: Calibration voltage 300 μv to 300 v in steps of 0.3, 0.5, 1, 2 and 3 volts with multipliers of 0.001, 0.01, 0.1, 1, 10 and 100. Tracking voltage 0.1 to 1 v in 0.1 volt steps and 0 to 3 v in 0.5 volt steps.
Accuracy: 300 v working voltage into attenuator, accurate within 0.1% dc and 0.25% ac, after a 30-minute warmup.
Long-term Stability: Less than 0.1% dc drift per week, less than 0.25% ac drift per week.
Attenuator Accuracy: Within ±0.1% or ±5 μv, whichever is larger.
Dimensions: 19" wide, 7" high, 15" deep.
Weight: Net 38 lbs. Shipping 75 lbs.
Price: 738AR, $875.00 (rack mount).

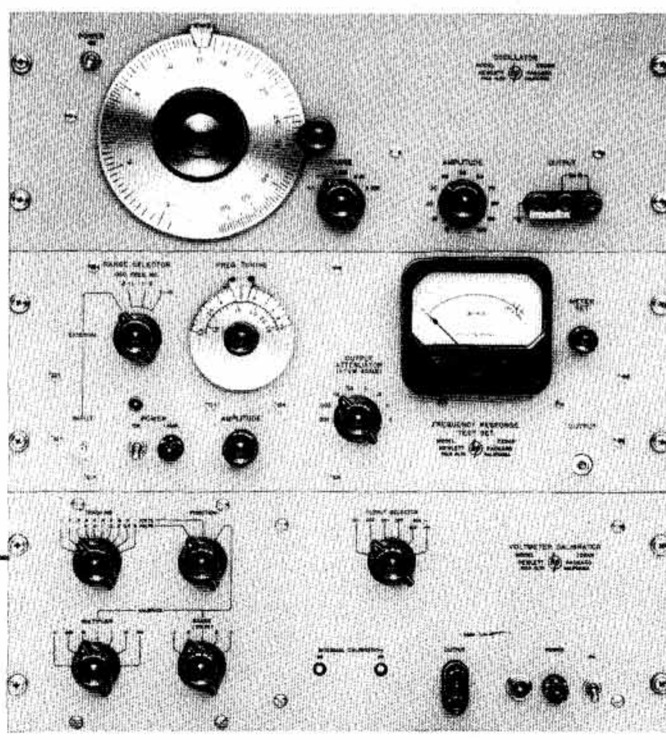
hp 739AR Frequency Response Test Set

Frequency Range: 300 KC to 10 MC in 3 ranges (5 cps to 10 MC with hp 200SR Oscillator).
Frequency Response of Monitoring Circuit: Flat within ±0.5% from 10 cps to 5 MC; within +0.5%, −1.5%, 5 cps to 10 MC. Monitoring circuit is average reading.
Dimensions: 19" wide, 7" high, 8¾" deep.
Weight: Net 20 lbs. Shipping 28 lbs.
Price: hp 739AR, $525.00 (rack mount).

hp 200SR Oscillator

Frequency Range: 5 cps to 600 KC in 5 ranges.
Output: 3 v rms into 50 ohms.
Dial Accuracy: ±2%.
Frequency Response: ±1 db, 1,000 cps reference.
Dimensions: 19" wide, 7" high, 14¼" deep.
Weight: Net 25 lbs. Shipping 35 lbs.
Price: hp 200SR, $230.00 (rack mount); hp 200S, $225.00 (cabinet).

NOTE: All three instruments are available in cabinet with single power cord and plug strip. Specify K02 738A, $1,870.00.



Top to bottom, hp 200SR, hp 739AR, hp 738AR

Extend the usefulness of your present hp voltmeters with these precision built hp accessories. Make fast, accurate measurements far beyond the original range of your instruments.

In addition to the time-saving accessories shown here, hp AC-21F Current Probe (use with your ac VTVM or scope to measure current) and hp AC-21J Low Frequency Probe are offered. For details, see page 19.

hp 452A Capacitive Voltage Divider

For hp 400 series and 410B. Safely measures power voltages to 25 kv. Accuracy ± 3%. Division ratio 1,000:1. Input capacity 15 pf ± 1. Maximum voltage ratings at 60 cps, 25 kv; 100 KC, 22 kv; 1 MC, 20 kv; 10 MC, 15 kv; 20 MC, 7 kv. Usable for dielectric heating, power and supersonic voltages. Price, $125.00.

452A-95A Adapter: (Not shown.) Connects 410B to shielded connector. $25.00.

hp 453A Capacitive Voltage Divider

For hp *410B* Voltmeter. Increases range so transmitter voltages can be measured quickly, easily. Accuracy ± 1%. Division ratio, 100:1. Input capacity approximately 2 pf. Maximum voltage 2,000 v. For frequencies 10 KC and above. $30.00.

hp 454A 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, 1,500 v. Price, $50.00.

hp 455A Probe Coaxial "T" Connector

For hp 410B Voltmeter. Measures voltages between center conductor and sheath of 50 ohm transmission line. Maximum standing wave ratio 1.1 at 500 MC, 1.2 at 1,000 MC. Male and female type "N" fittings. Price $40.00.

hp 458A Probe Coaxial "N" Connector

For hp 410B Voltmeter. Measure at open end of 50-ohm transmission line. (No terminating resistor.) Has female type "N" fitting. Price, $30.00.

hp 459A 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 12,000 megohms. Maximum voltage 30 kv. Maximum current drain 2.5 microamperes. Price, $50.00.

hp 470A-470F Shunt Resistors

For hp 400 series Voltmeters, to measure currents as small as 1 μa full scale. Accuracy ± 1% to 100 KC, ± 5% to 4 MC (470A, ± 5% to 1 MC). Maximum power dissipation 1 watt.

INSTRUMENT	MAX. CURRENT	MAX. VOLTAGE	VALUE	PRICE
hp 470A	3 a	0.3 v	0.1 Ω	$35.00
hp 470B	1 a	1.0 v	1 Ω	20.00
hp 470C	0.3 a	3.0 v	10 Ω	20.00
hp 470D	0.1 a	10.0 v	100 Ω	20.00
hp 470E	40 ma	25.0 v	600 Ω	20.00
hp 470F	30 ma	30.0 v	1,000 Ω	20.00

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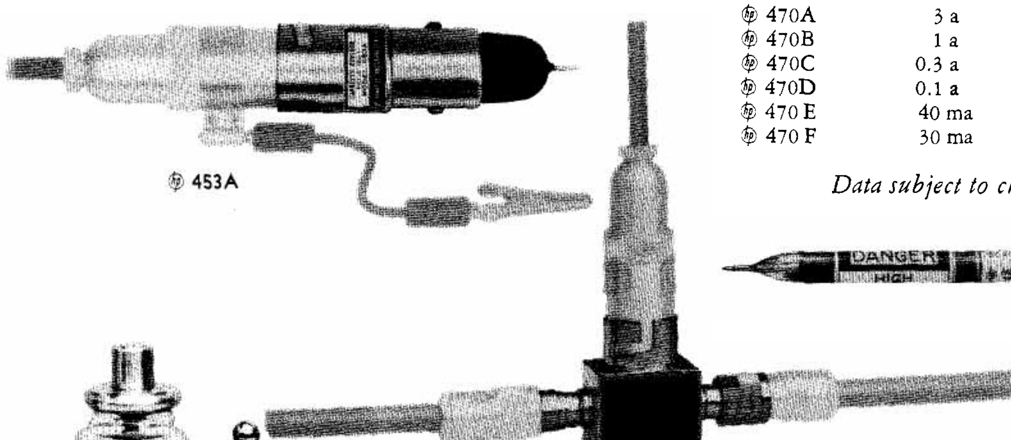
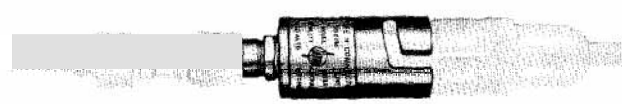


hp 453A

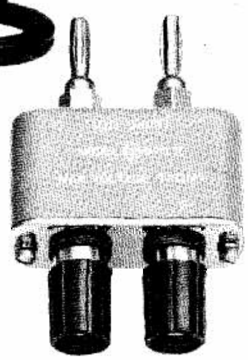
hp 455A

hp 459A

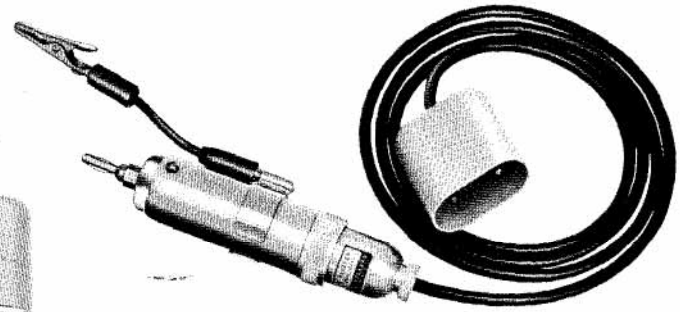


hp 458A

hp 452A



hp 470B



hp 454A

AMPLIFIERS

Hewlett-Packard amplifiers cover a wide variety of measuring requirements.

General-Purpose Amplifiers

hp 450A Amplifier *(page 90)* is a general-purpose instrument, usable wherever wide frequency range and stable gain are desired. Because of a large amount of feedback, the instrument has an extremely stable 20 or 40 db gain over a continuous frequency range of 5 cps to 1 MC. In addition, it can be used up to 3 MC with some sacrifice in gain and stability.

The new hp 466A AC Amplifier *(page 90)* is an extremely compact, high stability instrument ideal wherever low distortion, wide frequency range and ready portability are required. It is particularly suited for increasing sensitivity of voltmeters and oscilloscopes, and for field measurements where high input impedance is required.

Distributed Amplifiers

hp 460A and 460B Distributed Amplifiers *(pages 86, 87)*, are wide-range amplifiers providing distortionless pulse amplification. They combine extremely short rise time with zero overshoot.

These instruments are employed to amplify pulses faster than 0.01 microsecond. They provide suitable output for operating scalers or coincidence devices, or investigating characteristics of pulse circuitry in nuclear work or television, uhf and vhf networks. They increase sensitivity of oscilloscopes and voltmeters and are useful for other amplification purposes up to 120 MC. Response is substantially constant down to 20 KC.

Operating Techniques

hp 460A is a two stage voltage amplifier (which does not invert the input signal) with approximately 20 db gain and a rated output of 8 volts into an open circuit. This is sufficient for operating scalers, etc. For higher voltages required for cathode ray tube deflection, hp 460B is recommended. This instrument is a wideband amplifier designed to supply a maximum of 125 volts peak (negative) open circuit. This is sufficient to provide full deflection on any commonly-used cathode-ray tube. One or more 460B amplifiers can be cascaded with one or more 460A amplifiers to provide a high-gain pulse amplifier with very rapid rise time and zero overshoot *(see Figure 1)*.

Cascading Amplifiers

When cascading distributed amplifiers, consideration must be given to polarity as well as amplitude of the pulse to be amplified. Model 460B, unlike Model 460A, consists of a single stage and will invert the polarity of the applied pulse. For maximum deflection on the cathode-ray tube, the setup must be arranged so that the input to the last 460B is positive and of approximately 8 volts peak amplitude. This can be achieved by preceding the final 460B with another 460B whenever necessary.

The rise time of amplifiers in cascade is greater than that of a single amplifier by $T \times \sqrt{n}$ where n is the number of 460 amplifiers in the system and T is the rise time of one 460 amplifier (3.0×10^{-9} seconds). In addition, the rise time of the RC combination formed by the capacity of CRT deflection plates and the internal impedance of the 460B (200 ohms) should be considered.

Traveling-Wave Tube Amplifiers

Hewlett-Packard traveling-wave tube amplifiers *(pages 88, 89)* are high gain broadband linear devices covering the frequency range of 1 to 12.4 GC (KMC). Besides amplifying any type rf signal in their pass band they may be used to modulate rf signals with pulses of nanosecond rise and decay time. They may also be used to frequency modulate and phase modulate rf signals. In addition they are suitable as broadband rf amplifiers for receiver and detector applications.

hp Models 490B, 492A and 494A are intended primarily for high gain, low level application. They provide 30 db (25 db for the 494A) amplification, with a noise figure of not more than 25 db above theoretical. All can be grid and helix modulated.

hp Model 491A provides an output power of at least 1 watt over the entire S-band frequency range. This output, when coupled with the instrument's 30 db gain, makes it possible to use 491A with a standard 1 milliwatt S-band signal generator (such as hp 616B) to provide a flexible 1 watt source in the 2 to 4 GC band.

Noise Consideration in Amplifiers

The limit of minimum useful input signal level to an amplifier is determined by random varying voltages and currents present in the circuit and tubes.

In distributed amplifiers, the noise factor is proportional to $1/\sqrt{n}$, where n is the number of tubes in the first stage. hp 460B has less internal generated noise than hp 460A (460B has 13 tubes in the first stage whereas 460A has only 5). hp 460B should thus be used to start a cascade chain when extremely small signals are to be examined.

hp traveling-wave tube amplifiers have low noise figures but because of their extreme bandwidth they have a large theoretical thermal noise power. When cascading two amplifiers for increased power gain, the system will approach saturation due to this noise level. Cascading the amplifiers will provide a source of noise power approaching white noise for the frequency spectrum. If narrow band amplification is desired, a band pass filter may be used following the first amplifier. This will decrease the theoretical thermal noise power and increase the signal-to-noise ratio of the system.

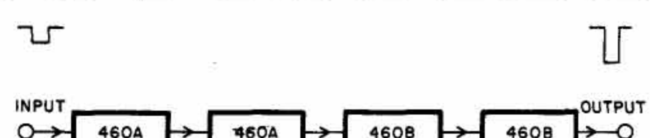


Figure 1. Typical cascading of 460A/B Amplifiers to give approximately 70 db gain and 125 volt pulse output.

ⓗ 460AR/BR WIDE-BAND AMPLIFIERS

Wide-Band Distortion-Free Fast-Pulse Amplifiers

Advantages:

20 db gain—up to 90 db in cascade

True amplification of nanosecond pulses

Rise time 3 nsec

No ringing or overshoot

125-volt open circuit output

Response follows Gaussian curve.

Uses:

Fast-pulse nuclear work

TV, vhf, uhf, shf, research

Simplifies measurement of small outputs

100 MC pre-amplifier for oscilloscope

Increases VTVM sensitivity 10 times at frequencies up to 200 MC.

General laboratory amplifier

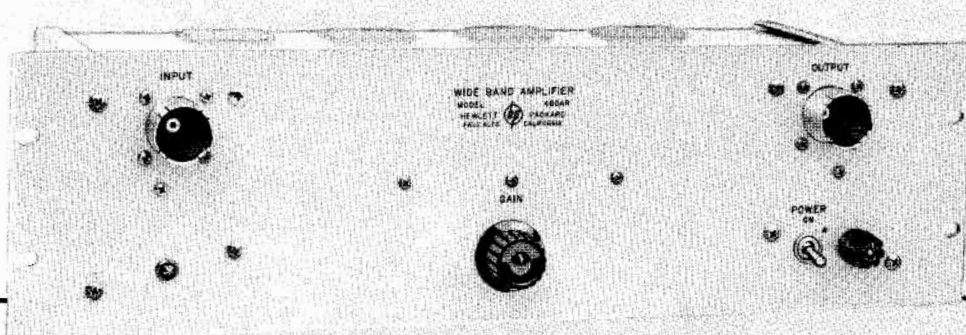
Model 460A/B Amplifiers make it possible for you to obtain at moderate cost true amplification of fast pulses at power levels sufficient to operate scalers, counting meters and cathode ray tubes.

ⓗ 460A Wide-Band Amplifier is used fundamentally to provide voltage gain, (approximately 20 db). Its companion equipment, ⓗ 460B, is designed as a terminal amplifier to give maximum voltage or power output. The amplifier's ultra-short rise time of 0.003 μsec, combined with zero overshoot, insures distortion-free amplification of pulses faster than 0.01 μsec. ⓗ 460B cascaded with 460A provides linear amplification of 16 volts peak output; and with two 460B's, pulse amplification of 125 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 still further convenience as general-duty wide-band amplifiers for all types of laboratory problems.

Operation

ⓗ 460A incorporates an amplifier with a very wide transmission band—approximately 200 MC. The equipment has two stages of 5 and 7 tubes, respectively.



ⓗ 460AR

Tube grids are connected along one transmission line to form the input circuit. Tube plates are connected along a second transmission line, forming the output circuit. A wave, traveling along the input line, excites the grids in succession; half the corresponding wave (generated in the plate circuit) travels down the plate toward the output. This wave is reinforced at each successive plate.

The part of the wave in the plate line which travels in the reverse direction is absorbed by a termination at the opposite end of the line. By the time the wave in the plate line reaches the output, it has been amplified by about 10 db. The second stage of the amplifier also increases the gain by approximately 10 db, making a total approximate gain of 20 db for the unit.

-hp- 460B operates on a similar principle except that it consists of one long amplifier chain or a single stage providing maximum power and voltage output but somewhat lower gain (approximately 15 db).

The faithfulness with which this equipment amplifies very fast pulses can be seen in Figure 1. The view at left (a) shows a 0.01 μsec pulse applied through one -hp- 460B Amplifier. The view at right shows a 0.02 μsec pulse applied through 3 amplifiers in cascade. Note the very short rise time and the complete absence of overshoot or ringing.

Response is shown in Figure 2. The curve follows the Gaussian norm very closely, even to a point well beyond 200 MC. This response also indicates how the amplifiers can be used with a vacuum tube voltmeter such as -hp- 410B *(see page 76)* to increase voltmeter sensitivity up to 10 times. In this combination, accurate readings are easily made of voltages as small as 0.01 volts, at frequencies from 200 KC to 200 MC.

200-Ohm Coaxial System

Since the best interconnecting impedance level for these amplifiers is 200 ohms, -hp- has designed Series 46A accessories comprising a complete 200-ohm coaxial system of connectors and cables. These include leads with fittings, panel jacks and plugs, adapters to connect to a 50-ohm Type N system and a special adapter for use with -hp- 410B Vacuum Tube Voltmeter. (See Specifications for details.)

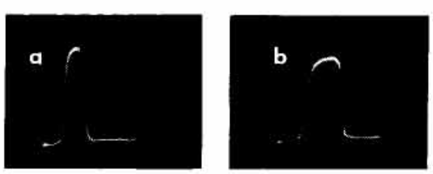


Figure 1. (a) 0.01 μsec pulse through -hp- 460B Amplifier. (b) 0.02 μsec pulse through 3 amplifiers in cascade.

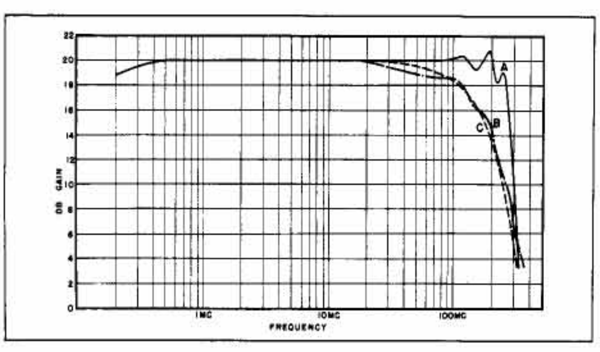


Figure 2. Typical response of 460A Amplifier working into (B) resistive load and (A) using -hp- 410B Vacuum Tube Voltmeter. (C) Gaussian curve.

Specifications

-hp- 460AR*

Frequency Response: *High Frequency*—closely matches Gaussian curve when operating into a 200-ohm resistive load. 3 db point is 120 MC. *Low frequency*—off approximately 3 db at 20 KC when operating into a matched load. Off approximately 3 db at 3 KC when operating into an open circuit (i.e. CRT plates). With -hp- 410B and 46A-95D: ±1 db, 200 KC to 200 MC.
Gain: Nominally 20 db into 200-ohm load. Gain control has range of 6 db. 5 amplifiers may be cascaded.
Sinusoidal Output: Approx. 8 v peak open circuit, less than 5% distortion.
Pulse Output:

Input Pulse	Maximum Output	
	Unloaded	Loaded
+	+8 v	+3.2 v
—	—20 v	—8 v

Input Impedance: 200 ohms.
Output Impedance: 300 ohms.
Noise Figure: Less than 10 db.
Delay Characteristics: Approx. 0.014 μsec.
Rise Time: Nominally 0.003 μsec (10% to 90%). No appreciable overshoot.
Power: 115/230 v ±10%, 50/1,000 cps, 50 watts.
Dimensions: Rack Mount: 19″ wide, 5¼″ high, 7″ deep behind panel.
Weight: Net 12 lbs. Shipping 18 lbs.
Price: -hp- 460AR, $225.00.

-hp- 460BR*

(Same as 460A except as follows)

Gain: Nominally 15 db into 200-ohm load.
Sinusoidal Output: Approximately 8 v peak into 200 ohms load or 16 v peak open circuit.
Output:

Input Pulse	Maximum Output			
	Pulse		Linear	
	Unloaded	Loaded	Unloaded	Loaded
—	+16 v	+8 v	+16 v	+8 v
+	—125 v	—60 v	—16 v	—8 v

NOTE: + 8 v input required for —125 v output.

Input Impedance: 200 ohms.
Output Impedance: 200 ohms.
Rise Time: Nominally 0.003 μsec (10% to 90%). No appreciable overshoot.
Duty Cycle: 0.10. Higher duty cycles may be employed at sacrifice of output voltage.
Delay Characteristics: Approx. 0.016 μsec.
Noise Figure: Less than 6 db.
Price: -hp- 460BR, $275.00.

*AR and BR designate rack mount. Cabinet mount not available.

-hp- Accessories

46A-16A Patch Cord—200 ohms, 2′ long. $22.50.
46A-16B Patch Cord—200 ohms 6′ long. $31.50.
46A-95A Panel Jack—For 200-ohm cables, low capacitance. $5.00.
46A-95B Cable Plug—For 200-ohm systems. $5.00.
8120-0014 Cable—200-ohm cable in length to specification. Per foot $2.25.
46A-95C 50-Ohm Adapter—Type N connector for coupling 50-ohm line into -hp- amplifiers. $17.50.
46A-95D Adapter—Bayonet sleeve for connecting -hp- 410B VTVM to output of 460A amplifiers. $40.00.
46A-95E Connector Sleeve—Joins two 46A-95B Cable Plugs. $7.50.
46A-95F Adapter—For connecting to 5XP CRT. $9.00.
46A-95H Adapter—Type N to -hp- 460, 200-ohm termination. $17.50.
46A-95J Adapter—Type N to -hp- 460, no termination. $15.00
46A-95K Adapter—-hp- 410B VTVM to -hp- 460, 200-ohm termination. $35.00.
460B-95A Adapter—Connects to -hp- 150A/AR oscilloscope plates. $35.00.

Data subject to change without notice.

hp 489A/495A TRAVELING-WAVE TUBE AMPLIFIERS

Broad Band, High Gain, High Power Amplification, 1 to 12.4 GC (KMC)

Advantages:

- Coupled-helix design
- Frequency coverage 1 to 12.4 GC(KMC)
- High power output
- 30 db gain
- Nanosecond pulse modulation
- Front panel metering, monitoring
- Compact, portable, easy to use
- Encapsulated replacement tubes

Use For:

- Calibrating CW Doppler radar
- Eliminating klystron delay, jitter
- FM'ing signal from stable shf sources
- Pre-amplification for receivers and detectors
- Measuring antenna patterns
- Measuring wide range attenuators
- Low level, low noise amplification
- High speed pulse generation

Hewlett-Packard Traveling-Wave Tube Amplifiers are precision, broadband linear instruments making easily available a complete group of measurements otherwise almost unobtainable.

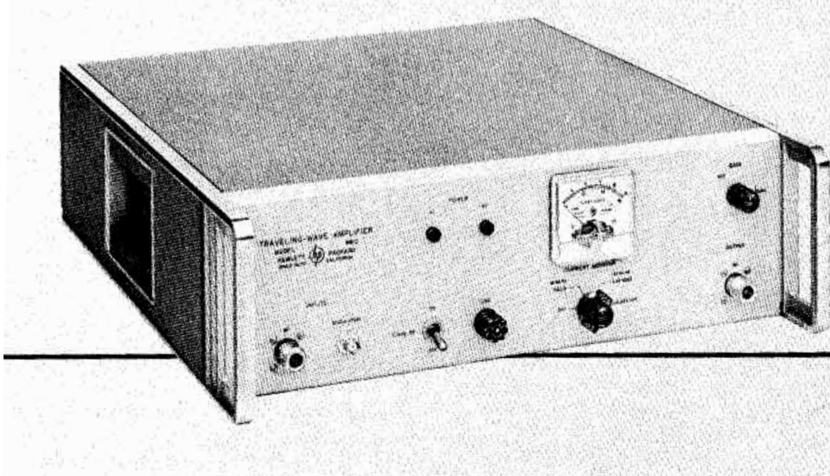
Traveling-Wave Tube Amplifiers were first described in 1946. But until development of this hp equipment, the problem of coupling broadband signals into and out of the tube was not satisfactorily solved, and the industry had no practical, dependable equipment of this type.

hp 490B, 491A, 492A and 494A utilize a simple broadband coupling method employing input and output coupling helices *(Figure 1)*. There is no mechanical connection to the inner helix, yet full energy transfer is effected. A similar helix is used for a coupled attenuator which surrounds the central portion of the tube, preventing amplified energy from causing regeneration.

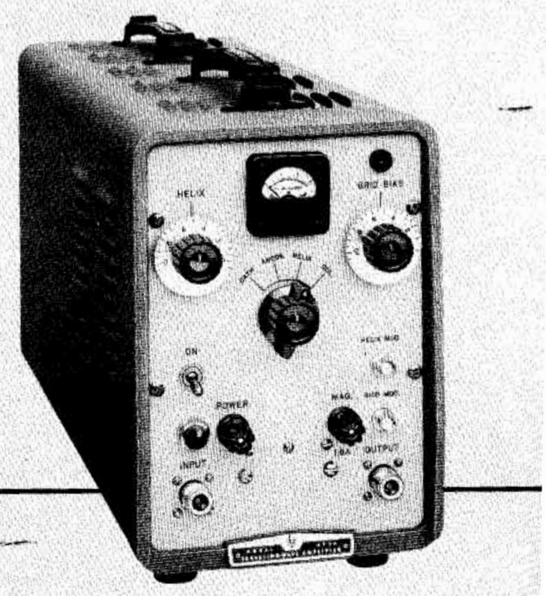
Standard TWT Amplifiers

hp 490B provides at least 10 milliwatts output, 30 db gain with noise figure of less than 25 db, excellent pulse modulation characteristics and helix modulation.

hp 491A has a full range output of 1 watt, with minimum gain of 30 db. This instrument, together with a 1 milliwatt S-band signal generator such as hp 616A *(see section on Signal*



hp 491C



hp 492A

Generators in this catalog) provides a versatile full watt source for high power testing at 2 to 4 GC (KMC). When modulated output is desired, the 616A Signal Generator may be modulated and the 491A will faithfully amplify the modulated signal.

492A (4 to 8 GC) and **494A** (7 to 12.4 GC) are low level, high gain instruments with 30 db gain and 20 mw output. They offer the unique versatility of amplitude, pulse, phase or FM modulation, and are ideal for use as broadband amplifiers or isolating buffer stages.

Encapsulated Replacement Tubes

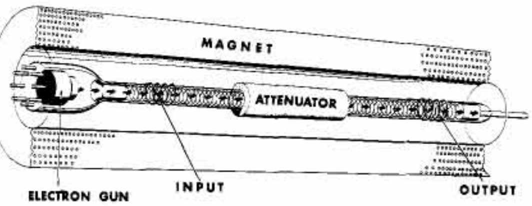


Figure 1. Construction of the Traveling Wave Tube showing input and output coupling helices and attenuator helix.

Adjustment of coupling helices of the traveling-wave tubes is highly critical, and the tubes themselves are somewhat fragile. To eliminate field adjustment and need for excessive care in handling, the tubes are encapsulated in an assembly which protects the tube and includes integral coupling helices. The capsule includes tube plugs, coaxial lines and front panel connectors. When delivered, the assembly is tested and ready to install. Credit is allowed for defective tube assemblies returned intact on exchange, since many parts are reusable.

New High Power TWT Amplifiers

These new high power TWT amplifiers provide at least one watt output for a one milliwatt input over their complete frequency range.

Amplitude modulation circuitry has been specially designed for wide bandwidth (down to dc) and with internal amplification so that small modulation signals cause a large output power change. Not only does the modulation circuitry permit amplitude modulation with small input signals, but power leveling may be achieved with external elements. To complete the feedback loop, the rf output is sampled by a directional coupler, detected and then amplified to approximately 10 volts. Any tendency of the rf output to change is coupled to the modulator circuit which compensates and maintains constant rf output.

These high power TWT amplifiers utilize periodic PM focusing; they are lightweight, compact, and have low power consumption. They may be easily converted from cabinet to rack-mounting configuration merely by removing the feet and attaching brackets and a strip (supplied), so that the panel meets EIA Standards.

Specifications

Models—489A, 491C, 495A

Model:	489A	491C	493A	495A
Frequency Range:	1-2 GC	2-4 GC	4-8 GC	8.2-12.4 GC
Price:	$1,970.00	$1,970.00	$2,900.00	$2,900.00

Common Specifications

Output For 1 mw Input: At least 1 watt.
Maximum rf Input: 100 mw.
Small Signal Gain: Greater than 30 db.
Amplitude Modulation Passband: DC to 300 KC.
Modulation Sensitivity: Approx. 20 db rf change for a 20 v pk input signal.
Input Impedance: 50 ohms, SWR less than 2.5.
Output Impedance: 50 ohms, SWR less than 2.5.
Connectors: Type N female.
Front Panel Controls: GAIN.
Meter Monitors: Anode, helix, collector and cathode current.
Dimensions: Cabinet: 16¾" wide, 5½" high, 18⅜" deep.
Rack: 19" wide, 5¼" high, 16⅛" deep behind panel.
Weight: Net 40 lbs. Shipping 60 lbs.
Power: 115/230 v ± 10%, 50/60 cps, approx. 200 watts.

Specifications

	490B	491A	492A	494A
Frequency Range:	2 GC to 4 GC.	2 GC to 4 GC.	4 GC to 8 GC.	7 GC to 12.4 GC.
Gain:	30 db minimum.	30 db minimum.	30 db minimum.	30 db minimum.
Output Power:	10 milliwatts minimum into 50 ohm load.	1 watt minimum into 50 ohm load.	20 milliwatts minimum into 50 ohm load.	20 milliwatts minimum into 50 ohm load.
Noise Figure:	Less than 25 db.	Less than 30 db.	Less than 30 db.	Less than 30 db.
Pulse Rise & Decay Time:	Approx. 0.015 μsec.	Mod. not provided.	Approx. 0.015 μsec.	Approx. 0.015 μsec.
Modulated Pulse Delay:	Approx. 0.035 μsec.	Mod. not provided.	Approx. 0.020 μsec.	Approx. 0.015 μsec.
Amplitude Modulating Voltage:	Approx. 50 volts peak-positive pulse will produce a 40 db change in rf power output. Sensitivity, approximately 1 db/volt.	Mod. not provided.	Approx. 50-volt peak positive pulse will produce a 40 db change in rf power level. Sensitivity, approximately 1 db/volt.	Approx. 50 volt peak positive pulse will produce a 40 db change in rf power level. Sensitivity, approximately 1 db/volt.
Helix Modulating Voltage:	Approx. 30 volts peak-to-peak provides 360° phase shift. Input-impedance 1 megohm.	Mod. not provided.	Approx. 40 volts peak-to-peak provides 360° phase shift. Input impedance 100 K.	Approx. 50 volts peak-to-peak provides 360° phase shift. Input impedance 100 K.
Hum, Spurious Modulation:	At least 30 db below signal level.	At least 30 db below signal level.	At least 40 db below signal level.	At least 40 db below signal level.
Input Impedance:	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.
Output Internal Impedance:	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.
Dimensions and Weight:	7½" wide, 11½" high, 19½" deep. 55 lbs.	7½" wide, 11½" high, 20" deep. 73 lbs.	7½" wide, 11½" high, 20" deep. 66 lbs.	7½" wide, 11½" high, 20" deep. 64 lbs.
Power Supply:	115 volts ±10%, 50/-1,000 cps, approx. 125 w.	115 volts ±10%, 50/60 cps., approx. 370 w.	115 volts ±10%, 50/60 cps, approx. 200 watts.	115 volts ±10%, 50/60 cps, approx. 225 watts.
Traveling-Wave Tube:	Huggins Laboratories HA-1HP.	Huggins Laboratories HA-2HPA.	Microwave Electronics Corp. M2207.	Microwave Electronics Corp. M2201-K.
Price (including tube):	$1,400.00	$1,400.00.	$1,500.00.	$1,800.00.

All instruments equipped with front panel metering for cathode, anode, helix and collector current. *Data subject to change without notice.*

466A AC Amplifier

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. Its light weight and small size recommend it for field application.

Specifications

Gain: 20 db (x10) or 40 db (x100) ± 0.2 db at 1,000 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 1,500 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: 115/230 v ± 10%, 50 to 400 cps, approximately 1 watt (supply normally furnished). Battery operation optional: 3 radio type mercury batteries, TR234 or equivalent, 3 required (hp #1420-0006). Battery life approximately 150 hours.
Size: 6¼" wide, 4" high, 6¼" deep. Weight 3 lbs.
Price: hp 466A, $150.00, ac or battery operation. (Please specify.)

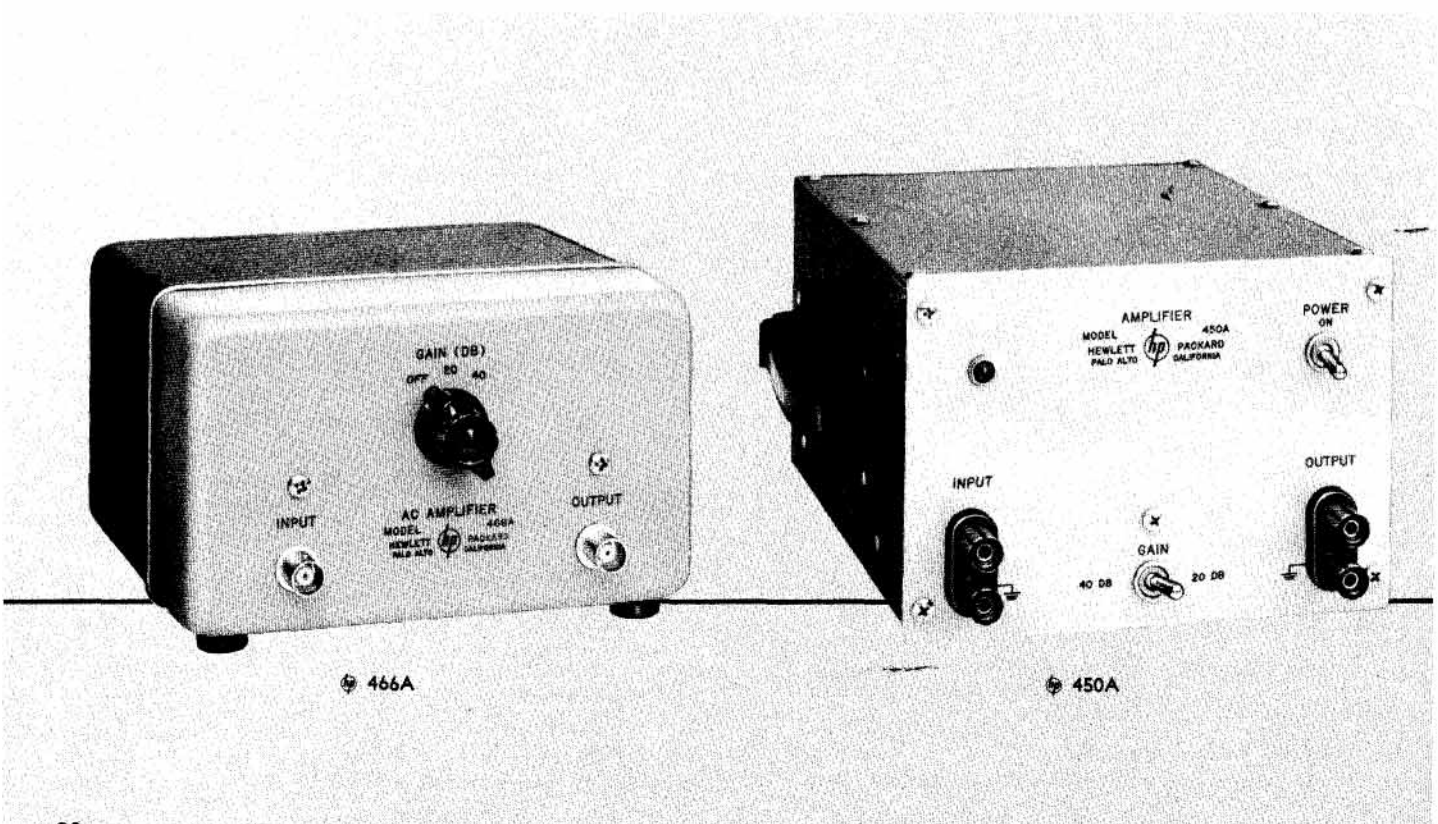
Data subject to change without notice.

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 using a dc filament supply for input amplifier tubes.

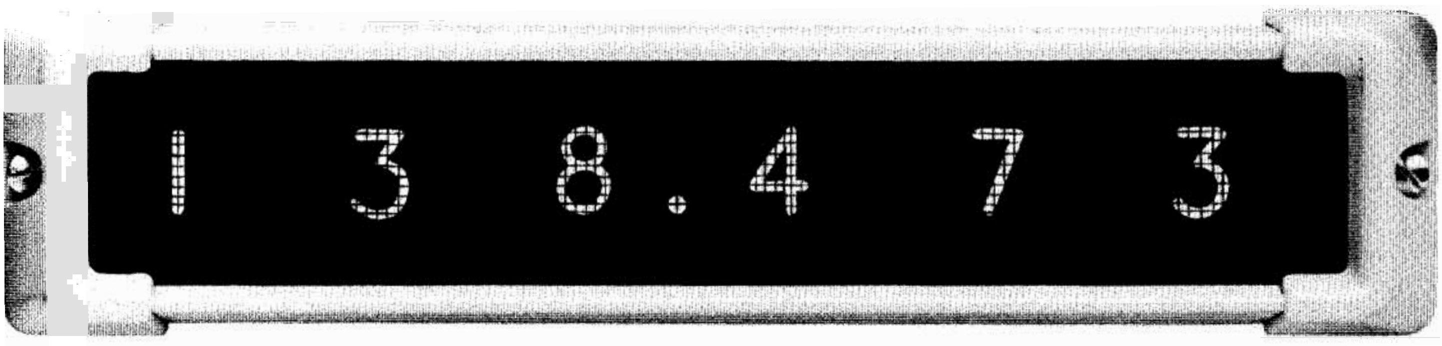
Specifications

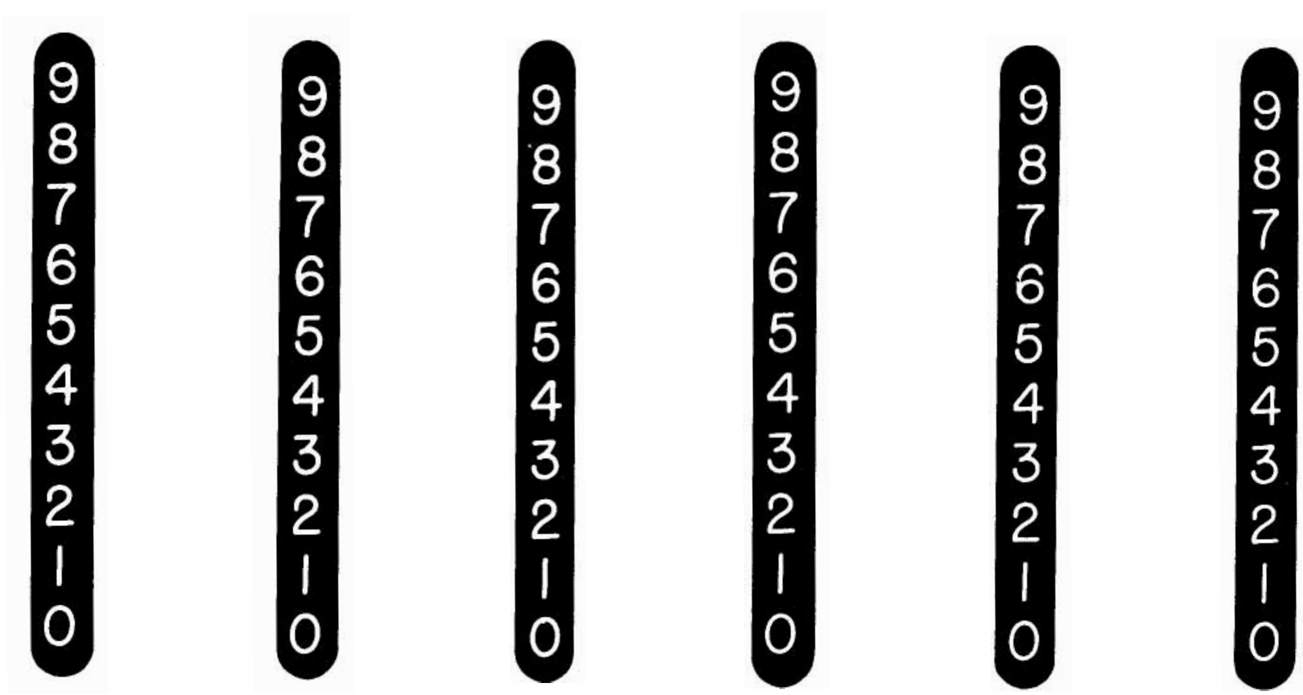
Gain: 20 db (x10) or 40 db (x100) ± ⅛ db at 1,000 cps.
Frequency Response: 40 db gain: ± ½ db, 10 cps to 1 MC; ± 1 db, 5 cps to 2 MC.
20 db gain: ± ½ db, 5 cps to 1 MC; ± 1 db, 2 cps to 1.2 MC.
Stability: ± 2%, includes line voltage variation (115/230 v ± 10%).
Impedance: Input, 1 megohm, 15 pf shunt. Output, less than 150 ohms.
Distortion: Less than 1%, 2 cps to 100 KC; approximately 2% above 100 KC.
Output: 10 v max. into 3,000 ohm or greater load.
Noise Referred to Input: 40 db gain, 40 μv; 20 db gain, 250 μv.
Power: 115/230 v ± 10%, 50/1,000 cps, 50 watts.
Size: 8¼" wide, 5½" high, 10½" deep. Weight, 10 lbs. Rack Mount: 19" wide, 5¼" high, 10⅝" deep behind panel.
Price: hp 450A, $160.00 (cabinet); hp 450AR, $165.00 (rack mount).



hp 466A hp 450A

FREQUENCY AND TIME MEASURING EQUIPMENT





By means of electronic circuits, frequencies can be added, subtracted, multiplied and divided with precision. When such circuits are used in conjunction with a high quality time base, measurements of frequency and time can be made with accuracy approaching that of the time base itself.

Frequency and time measuring instruments are used in every branch of science and engineering where these quantities are considered. The complexity and precision of frequency and time measuring instruments depend largely upon their intended application.

Hewlett-Packard instruments for frequency and time measurements presented in this section of the catalog can be categorized as:

Electronic Counters
Transfer Oscillators
Digital Recorders and Digital Clocks
Electronic Frequency Meters and Tachometers
Tachometer Instruments and Transducers
(See also pages 52 and 53)

ⓗⓟ equipment in these categories measures frequencies from 0 cps to 40 GC(KMC), and time intervals from 1 microsecond to 100 days with instrument stability as high as 5 parts in one hundred million per week.

ⓗⓟ frequency/time standard systems are described in a separate section of this catalog. See pages 118-125.

Special purpose counters and other digital equipment manufactured by Dymec division of Hewlett-Packard are described on pages 195-210.

Electronic Counters

The development of pulse counter circuits has led to the manufacture of electronic counters capable of many measurements which were not previously possible, particularly those involving frequency and time. Hewlett-Packard electronic counters offer the convenience of rapid, automatic readings, in direct numerical form, of frequency, period, time interval and phase angle. They are designed for simple operation and may be used readily by non-technical personnel. They are engineered for utmost dependability and accuracy.

ⓗⓟ electronic counters and their basic characteristics are listed in Table 1.

Frequency Measurements

In the frequency measurement mode, an unknown frequency signal is shaped and applied to the signal gate. *(See Figure 1.)*

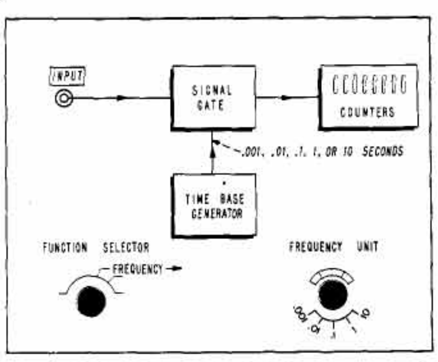


Figure. 1. Basic diagram of ⓗⓟ 524 when measuring frequencies below 10 MC.

Instrument	Maximum Counting Rate	Number of Digits	Display	Frequency	Period	Time Interval	Time Base Accuracy
521A	120 KC*	4	Column	X			Power Line**
521C	120 KC*	5	Column	X			± 0.01%
521D	120 KC*	4	In Line	X			Power Line**
521E	120 KC*	5	In Line	X			± 0.01%
522B	120 KC*	5	Column	X	X	X	$1/10^5$/week stability***
5212A‡	300 KC	5	Column	X	X		± 0.01%
5512A‡	300 KC	5	In Line	X	X		± 0.01%
521G	1.2 MC	5	Column	X			Power Line**
5232A‡	1.2 MC	6	Column	X	X		$3/10^7$/month stability***
5532A‡	1.2 MC	6	In Line	X	X		$3/10^7$/month stability***
523C	1.2 MC	6	In Line	X	X	X	$2/10^8$/week stability***
523D	1.2 MC	6	Column	X	X	X	$2/10^8$/week stability***
524C	10.1 MC†	8	In Line	X	X	X	$5/10^8$/week stability***
524D	10.1 MC†	8	Column	X	X	X	$5/10^8$/week stability***
5275A‡	100 MC	7	Column			X	Ext. Standard

*220 KC available on special order.

**Power line frequency in most of the United States is held accurate within ±0.1%. A crystal time base with accuracy of 0.01% is available on special order.

***Time base stability specifies the maximum amount the time base oscillator will drift. Absolute accuracy is determined by the calibration technique employed.

†Plug-in units extend frequency range to 510 MC; permit time interval measurement from one microsecond to 100 days; extend period multiplication factor up to 10,000; increase sensitivity; and improve phase angle measurement capability.

‡For a discussion of new Hewlett-Packard transistor counters, see page 107. Detailed specifications are given on pages 108, 109, 110.

Table 1. ⓗⓟ Electronic Counters

The gate is held open for a precise length of time determined by the time base generator, a crystal oscillator with high stability. The unknown frequency pulses are passed to the counter circuits while the gate is open, where they are totalized and the frequency automatically displayed on the instrument, complete to the decimal point. Measurement accuracy is determined by the accuracy of the time base generator and the ± 1 count error inherent in the gate-and-count type of instrument. *(See Figure 2.)*

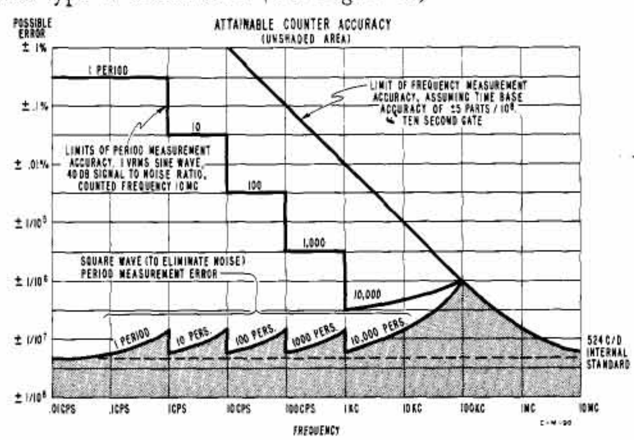


Figure 2. Attainable counter accuracy (unshaded area). ⓗⓟ 524C/D with 526C plugged in.

The higher the degree of refinement to which frequency measurements must be made, the greater are the performance requirements for the time base crystal oscillator.

In the case of ⓗⓟ 524 C/D counters, the internal time base is capable of performance ordinarily found only in oscillators intended for use as frequency standards. (Many ⓗⓟ 524C/D owners are obtaining double usefulness from their instruments by their use as a house standard.) This time base has long-term stability better than ± 5 parts in 10^8 per week, and a short-term stability of ± 3 parts in 10^8.

In terms of frequency measurement, this means, for example, that a measurement of a 100 megacycle signal (using the 524C/D Counter with the 525A, 525B or 525C converter) will be accurate within ± 8 cycles in the week following calibration, or ± 13 cycles in the second week, ± the 1 count error inherent in gate-and-count type of instrument. The ⓗⓟ Journal, Volume 10, No. 3-4, discusses in detail the performance of this time base, and presents actual data for typical usage situations.

Period Measurements

ⓗⓟ counters are designed to measure the period of an unknown frequency directly. *(See Figure 3.)* This is particularly important for measurements at lower frequencies when the ± 1 count error becomes a seriously limiting factor. This is graphically illustrated in Figure 2.

In the period measurement mode, the unknown frequency is shaped and applied to the signal gate, holding it open for one or more periods. During that time, a standard frequency from the time base generator is applied to the counter circuits. The standard frequency pulses are totalized, and the period of the unknown signal is automatically displayed on the instrument in proper decimal notation.

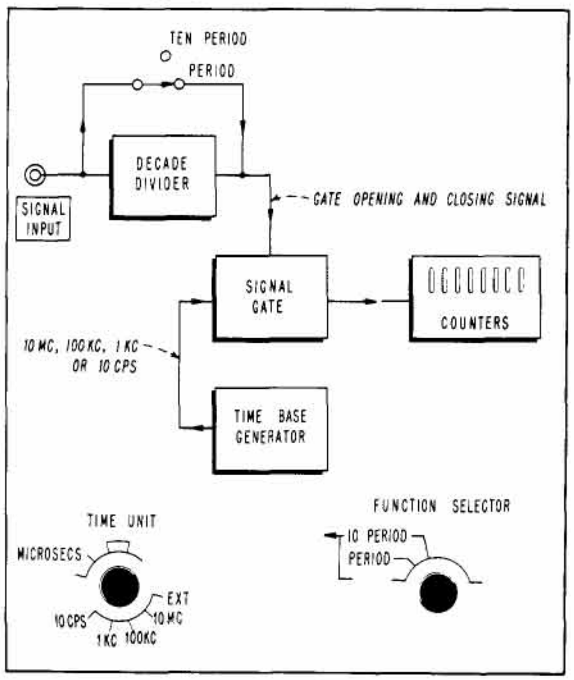


Figure 3. Basic diagram of ⓗⓟ 524 when making period measurements.

The accuracy of period measurements is largely determined by the consistency with which triggering occurs at the same point on consecutive cycles of the unknown signal voltage. For a signal of given frequency, this triggering accuracy will improve as the signal-to-noise ratio improves. For a sine wave, the total possible time error from triggering can be be expressed as $\frac{1}{\pi}\frac{E_n}{E_s}$, where E_n is the total noise, including that from the counter circuitry, and E_s is the signal.

The curves of Figure 2 for ⓗⓟ 524C/D with ⓗⓟ 526C plug-in illustrate attainable accuracy under assumed conditions of a 40 db signal-to-noise ratio for a sine wave and for measurements where the signal is a square wave. In the case of square waves (or other signals with very steep slopes) triggering error is virtually eliminated, and the factors influencing measurement accuracy again become time base accuracy and the ± 1 count ambiguity.

The curves of Figure 2 show how the ⓗⓟ 526C period multiplier unit for ⓗⓟ 524 series counters increases attainable accuracy by making possible 100, 1,000, or 10,000 period measurements. This period multiplication reduces the significance of the triggering error and the ± 1 count, in direct proportion to the multiplication factor.

Time Interval Measurements

Time interval measurements are similar to period measurements except that the trigger points on the signal waveform or waveforms are adjustable. This adjustment permits separate signals to be used as start and stop signals, or permits measurements to be made from one part of a waveform to another part of the same waveform. Time interval measurements can be made with ⓗⓟ 522 and 523 series counters, or with ⓗⓟ 524 series plus a 526B plug-in unit.

As in the case of period measurements, the input signals control the opening and closing of the gate, while the standard frequencies are passed to the counters as time units *(Figure 4)*. Thus the unknown interval is measured and automatically displayed in microseconds, milliseconds or seconds. Where trigger signal noise and rise time are not deteriorating factors, accuracy of this method is ± the accuracy of the internal time base and ± 1 count.

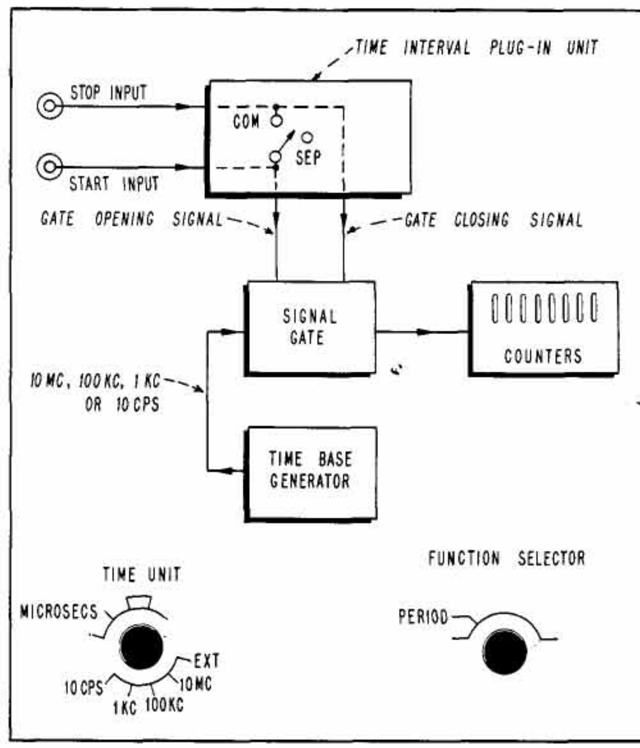


Figure 4. Basic diagram of ⓗⓟ 524 when measuring time interval.

Phase Angle Measurements

ⓗⓟ counters in the 522, 523 and 524 series may be used for phase angle measurements. Their speed and simplicity of operation make the counters suitable for phase measurements on the production line as well as in the laboratory. Operating in the time interval mode, the counters measure phase difference in units of time, based on the internal standard.

For phase measurements at frequencies from 396 to 404 cps, the 526D phase unit plug-in for the 524 series counters includes a 3,600 frequency multiplier, which allows phase angle readings to be displayed directly in tenths of degrees. The accuracy of phase angle measurements with the 526D at frequencies from 1 cps to 20 KC is $\pm 0.1^\circ \pm \left(\frac{F_p}{F_c} 360\right)^\circ$ $\pm$ time base accuracy, where F_p is the frequency of the phase-measured signal, F_c is the counted frequency; assuming noise 65 db below signal.

hp 523 and 524 series counters are probably the most accurate, convenient, wide-range phase-measuring instruments available.

Random Event Counting

Random events may be totalized over any selected gate time or may simply be totalized by use of the manual gate feature on all hp counters. Provisions are made on some models for the use of external time bases, such as electromechanical timers, for the longer totalizing periods encountered in nuclear work.

Ratio Measurements

The ratio f_1/f_2 may be measured with hp counters by using f_2 to open and close the signal gate, and counting f_1 while the gate is open. With proper transducers, ratio measurements may be extended to any phenomena which may be represented by frequencies or pulse rates within the range of the counter.

Ratio measurement accuracy is determined by the same factors as period measurement accuracy: the consistency of triggering by the lower input frequency (opening and closing the gate) and the inherent error of $\pm$ 1 count of the higher frequency. As with period measurements, the 526C period multiplier can be used to reduce the error by extending the number of periods of the lower frequency over which the measurement is made. For each factor of ten that the measurement is extended, the trigger error is decreased by a factor of ten.

Transfer Oscillators

Direct frequency measurements with hp electronic counters may be made up to 510 MC (524 series counter with hp 525 Frequency Converter unit). Hewlett-Packard Model 540B transfer Oscillator makes it possible to extend frequency measurements to 12.4 GC(KMC) and beyond, with electronic counter accuracy. Figure 5 graphs the frequency coverage possible with the hp 524 counter, 525 series plug-ins, 540 transfer oscillators and accessory equipment.

hp 540B employs a highly stable 100 to 220 MC oscillator generating harmonics to at least 12.4 GC. The instrument contains a broadband mixer system, an amplifier and an oscilloscope for comparison of these frequencies with the unknown. Recently developed untuned mixers and an excellent vernier tuning system make it a simple matter to obtain zero beat, at which time the fundamental frequency is measured with the 524/525B combination. A harmonic generator is also included which may be used to drive external traveling wave amplifiers and waveguide mixers for extending measurements considerably above X-band. hp Application Notes 2 and 21 describe equipment and techniques for making frequency measurements to 40 GC.

For detailed information on hp 540B, refer to pages 112, 113.

Digital Recorders and Other Output Devices

Once any variable has been measured with an hp electronic counter, output information is available in a form which is, or can be made, compatible with digital data handling devices such as digital recorders, tape punches, card punches, magnetic tape recorders, automatic typewriters, computers and similar equipment. Typical digital control systems available in the electronics industry include automated test systems, go/no-go systems, multiple comparator systems, and digital servo systems.

hp Digital Recorders

Hewlett-Packard builds three types of digital recorders, Models 560A, 561B and 562A.

The hp 560A is an 11-digit, parallel entry recorder which operates on the one-line staircase code from hp decade counter units. It will print up to 11 digits at a maximum rate of 5 lines per second.

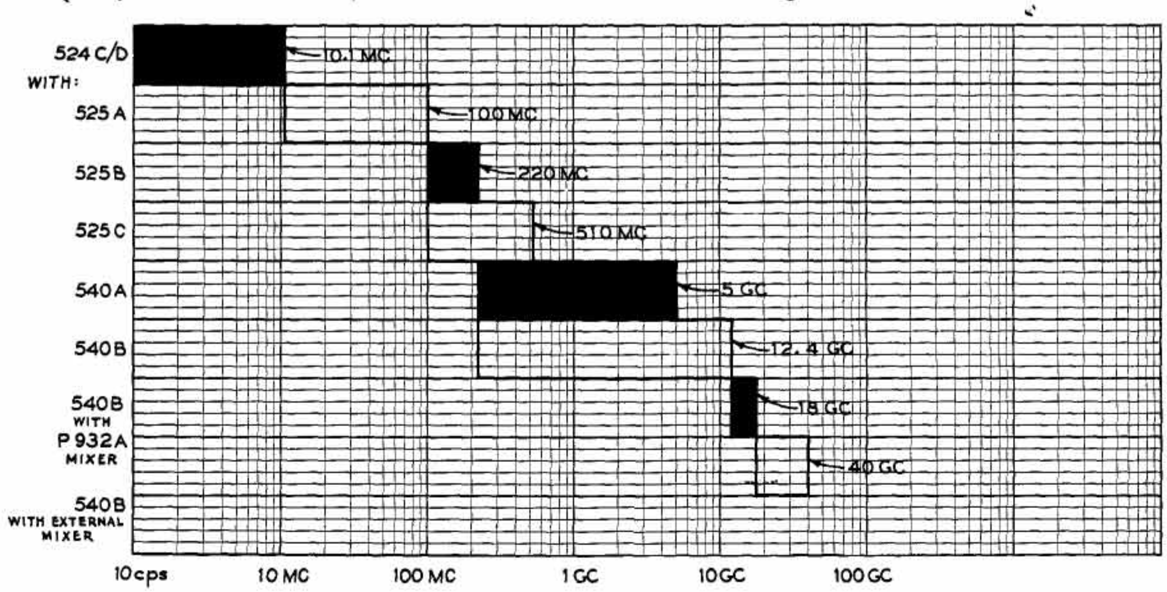


Figure 5. Frequency measuring range, hp 524C/D and accessory equipment.

Model 560A has a unique output feature which provides analog records of unusual flexibility and resolution. Data plots may correspond to any three successive columns being printed and are especially useful for close observation of trends.

Since the analog output is synthesized from digital information, essentially error-free zero-suppression is possible. This provides records of extreme resolution from potentiometer or galvanometer strip charts, or X-Y recorders.

Another important characteristic of the analog output is an automatic range-shifting feature, which applies known zero-suppression or elevation as required to keep the record on scale.

The ⓗⓟ 560A was designed specifically to record from any ⓗⓟ counter. It may also be used with other instruments, such as digital voltmeters or clocks, with the proper one-line staircase output.

Hewlett-Packard 561B Digital Recorder has the same printing capabilities as the 560A, but utilizes a 10-line code. Since input information may be in the form of contact closures or voltage changes ⓗⓟ 561B is appropriate for many uses.

Model 562A is a transistorized digital recorder utilizing 4-line BCD code. In addition to its use as an output device for ⓗⓟ transistor counters, it is especially suitable for applications with various data handling systems where BCD code is employed. Special models may be obtained for operation from 10-line code. The ⓗⓟ 562A is similar in printing capabilities to the 560A and 561B.

ⓗⓟ Application Note 32 describes all interconnections between ⓗⓟ digital recorders and counters, including the use of dual-input couplers. It also tabulates the print wheels carried as stock items.

For custom systems and special applications, ⓗⓟ 565A Digital Printer is available. This printer is mechanically similar to the printing mechanisms in ⓗⓟ 560A and 561B Digital Recorders. For maximum adaptability with the input and control systems encountered, and for simplifying field maintenance, all connections (commutators, brushes, clutch solenoid, print wheel solenoids, etc.) are made through connectors at the rear of the 565A.

More detailed information on ⓗⓟ Models 560A, 561B, 562A and 565A will be found on pages 114-117.

Digital Clocks

ⓗⓟ 570A and 571B Digital Clocks mount in the left-hand side of ⓗⓟ 560A and 561B Digital Recorders. These clocks add time of day information to other recorded data, and can control rates at which measurements are made. The clocks indicate time to 23 hours, 59 minutes, and 59 seconds in an in-line display, and can establish precise print rates of 1/sec, 6/min, 1/min, 6/hour, or 1/hour. Independent contact closures at the selected intervals are provided for operation of other external equipment.

Electronic Frequency Meters

Instead of counting each input pulse directly, ⓗⓟ 500B Frequency Meter responds to the rate of input pulses for frequency measurement applications which require an analog presentation.

Frequency is indicated on a meter, and scale expansions of x3 and x10 are provided. The instrument is equipped with an output for driving potentiometer strip charts, X-Y recorders and galvanometer recorders requiring up to 1 milliampere.

The 500B also provides, on any given range, a constant energy output pulse whose repetition frequency is determined by the rate of input pulses. This output may be used for stroboscopic purposes, and is especially useful for measuring or recording the characteristics of FM deviation.

Model 500B is described on pages 96 and 97.

Tachometry Instruments

ⓗⓟ tachometry equipment includes transducers (which convert mechanical motion into electrical pulses) and tachometer indicators (which measure the rate of these pulses).

ⓗⓟ 508 series Tachometer Generators are low torque, compact units for measuring shaft speed. The pulse output from these generators may be used by any ⓗⓟ counter or frequency meter. Useful shaft speed range is 15 to 40,000 rpm. The four models available in the ⓗⓟ 508 Tachometer Generator series are described in detail on page 98.

Another ⓗⓟ transducer, Model 506A Optical Tachometer Pickup, uses a light source and phototube receiver to generate electrical pulses corresponding to shaft rotation rate. This optical method does not load the machinery under test. It can be used over a wide range of speeds from 180 to 300,000 rpm. Even this range may be extended by relatively simple techniques.

Detailed data on the ⓗⓟ 506A may be found on page 98.

Tachometer indicators measure transducer-produced electrical pulses, and display this information in units of shaft speed. Tachometer system accuracy depends largely upon these indicators.

Hewlett-Packard indicators include frequency meters and electronic counters. The frequency meters respond to the rate of input pulses; the counters directly count each input pulse. Frequency meters have the necessary accuracy for many industrial applications. ⓗⓟ electronic counters are capable of a much higher degree of precision, and are suitable for the most exacting design applications. Any ⓗⓟ electronic counter will operate with all ⓗⓟ tachometer transducers for speed measurement.

ⓗⓟ 500C Electronic Tachometers are similar to ⓗⓟ 500B Frequency Meters described above, except that calibration is in rpm instead of cps. A detailed description of Model 500C appears on pages 96 and 97.

Digital Delay Generators

ⓗⓟ 218A Digital Delay Generator is a unique instrument providing two independent delays adjustable from 1 microsecond to 10,000 microseconds in steps of 1 microsecond. Model 218A and associated plug-in units provide an extremely versatile system for generating or measuring time intervals with very high accuracy. Details of Model 218A and related plug-ins appear on pages 52 and 53.

ⓗⓟ 500B/C ELECTRONIC FREQUENCY METER

Measures Frequency of ac Voltages as High as 100 KC

Advantages:

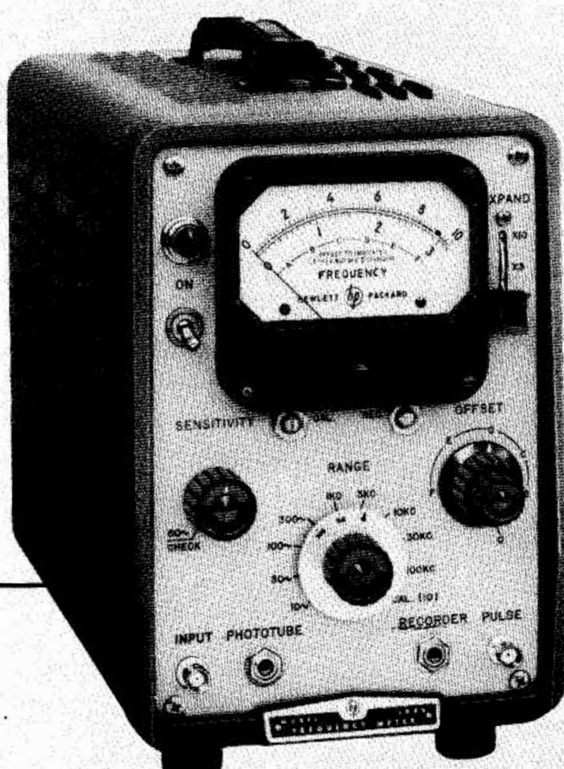
- Wide frequency range
- Accurate
- Good sensitivity
- Accuracy independent of line voltage changes and tube characteristics
- Nine convenient scale ranges
- Expanded scale feature
- Output pulse provision

Use It To Measure:

- Beat frequency between two rf signals
- Crystal frequency deviation
- Audio frequencies
- Speed of rotating machinery
- Oscillator stability
- Frequency modulation

The ⓗⓟ Model 500B directly measures the frequency of an alternating voltage from 3 cps to 100 KC. It is suitable for laboratory and production measurements of audio and supersonic frequencies, or for direct tachometry measurements with a transducer such as ⓗⓟ 506A or 508A/B/C/D. Use of ⓗⓟ 508A (which produces 60 pulses per revolution) converts the 500B's scale calibration from cps to rpm. Or, for still greater convenience in tachometry work this instrument is available as ⓗⓟ 500C with scale calibration in rpm. *(See opposite page, and page 98.)*

The frequency meter consists of a wide band amplifier, a Schmitt trigger, a constant current source, a current switching tube, a phantastron and an output meter. The Schmitt trigger is used to trigger the current switching tube in accordance with the rate of input pulses. A phantastron controls the "on" time of the switching tube during which time the plate current is directed to the output meter. The circuit is designed so that each pulse of charging current has the same energy making the meter reading proportional to the number of pulses per second, and hence proportional to the frequency of the input signal.



ⓗⓟ 500B

Independent of Signal Voltage Waveform

Readings are not affected by variations of input signal level or power line voltage. The frequency 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.

Expanded Scale Feature

Any 10% or 30% portion of a selected range may be expanded to full meter scale.

In practice, this means that for repetitive or differential type measurements the meter can be set for expanded scale readings and left in this position to better observe small fluctuations in readings. The expanded scale permits accurate measurement of small frequency changes.

Pulse Output

A pulse output synchronous with each input pulse is made available on the front panel. This output provides uniform pulses which can be used to measure the FM component of the input signal or to sync a stroboscope or an oscilloscope.

The output pulse could be used, for example, in conjunction with a stroboscope for observation of the various parts of a gear train when checking for the presence of vibration or torsion.

Specifications -hp- 500B

Frequency Range: 3 cps to 100 KC; nine ranges in a 10, 30, 100 sequence.

Expanded Scale: Allows any 10% or 30% portion of a selected range to be expanded to full meter scale.

Input Voltage: Sensitivity: 0.2 volts rms minimum for sine waves, 1.0 volt peak minimum for pulses.

Maximum: 250 v peak. Sensitivity control reduces threshold sensitivity.

Input Impedance: Approximately 1 megohm shunted by 40 pf. BNC connector for input.

Accuracy: Unexpanded Scale, better than ± 2% full scale value of range selector setting. Line voltage variations of nominal ± 10% affect reading less than ± ½%.

Expanded x3 Scale, (differential measurements of 30% or less), better than ± 1½% of range switch setting. Line voltage variations of ± 10% affect reading less than ±½%.

Expanded x10 Scale, (differential measurements of 10% or less), better than ± ¾% of range switch setting. Line voltage variations of ± 10% affect reading less than ±¼%.

Output Linearity: (Relation of input frequency to output current at the external meter jack.) On 100 KC range: within approximately ±¼% of full-scale value. On all other ranges: within approximately ± 1/10% of full-scale value.

Self-Check: Allows calibration of internal constant current source and check against 60 cps line frequency.

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 -hp- 506A Optical Tachometer.

Power: 115/230 v ± 10%, 50/1,000 cps, 110 watts.

Dimensions: Cabinet Mount: 7½" wide, 11½" high, 14¼" deep. Rack Mount: 19" wide, 7" high, 12½" deep.

Weight: Net 17 lbs. Shipping 22 lbs. (cabinet mount). Net 20 lbs. Shipping 32 lbs. (rack mount).

Accessories Available: -hp- 506A Optical Tachometer Pickup, $150.00. -hp- 508A/B/C/D Tachometer Generators, $125.00 each. -hp- AC-2A/B Dual Rack Panel *(page 194)*.

Price: -hp- 500B, $300.00 (cabinet); -hp- 500BR, $305.00 (rack mount).

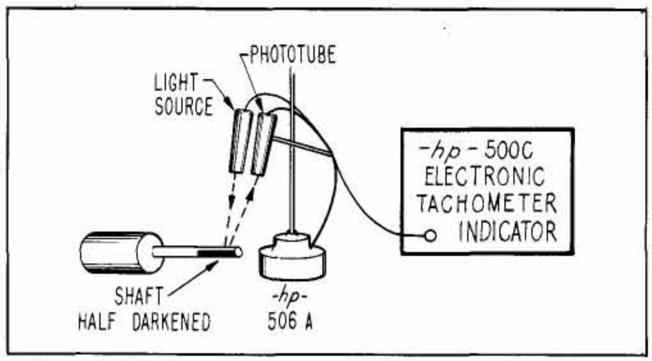


Figure 1. Tachometry measurements with -hp- 500C and 506A.

-hp- 500C Electronic Tachometer Indicator

Model 500C Electronic Tachometer Indicator is identical in construction and circuitry to -hp- 500B, but is calibrated in rpm for greater convenience in tachometry applications.

Specifications -hp- 500C

Circuit and Construction same as -hp- 500B except for meter calibration.

Speed Range: 180 rpm (15 rpm with multiplying transducer) to 6,000,000 rpm in nine ranges.

Price: -hp- 500C, $300.00 (cabinet); -hp- 500CR, $305.00 (rack mount).

Data subject to change without notice.

hp 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 from 15 to 40,000 rpm. They are specifically designed to operate with hp electronic counters and frequency meters.

The 508A Tachometer Generator produces 60 output pulses per shaft revolution. Thus when it is connected to an indicating instrument calibrated in cps, speeds are automatically recorded in rpm. The relationship between output voltage and shaft speed is virtually linear up to 5,000 rpm, making practical oscilloscope presentation of shaft speed as a function of time for analyzing clutches, brakes or acceleration rates.

hp 508B, C, and D are identical to hp 508A except that they produce 100, 120, and 360 pulses, respectively, per shaft revolution and their output voltages peak at successively slower shaft speeds.

Specifications

Shaft Speed Range: 508A, 40 to 40,000 rpm; 508B, 30 to 30,000 rpm; 508C, 40 to 25,000 rpm; 508D, 50 to 5,000 rpm.

Output Frequency: 508A, 60 cycles/rev.; 508B, 100 cycles/rev.; 508C, 120 cycles/rev.; 508D, 360 cycles/rev.

Output Voltage: Greater than 0.2 v rms over shaft speed range.

Drive Shaft: 1/4" diameter; projects 19/32".

Running Torque: Approximately 0.15 in.-oz.; 1/2 in.-oz at 1,500 rpm.

Peak Starting Torque: Approximately 4 in.-oz.

Dimensions: 2 - 7/16" high x 3½" wide x 3¾" deep.

Price: hp 508A/B/C/D, $125.00 each.

hp 506A Optical Tachometer Pickup

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. The instrument will measure very high speeds—up to 300,000 rpm—and will measure speed of moving parts which have small energy or cannot be connected mechanically to measuring devices.

Operation of the transducer is extremely simple. The part to be measured is prepared with alternate reflecting and absorptive surfaces. Light from the light source is interrupted by rotation of the part; the interrupted reflected light is picked up by the phototube and converted into electrical impulses.

Specifications

Range for Direct Reading:
with hp 521 Series, 1 to 5,000 rps.
with hp 500B, 3 to 5,000 rps.
with hp 500C, 180 to 300,000 rpm.
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 volt automotive bulb.

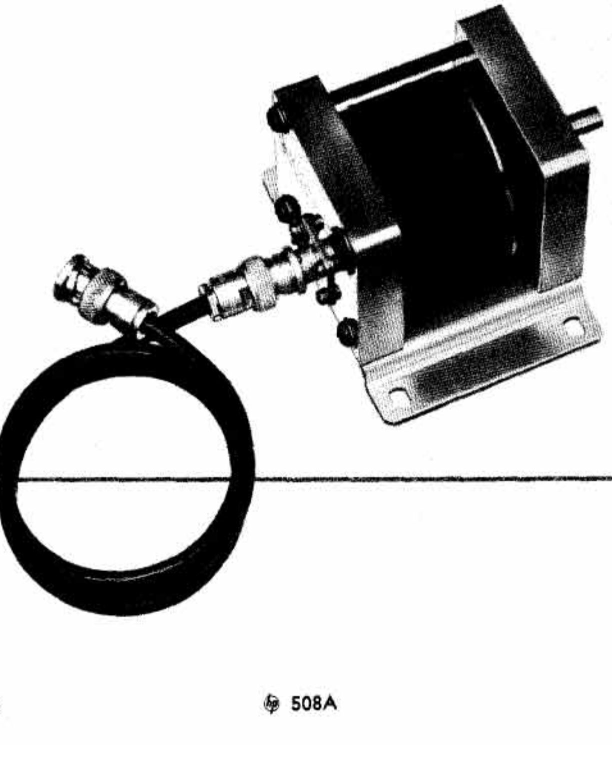
Phototube: Type 1P41.

Phototube Bias: +70 to +90 volts dc (supplied by hp 500B/C, 521).

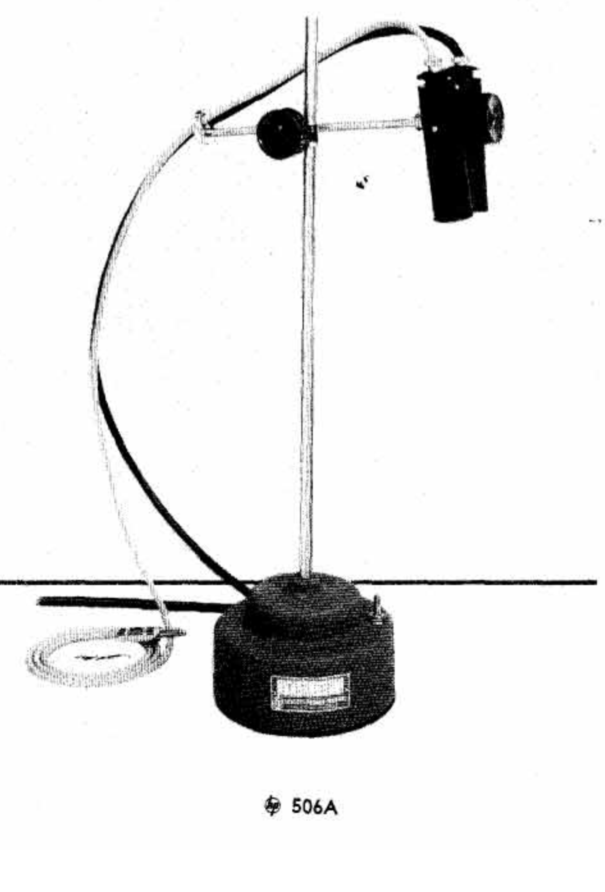
Accessories Available: hp 56A-16B Adapter Cable (connects hp 506A to hp 522B Counter), $40.00.

Price: hp 506A, $150.00.

Data subject to change without notice.



hp 508A



hp 506A

Low Cost, Flexible, Easy-To-Use; 1 cps to 1.2 MC!

The Hewlett-Packard 521 Series Electronic Counters are rugged, versatile instruments for production, processing and laboratory applications.

hp 521 Series Counters measure frequency and speed, and count events occurring at random within a selected period of time. With proper transducers converting mechanical into electrical phenomena, the instruments measure weight, pressure, temperature and other quantities which can be related to frequency.

Digital Recorder Operation

Versatile 521 Series Counters may be adapted easily to operation of hp 560A or 561B Digital Recorders *(see pages 114, 115)* with the installation of a kit. This kit can be installed by the hp factory before shipment (slight extra charge), or can be purchased for field installation later.

Model	521A	521C	521D	521E	521G
Maximum Frequency	120 KC*	120 KC*	120 KC*	120 KC*	1.2 MC
Count Presentation	4 places, neon	5 places, neon	4 places, in-line	5 places, in-line	5 places, neon
Gate Time	0.1, 1 sec	0.1, 1, 10 sec	0.1, 1 sec	0.1, 1, 10 sec	0.1, 1 sec
Power	150 watts, 200 w with Xtal time base	215 watts	155 watts, 205 w with Xtal time base	215 watts	160 watts, 210 w with Xtal time base
Size (cabinet)	9¾" W, 15¼" H, 14¼" D	9¾" W, 15¼" H, 14¼" D	9¾" W, 15¼" H, 15½" D	9¾" W, 15¼" H, 15½" D	9¾" W, 15¼" H, 14¼" D
Price (cabinet) (rack mount)	$475.00 480.00	$650.00 655.00	$750.00 755.00	$950.00 955.00	$700.00 705.00

*220 KC optional, add $35.00.
Add $45.00 for 560 or 561 Digital Recorder operation (561 with 521D/E only).
Crystal Time Base, standard equipment in 521C and 521E, optional for 521A, 521D and 521G, add $100.00.
Binary Coded Decimal Output (1-2-2-4) compatible with Dymec equipment, add $130.00 for 521A, $145.00 for 521C, G; $120.00 for 521D, $135.00 for 521E; prefix model with H60, i. e., H60-521A.

FOR ALL MODELS

Accuracy: ±1 count ± time base accuracy (approx. ±0.1% with line frequency, ±0.01% with Crystal Time Base).

Input Requirements: 0.2 v rms minimum or output from 1P41 Phototube (or equal). Phototube bias provided at "PHOTOTUBE" jack. ½ v rms required at frequencies above 120 KC with 220 KC option. Attenuator reduces sensitivity to 100 v rms to overcome noise.

Input Impedance: Approximately 1 megohm, 50 pf shunt (500,000 ohms on "PHOTOTUBE" jack).

Manual Gate: Controlled by "Count" switch or external contacts.

Display Time: Variable from gate time to approximately 15 seconds; or display can be held indefinitely.

Reset to Zero: Automatic or manual.

Reads In: Directly in cps or rps or in rps or rpm with hp 506A or 508A Tachometer Accessories.

Self Check: Counts 50/60 cps line frequency for any selected gate time. 10 KC with Crystal Time Base.

External Standard: Can be operated from any multiple of 10 cps, 10 cps to 100 cps.

Size: Rack Mount: 19" wide, 8¾" high, 14½" deep behind panel.

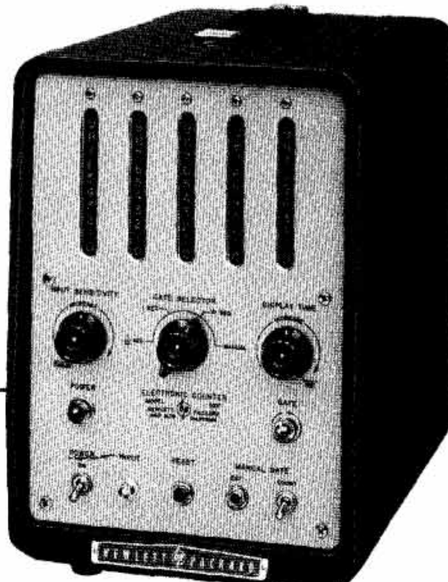
Weight: Cabinet Mount: Net 28 lbs. Shipping 41 lbs. Rack Mount: Net 28 lbs. Shipping 35 lbs.

Accessories Provided: hp AC-16D Cable Assembly, 44" RG-58/U cable terminated one end with UG-88/U Type BNC connector.

Accessories Available: hp Model 506A Optical Tachometer Pickup. $150.00. hp Model 508 Series Tachometer Generators, $125.00 each.

Data subject to change without notice. Prices f.o.b. factory

Model 521D



Model 521C

522B ELECTRONIC COUNTER

Versatile, Low Cost Precision Counter Covers 10 cps to 120 KC

Advantages:

Measures frequency, period, or time
High stability
High quality, low cost
Easily used by anyone
Direct, automatic readings

Use To Measure:

Frequency:
- Production quantities
- Nuclear counting
- Power line frequencies
- Rps and rpm
- Very low frequencies
- Oscillator stability
- Repetition rates
- Weight, pressure, temperature and acceleration—remotely

Time Interval, Period:
- Elapsed time between impulses
- Pulse lengths
- Shutter speeds
- Projectile velocity
- Relay operating times

This all-purpose Hewlett-Packard counter is used in an ever-increasing variety of manufacturing and research measurements.

The 522B counter offers the convenience of frequency, period *and* time interval measurement over a broad frequency range. Results are displayed automatically in direct reading form—either in cps, KC, seconds or milliseconds. Unskilled personnel can use the equipment immediately—no training or technical background is necessary.

Specifications

Frequency Measurement:

Range: 10 cps to 120 KC. (220 KC at slight extra charge).
Accuracy: ± 1 count ± time base accuracy.
Stability: 10 parts per million per week or better. May be standardized against WWV.
Registration: 5 places. Output pulse available to actuate trigger circuit for mechanical register to provide increased count capacity.
Input Requirements: 0.2 volt rms minimum. Input is direct-coupled.
Input Impedance: Approx. 1 megohm, 50 pf shunt.
Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds. May be extended to any multiple of one or ten seconds by manual control.

Display Time: Variable from 0.1 to 10 seconds in steps of gate time selected or until manually reset.
Reads In: cps or KC with the decimal point indicated.

Period Measurement:

Range: 0.00001 cps to 10 KC. Output pulse available to actuate trigger circuit for mechanical register to extend range to lower frequency.
Accuracy: ± 1 count ± 0.3% ± time base accuracy for measurement of one period. Accuracy for more than one period is ±1 count ±0.3% divided by number of periods ± time base accuracy.
Registration: Same as Frequency Measurement.
Input Requirements: 0.2 volt rms minimum. Direct-coupled input.
Input Impedance: Approx. 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 by manual control. This is limited to frequencies lower than 50 or 60 cps.
Std. Freq. 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 with decimal point indicated.

Time Interval Measurement:

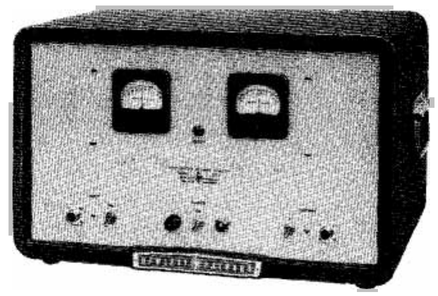
Range: 10 μsec to 100,000 seconds (27.8 hrs.).
Accuracy: ± 1/std. freq. counted ± time base accuracy.
Registration: Same as for Frequency Measurement.
Input Requirements: 1 v peak min. Direct-coupled input.
Input Impedance: Approx. 250,000 ohms, 50 pf shunt.
Start and Stop: Independent or common channels.
Trigger Slope: Pos. or neg. on start and/or stop channels.
Trigger Amplitude: Continuously adjustable on both channels from — 100 to + 100 volts.
Std. Freq. Counted: 1, 10, 100 cps; 1, 10, 100 KC; external.
Display Time: Same as for Period Measurement.
Reads In: Seconds or msec with decimal point indicated.

General:

Features: (a) Operates with ⓗⓟ 508 Series Tachometer Generators; ⓗⓟ 506A Optical Tachometer Pickup.
(b) Operates with ⓗⓟ 520A Decade Scaler for high speed nuclear scaling. *(See alongside.)*
(c) Measures frequency ratios.
(d) Makes time interval measurements with externally applied standard frequency.
(e) Operates as electronic stop watch with manual start, stop and reset.
(f) Totalizes events to 99,999.
(g) Operates as a secondary frequency standard providing precise rectangular output voltages at 1, 10, 100 cps; 1 and 10 KC and a 100 KC sine wave. Amplitude, approximately 1 volt peak.

Power: 115/230 v ± 10%, 50/60 cps, 260 watts.
Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14¼" deep. Rack Mount: 19" wide, 10½" high, 13⅝" deep behind panel. Can be used with ⓗⓟ AC-17 End Frames.
Weight: Net 50 lbs. Shipping 61 lbs. (cabinet mount). Net 43 lbs. Shipping 58 lbs. (rack mount).
Accessories Furnished: 2 AC-16D Cable Assemblies.
Price: ⓗⓟ 522B, $915.00 (cabinet); ⓗⓟ 522BR $900.00 (rack mount).
For 220 KC operation, add $35.00. For use with ⓗⓟ 560A Digital Recorder (ⓗⓟ 522B-95A installed), add $45.00. For BCD (1-2-2-4) output (compatible with Dymec instruments) add $180.00, prefix Model Number with H60 when ordering.

ⓗⓟ 520A HIGH SPEED DECADE SCALER



Model 520A makes possible quantitative measurement of extremely fast circuit pulses or nuclear parameters. The instrument is an aperiodic counter which operates at input rates of 10 MC and will resolve two sharp pulses spaced only 0.1 μsec apart.

The resolution capacity of the High Speed Decade Scaler makes it especially suitable for operation with scintillation counters. Since it provides an output pulse for every one hundred input pulses, its output may be connected to a conventional 100 KC counter to record large numbers of occurrences. This feature makes the ⓗⓟ 520A useful for measurement of frequencies up to 10 MC in applications where the accuracy of the last two places is unimportant.

Specifications

Required Input Polarity: Positive pulses only.
Amplitude: 5 volts minimum. 30 volts maximum. 10 volts minimum for maximum counting rate.
Required Rate of Rise: 10 volts per μsec, minimum.
Input Impedance: 5,000 ohms. UHF connector.
Resolving Time: Two pulses, 5 to 30 volts peak: 0.1 μsec. Three pulses, 5 to 30 volts peak: 0.2 μsec 1st to 3rd pulse. Maximum continuous uniform rate: 10^7 counts/sec. No lower limit on counting rate.
Counting Capacity: 100 counts in two decades, count indicated by two meters (0–90 and 0–9). Pushbutton resets both meters to zero.
Output: Positive or negative triangular pulse, approximately 35 volts amplitude and approximately 5 μsec wide at base. Rise time approximately 1 μsec. UHF connector.
Output Impedance: Operates into 5,000 ohms or more.
Power: 115 v ± 10%, 50/60 cps, 205 watts.
Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14¼" deep. Rack: 19" wide, 10½" high, 13⅞" deep behind panel.
Weight: Net 49 lbs. Shipping 60 lbs. (cabinet mount). Net 41 lbs. Shipping 56 lbs. (rack mount).
Accessories Available: 125-UG273/U uhf-BNC Adapters, $2.50. AC-16K Video Cable Assembly, $6.50; AC-16D Video Cable Assembly, $3.50.
Price: ⓗⓟ 520A, $700.00 (cabinet); ⓗⓟ 520AR, $685.00 (rack mount).

Data subject to change without notice.

Measures Period, Time or Frequency 10 cps to 1.2 MC!

Advantages:

Direct frequency, period or time interval readings
Highest quality, broad applicability, yet moderate cost
Basic accuracy $\pm$ 1 count; stability 2 ppm per week
Color-coded panel simplifies use by non-technical personnel
Pulse output for Z-axis oscilloscope modulation

Use To Measure:

Totalizing:

- Production quantities
- Nuclear scaling
- Frequency
- Rps and rpm
- Oscillator stability
- Repetition rates
- Weight, pressure and temperature

Time Interval, Period:

- Phase delay, phase angle
- Time between impulses
- Pulse length, shutter speeds
- Projectile velocity
- Relay operating times
- Precise event timing
- Interval stability
- Frequency. ratios
- Very low frequencies
- Power line frequencies

Model 523C is a broadly useful and popular electronic counter that measures frequency, period, time interval, phase delay, random events and ratios. It also totalizes electrical events, periodic or random.

Operation of the hp 523C is simple, fast and accurate. Measurements are made automatically and readings are displayed in direct numerical form with automatic decimal point. Controls are logically arranged and are color-coded for simple operation even by non-technical personnel.

Frequency Measurements

Typical frequency measurements with the 523C include oscillator and signal generator calibration and stability checks, measurement of telemeter and carrier frequencies, pulse repetition frequencies, test frequencies for narrow bandwidth circuits and rates of random pulses.

Period, Time Interval

Accuracy and resolution of the 523C make possible precise period measurements of power line voltages, test signals used in low frequency work and subsonic signals in general. Time for one cycle may be measured, or average time per cycle for 10 periods may be obtained. Time may be measured in terms of internal or external standard frequencies.

Model 523C is ideally suited to such time interval measurements as pulse length, pulse spacing, ballistic measurements, shutter speeds and relay operating times. Time interval between any two events (represented by electrical

hp 523C

pulses), from 1 μsec to 10^6 seconds are measured and indicated directly in μsec, milliseconds, or seconds. For normalized or measurements in other than time units, external frequencies may be counted. Separate start and stop channels are provided and each channel has trigger level and slope controls.

Pulses, generated whenever trigger level and slope conditions are met, may be used for intensity modulating an oscilloscope to identify the time interval measurement or for triggering auxiliary equipment.

Phase Measurements

Sensitivity and stability of the discriminator circuits make possible phase delay measurement with greatly improved accuracy. Accuracy of zero level determination makes the 523C ideal for phase measurements.

Phase delay is measured directly in μsec, milliseconds or seconds. Phase angle may be measured in degrees or 1/10 degrees by counting an external frequency (360 f_1 or 3,600 f_1) instead of the internal standard.

Measuring Other Quantities

hp optical and magnetic type speed transducers used with the 523C make possible highly accurate automatic speed measurements of jet engines, superchargers, centrifuges, etc.

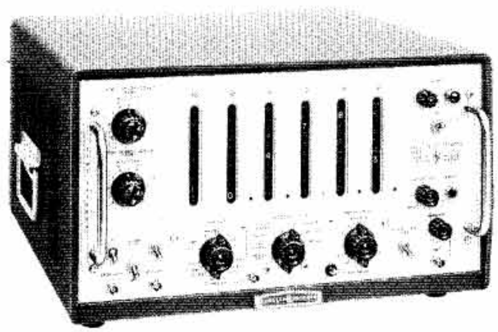
The 0.7 μsec resolving time of the 523C is well suited to nuclear measurements; i. e., totalizing or random rates.

Ratio measurements may involve any phenomena which can be represented by electrical impulses in the proper frequency range. The measurement of ratio provides increased accuracy in many measurements and is especially useful in certain control applications.

Transducers, available from various manufacturers, permit measurement of speed, acceleration, displacement, force, pressure, temperature, flow, and other physical variables.

The 523C can be furnished with internal circuitry and output jack for operating the hp Digital Recorders. Eleven columns of data can be printed by the Digital Recorders at rates up to five lines per second. Since only six columns are required for recording from the 523C, information from other counters, digital voltmeters or digital clocks may be recorded in the remaining columns.

hp 523D Electronic Counter



hp 523D Electronic Counter is identical to hp 523C except that registration is by 6 neon indicators.

Specifications hp 523C/D

General:

Registration: 523C, six in-line digital display tubes; 523D, six decimal places each indicated by lighted numbers.
Stability: 2/1,000,000 per week.
Display Time: Variable from approximately 0.1 to 10 seconds; display can be held indefinitely if desired.
Self Check: Automatic count of internal 100 KC and 1 MC.

Frequency Measurement:

Range: 10 cps to 1.2 MC.
Accuracy: ± 1 count ± time base accuracy.
Input Sensitivity: 0.1 volt rms; adjustable; 150 volts rms maximum input.
Input Trigger Level: −300 volts to +300 volts, adjustable, either positive or negative slope.
Input Impedance: Approx. 1 megohm, 50 pf shunt.
Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds.
Reads In: Kilocycles; automatic decimal point.

Period Measurement:

Range: 0.00001 cps to 100 KC.
Accuracy: ±0.3% ±1 count ± time base accuracy (one period). ±0.03% ±1 count ± time base accuracy (10 period average) at 0.1 volt rms. Accuracy increases with input voltage.
Input Requirements: 0.1 v rms minimum; direct coupled.
Input Impedance: Approx. 1 megohm 50 pf shunt.
Measurement Period: 1 or 10 cycles of unknown.
Standard Frequency Counted: 1 cps, 10 cps, 100 cps, 1 KC, 10 KC, 100 KC, 1 MC, external frequency.
Reads In: Seconds, msec, μsec, automatic decimal.

Time Interval Measurement:

Range: 1 microsecond to 10^6 seconds.
Accuracy: ± 1 count ± time base accuracy.
Input Impedance: Approx. 1 megohm, 50 pf shunt.
Input Requirements: 0.1 v rms min. DC or ac coupling.
Start and Stop Inputs: Separate or common input.
Start and Stop Marker Outputs: Approx. 5 μsec duration and +20 v peak, for oscilloscope intensity modulation.
Trigger Level: Both channels, 0 to ± 300 volts, either slope.
Standard Frequency Counted: 1, 10, 100 cps, 1, 10, 100 KC, 1 MC; external.
Reads In: Seconds, msec, μsec, automatic 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: $\pm 0.1^\circ \pm \left(\frac{360\ fp}{fc}\right)^\circ$ *(see pages 92-95)*
Other Data Measurement: Displays f_1/f_2, or $10f_1/f_2$, as an integer, with accuracy of ± 1.
f_1; 10 cps to 1.2 MC. f_2: 0.00001 cps to 100 KC
Totalize: Electrical events, periodic or random, to 999,999 at rates to 1.2 million/sec.
Output Frequencies: 1 cps, 10 cps, 100 cps, 1 KC, 10 KC rectangular, 100 KC and 1 MC sine wave. Stability $2/10^6$ per week.
External Standard: 100 KC can be applied.
Power: 115/230 v ± 10%, 50/60 cps, approx. 350 watts.
Size: Cabinet: 19" wide, 11¼" high, 18⅝" deep. Rack Mount: 19" wide, 8¾" high, 16" deep behind panel.
Weight: 48 lbs. Shipping weight approx. 85 lbs.
Accessories Furnished: 2 hp AC-16K Cable Assemblies.

Price: hp 523C, $1,575.00 (cabinet), 523CR, $1,550.00 (rack mount). hp 523D, $1,310.00 (cabinet), 524DR, $1,285.00 (rack mount). For BCD (1-2-2-4) output add $135.00, prefix Model No. with H60. For hp 561B (523C/CR only) or 560A Digital Recorder output add $45.00.

Data subject to change without notice.

524C/D ELECTRONIC COUNTERS

Measures Frequency to 12.4 GC (KMC)*—Time Base Stability 5/10⁸/ Week

Advantages:

Direct, instantaneous automatic readings
Easily used by non-technical personnel
Bright, big-numbered readout
Resolution 0.1 microseconds
Stability 5/100,000,000/week
Standardize with WWV
Available for printer operation
High sensitivity, high impedance
Extreme reliability
No calculation or interpolation
Automatic decimal point
Highest quality construction
Military design

Use For:

Frequency measurements 10 cps to 12.4 GC (KMC)*
Time interval measurements 1 μsec to 100 days
Period measurements 0 cps to 100 KC
Phase angle measurements to 20 KC
Standard frequency output of 10 cps, 1 KC 100 KC, 10 MC
Time and frequency ratios
High resolution tachometry ballistics measurements

Here is the electronic counter that provides extremely versatile frequency, time interval or period measuring coverage. You buy the basic 524C/D Counter with selected 525 or 526 series Plug-In Units covering your exact present requirements; later you can add other inexpensive plug-ins to increase the usefulness of the instrument. Still wider usefulness may be obtained by using the 524C/D in conjunction with 540B Transfer Oscillator for frequency measurements to 12.4 GC, and above *(see page 112)* and digital recorders for a permanent, printed record of measurements.

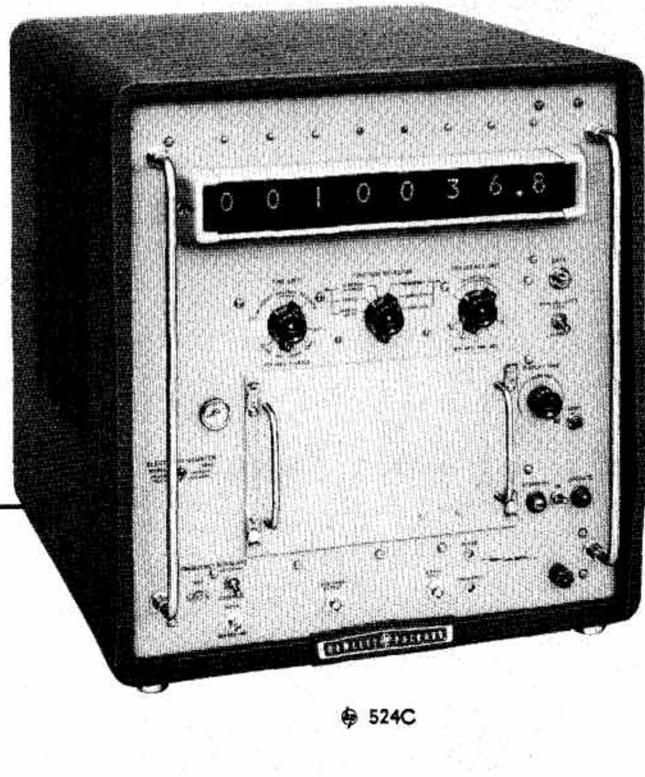
Great Versatility

The moderately priced 524C/D gives you more range, simplicity, usefulness and reliability than any *group* of instruments with comparable range ever offered. With this one all-purpose equipment, you measure transmitter and crystal oscillator frequencies, electrical, electronic and mechanical time intervals, phase angles, pulse lengths and repetition rates or frequency drift. You make high accuracy ballistics time measurements or high resolution tachometry measurements. The instrument also serves as a house frequency standard for many users, with a long-term stability of 5 parts in 10^8 per week. It is simple to operate and readily used by non-technical personnel.

Basic Counter Details

In the basic 524C Counter (without Plug-In Units) frequency from 10 cps to 10.1 MC is read over 5 selected gate

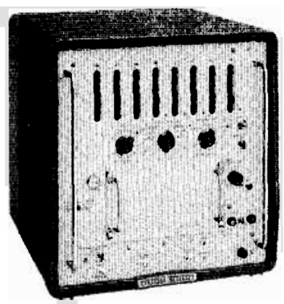
*With 540B Transfer Oscillator.



524C

times — 0.001, 0.01, 0.1, 1 and 10 seconds. Display time is variable, counts are automatically reset, and action is repetitive. Low frequencies (below approximately 300 cps) are more accurately measured by determining the period of one or ten cycles. Here the unknown frequency operates the gate and the internal standard frequency is applied to the counter. Thus the duration of a low frequency cycle is measured in time units. A 10-cycle sample may also be taken to improve accuracy. The result is determined automatically and presented in direct reading form with automatic illuminated decimal point.

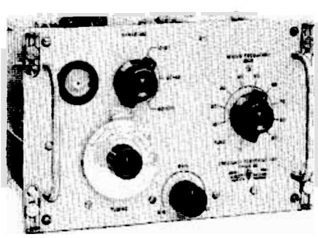
hp 524D Electronic Counter



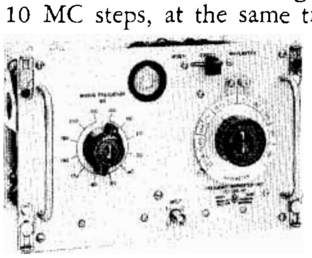
Model 524D is identical electrically with the hp 524C, but has 8-decade numerical readout using the widely accepted hp neon indicators instead of inline readout. Model 524D offers the same time-saving convenience of direct instantaneous, automatic readings without calculation or interpolation, but is priced slightly lower than the Model 524C.

Counter Plug-In Units

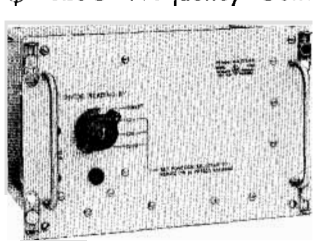
Addition of hp 525 and 526 series Plug-In Units will extend any hp 524 Counter's frequency range to 510 MC, provide increased sensitivity, and make available uniquely flexible time interval and phase angle measurements.



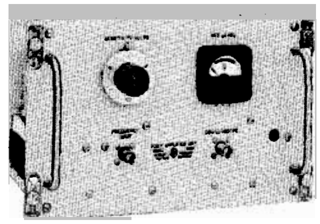
hp 525A Frequency Converter. This instrument extends the Counter's 10 MC direct-reading range in decade steps through 100 MC It maintains counter accuracy throughout the extended range. It provides additional amplification to increase sensitivity. A tuned input circuit simplifies determining the correct frequency range and rejects harmonics and spurious signals.



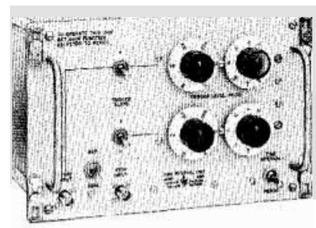
hp 525B Frequency Converter. Similar to 525A, this unit extends the counter's range from 100 MC to 220 MC in 10 MC steps, at the same time preserving the high accuracy of the basic counter. It maintains the same high sensitivity 0.2 volt minimum input throughout its range, and includes a wavemeter for determining the proper frequency decade range.



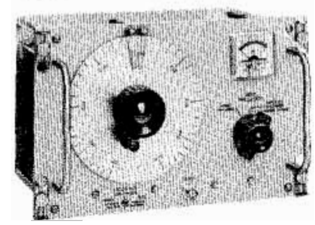
hp 525C Frequency Converter. Counter accuracy is extended over the wide range of 100 MC to 510 MC with this new heterodyne converter. Sensitivity is 100 mv over its range; it may also be used to increase counter sensitivity to 20 mv from 50 KC to 10.1 MC.



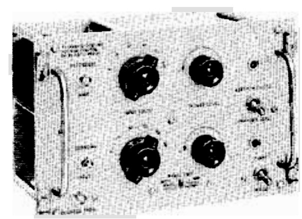
hp 526A Video Amplifier. This equipment increases the counter's 10 cps-to-10 MC sensitivity to 10 millivolts for frequency measurement at low power levels. A special probe assembly simplifies remote pickup at high impedance levels. An oscilloscope output terminal allows visual monitoring of the input waveform.



hp 526B Time Interval Unit. This instrument measures intervals from 1.0 μsec to 100 days with maximum accuracy of 0.1 μsec $\pm$ time base accuracy. Intervals are read direct in seconds, milliseconds or microseconds. Start and stop triggering is performed in either common or separate channels, and may be accomplished through the use of positive or negative going waves. Trigger voltage levels are continuously adjustable from — 192 to + 192 volts.



hp 526C Period Multiplier. This unit allows average measurements of 100, 1,000, and 10,000 periods. This insures greater accuracy for midrange frequency measurements.



hp 526D Phase Unit. Designed for precise phase angle measurements, the new hp 526D covers the range from 1 cps to 20 KC, reading in time units with resolution to 0.1 μsec. For measurements from 396-404 cps, this unit is designed to give phase angle readings directly in tenths of degrees.

Digital Recorder Operation

At nominal additional charge, Model 524C or 524D Electronic Counters can be modified to provide the following output signals:

1. A single-line staircase output for operation of the hp 560A Digital Recorder.
2. A 10-line code decimal output for operation of the hp 561B Digital Recorder. (524C only.)
3. A 4-line (1-2-2-4) binary coded decimal output for connection to data processing equipment.

Models 561B and 560A *(pages 114, 115)* are 11-column recorders which are slaves to the counter and print the counter reading at rates up to 5 per second.

Specifications

hp 524C/D Electronic Counter

Basic Unit, for Frequency Measurements, 0 cps to 10.1 MC

Frequency Measurement: (without plug-in units).
- **Range:** 10 cps to 10.1 MC.
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 seconds or manual control.
- **Accuracy:** $\pm$ 1 count $\pm$ time base accuracy *(see page 92)*.
- **Reads In:** Kilocycles; decimal point automatically positioned.

Period Measurement: (without plug-in units).
- **Range:** 0 cps to 100 KC.
- **Gate Time:** 1 or 10 cycles of unknown.
- **Accuracy:** ± 0.3% (measurement one period).*
  ± 0.03% (ten-period average).*
- **Standard Frequency Counted:** 10 cps; 1 or 100 KC; 10 MC, or externally applied frequency.
- **Reads In:** Seconds, milliseconds or microseconds; decimal point automatically positioned.

General:
- **Registration:** 524C, 8 digital display tubes; 524D, 8 numbered columns; 99,999,999 maximum display.
- **Stability:** $3/10^8$ short term; $5/10^8$ per week. May be standardized against broadcast standards or used with external 100 KC or 1 MC primary standard.

Display Time: Variable 0.1 to 10 seconds in steps of gate time selected. Display can be held indefinitely.
Output Frequencies: Secondary standard frequencies available at front panel: 10 cps, 1 KC rectangular; 100 KC positive pulse; 10 MC sine wave. (Stability as above.)
Self Check: Panel control provides automatic count of internal standard 100 KC and 10 MC frequencies to assure proper operation of counter.
Input Voltage: 1 v rms minimum 1.5 v peak. Rise time 0.2 sec max.
Input Impedance: Approx. 1 megohm, 40 pf shunt.
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: 470K, 40 pf shunt capacitance.
Power: 115/230 v ± 10%, 50/60 cps, 600 watts.
Dimensions: Cabinet Mount: 20" wide, 21⅛" high, 23½" deep. Rack Mount: 19" wide, 19¼" high, 17" deep.
Weight: Net 118 lbs. Shipping 161 lbs. (cabinet mount). Net 110 lbs. Shipping 161 lbs. (rack mount).
Accessories Furnished: 1 AC-16K Cable Assembly.
Accessories Available: 524B-16P ($30.00) and 524B-16Q ($20.00), Test Cable Sets for hp 525/526 units.
Price: hp 524C, $2,400.00. hp 524D, $2,150.00. Modified to operate hp 560A, add $75.00. Modified to provide BCD output (1-2-2-4) add $235.00. Modified to operate hp 561B (hp 524C only), add $150.00. Rack mount models available.

hp 525A Frequency Converter Unit

for Frequency Measurement, 10 cps to 100 MC. Plugged into hp 524:

Range: As amplifier for counter, 10 cps to 10.1 MC. As converter for counter, 10.1 MC to 100 MC.
Accuracy: Retains accuracy of 524 Counter.
Registration: 8 places; first place indicated on converter selector switch labeled 0, 10, 20 . . . 90; next 7 as indicated by counter.
Input Voltage: 0.1 v rms minimum, 10 cps to 10.1 MC; 10 mv rms minimum, 10.1 MC to 100 MC.
Input Impedance: Approx. 1 megohm shunted by 40 pf, 10 cps to 10 MC; approx. 50 ohms, 10 MC to 100 MC.
Level Control: Tuning eye aids frequency selection; indicates correct voltage level adjustment.
Weight: Net 5 lbs. Shipping 8 lbs.
Price: hp 525A, $250.00.

hp 525B Frequency Converter Unit

for Frequency Measurement, 100 MC to 220 MC. Plugged into hp 524:

Range: 100 MC to 220 MC.
Accuracy: Retains accuracy of 524 Counter.
Registration: 9 places; first two places indicated on converter selector switch labeled 100, 110, 120 . . . 210, next 7 indicated by counter.
Input Voltage: 0.2 v rms minimum.
Input Impedance: Approximately 50 ohms.
Level Control: Same as 525A above.
Weight: Net 5 lbs. Shipping 8 lbs.
Price: hp 525B, $300.00.

hp 525C Frequency Converter Unit

for Frequency Measurement, 100 MC to 510 MC. Plugged into hp 524:

Range: As converter for counter, 100 MC to 510 MC. As amplifier for counter, 50 KC to 10.1 MC. Direct connection for 0 to10.1 MC.
Accuracy: Retains accuracy of 524 counter.
Registration: 9 places; first two places indicated on converter dial, next 7 displayed by counter.

*See pages 92-95 for a discussion of counter accuracy considerations.

Input voltage: 20 mv rms minimum, 50 KC to 10.1 MC; 100 mv rms minimum, 100 MC to 510 MC.
Input Impedance: Approximately 700 ohms, 50 KC to 10.1 MC. Approximately 50 ohms, 100 MC to 510 MC.
Level Control: Meter aids frequency selection; indicates relative voltage level.
Weight: Net 6½ lbs., shipping 11 lbs.
Price: hp 525C, $425.00.

hp 526A Video Amplifier Unit

for Frequency Measurement, 10 cps to 10.1 MC high sensitivity. Plugged into hp 524:

Range: 10 cps to 10.1 MC.
Accuracy: Retains accuracy of 524 Counter.
Input Voltage: 10 mv rms minimum.
Level Control: Meter indicates input signal level, correct voltage adjustment.
Output Terminal: Provides 10 times input voltage from 93-ohm source, for oscilloscope monitoring of input signal without loading circuit.
Reads In: Same as basic 524 Counter.
Weight: Net 5 lbs. Shipping 8 lbs.
Accessories Furnished: 1 526A-16A Probe.
Price: hp 526A, $200.00.

hp 526B Time Interval Unit

for Time Interval Measurement. Plugged into hp 524:

Range: 1 μsec to 10^7 seconds.
Accuracy: ± 1/standard frequency counted, ± time base accuracy. *(see 524 General Specifications).*
Input Voltage: 1 v peak minimum, direct-coupled input.
Input Impedance: Approx. 1 megohm, 40 pf shunt.
Start and 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 v.
Standard Frequency Counted: 10 cps, 1 or 100 KC; 10 MC or externally applied frequency.
Reads In: Seconds, milliseconds, or microseconds; decimal point automatically positioned.
Weight: Net 5 lbs. Shipping 8 lbs.
Accessories Furnished: 1 AC-16K Cable Assembly.
Price: hp 526B, $200.00.

hp 526C Period Multiplier Unit

for Period Measurement. Plugged into hp 524:

Range: 0 to 100 KC.
Gate Time: 1, 10, 100, 1,000, and 10,000 cycles of the unknown frequency.
Accuracy: ± 1 count ± 0.3%/number of periods measured,* ± time base accuracy. *(See 524 General Specifications).*
Standard Frequency Counted: 10 cps, 1 KC, 100 KC, 10 MC, or externally applied frequency.
Reads In: Seconds, milliseconds, or microseconds.
Input Voltage: 1 v rms minimum.
Input Impedance: 1 megohm, 40 pf shunt.
Weight: Shipping 8 lbs.
Price: hp 526C, $225.00.

hp 526D Phase Unit

for Phase Comparisons. Plugged into hp 524:

Range: Phase angle, 0-360° lead or lag
Frequency Range: 1 cps to 20 KC.
Reads In: Seconds, milliseconds, microseconds; × 3600 multiplier provides readings direct in tenths of degrees for signals 396-404 cps.
Accuracy: $\pm\ 0.1^\circ \pm \frac{F_p}{F_c}\ 360^\circ$, where F_p is frequency of phase-measured signal, F_c is counted frequency; assuming noise 65 db below signal and negligible counted frequency error.
Input Voltage: ~~5 to~~ 120 volts rms.
Input Impedance: Approximately 1 megohm, 80 pf shunt.
Weight: Net 7 lbs. Shipping 15 lbs.
Price: hp 526D, $750.00.

Data subject to change without notice.

NEW hp TRANSISTOR FREQUENCY AND TIME INTERVAL COUNTERS

An integrated development program combining new advances in component development and broad innovations in instrument layout and design has made possible a whole new family of frequency and time measuring devices. These solid-state instruments provide:

1. **Display storage** — making readings possible even while a count is in progress.
2. **Faster repetitive counts** — display time is no longer limited to an integral multiple of the gate time.
3. **Solid-state circuits** — with low heat dissipation and reliable operation from −20 to +65°C.
4. **Positive frequency division**—giving maximum reliability to all gate times.
5. **Multiple period average** — improving period measurement accuracy, even for noisy signals.
6. **Plug-in modules** — for clean design and easy serviceability.
7. **Compact, stackable cabinets** — only 3½ inches of rack space required.

Behind these instruments stand Hewlett-Packard's years of experience as the world's leading manufacturer of precision frequency and time measuring equipment.

We believe the new counters are the finest of their type available. They combine operational utility and rugged serviceability with true functional beauty. They are compact, light, have low power consumption and can operate over a wide temperature range without degradation of performance. Plug-in module construction (see photograph) increases instrument versatility, simplifies maintenance, and helps assure uniform high quality.

New hp Counters

Two basic counters give maximum counting rates of 1.2 MC and 300 KC with choice of either column or in-line readout. Measurements of frequency, period, ratio and total count are made with typical electronic counter precision. (Counter accuracy considerations are discussed in detail on pages 92-95 of this catalog.) Input sensitivity is adjustable to a maximum of 0.1 volts rms.

Conservative design features, such as the use of decade dividers in the gate generating circuits, greatly improve operational stability. This positive-action frequency division combined with front panel self-check provisions gives confidence in readings at every position of the function selector switch.

Dual use of decade dividers in these counters permits multiple period average measurements as a standard feature, increasing measurement accuracy in proportion to the multiplication factor.

Display storage provides a continous visual display even while the instrument is totalizing a new count. Only if the new count differs from the previous count will the display change, in which case it will shift directly to the new reading. For most repetitive measurements, this feature will improve readability. For appropriate applications, storage may be disabled by a rear panel switch.

Display time is controllable from approximately 0.2 seconds to 5 seconds and is not limited by the gate time. For 1- and 10-second gates, this substantially increases the possible rate of sampling over units whose minimum display time is equal to the length of the selected gate.

Output in four-line BCD code (1-2-2-4) is available for system use or operation of output devices such as the hp 562A Digital Recorder *(see page 116)*. Dymec Division equipment compatible with these counters and with many other types of output recorders is described on page 204 of this catalog.

The extremely clean and compact design is shown in figure 1. Occupying just 3½ inches of rack space, these counters are light, have low power consumption and can operate over a temperature range of −20 to +65°C.

10 Nanosecond Time Interval Counter

This remarkable instrument measures time intervals from 10 nanoseconds to 0.1 seconds with 10 nanosecond resolution. Readout is direct in microseconds from neon columns. The hp 5275A Time Interval Counter has storage display and electrical readout features similar to the counters described above. The same clean, compact packaging is also used.

The 5275A is ideally suited for precise digital measurements of the time interval between two events which can be represented by suitable electrical pulses. *(See page 110 for trigger specifications.)* It is designed to be equally at home in the system console or the research laboratory.

Time interval measurement accuracy is ±1 count, ± the time base accuracy. The hp 101A 1 MC Oscillator is recommended as the time base for the hp 5275A, where a house standard of suitable stability is not available. hp 101A is a transistorized version of the same proven oscillator used as the time base in the hp 524C/D Counters. The long-term stability of this oscillator is 5 parts in 10^8 per week. Sufficient output power is available to drive as many as 20 hp 5275A's. A complete description of this oscillator can be found on page 125.

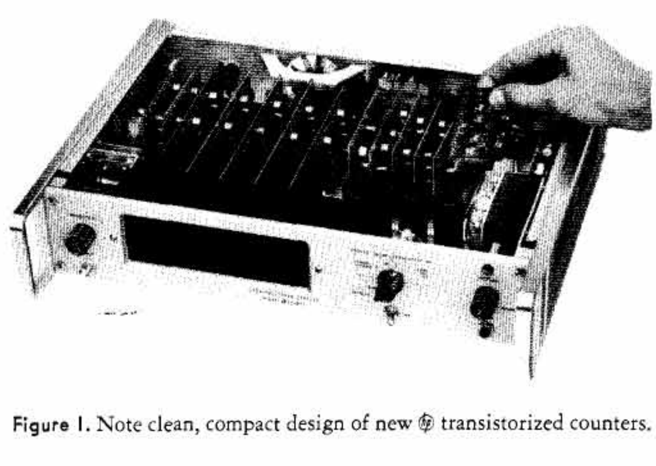


Figure 1. Note clean, compact design of new hp transistorized counters.

5212A/5512A/5232A/5532A ELECTRONIC COUNTERS

New Ease of Operation, Measure Frequency, Period, Ratio; Fully Transistorized

Advantages:

Reliable service; rugged and compact packaging

More accurate low frequency measurements, with multiple period averages

Low-level measurements without accessories; 0.1 volt sensitivity

Operational flexibility and reduced operator errors with display storage

Minimum bench or rack space, with new modular cabinets.

Low heat dissipation and power consumption, with solid-state components

Higher sampling rates; "inactive" time no longer an integral multiple of gate time

Major improvements in operating convenience and outstanding reliability with all solid-state components, are important features of the new Hewlett-Packard family of transistor counters.

Two basic counters give maximum counting rates of 300 KC and 1.2 MC, with a choice of column or in-line readout. Just 3½" high, the unique cabinet design makes these instruments suitable either for bench use or rack mounting. The front panel has input attenuation control, display control, reset button and function switch. In the rear are the storage-disable switch, external standard input jack (which permits the use of an external oscillator as the counter time base) and recorder output jack (optional).

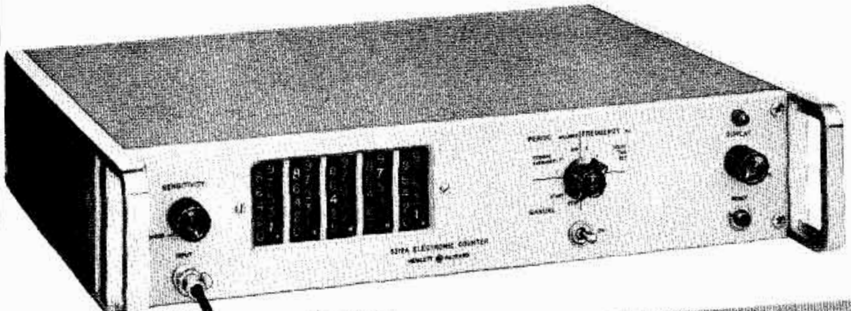
Conservative design features, such as the use of decade dividers in the gate generating circuits, greatly improve operational stability and reduce calibration problems. Dual use of these same decade dividers permits multiple period average measurements, with its resultant increase in accuracy, as a standard feature. Careful component choice makes these transistor counters operable in ambient temperatures from −20 to +65°C. Self-check is provided for both frequency and period measurement modes.

Display Storage

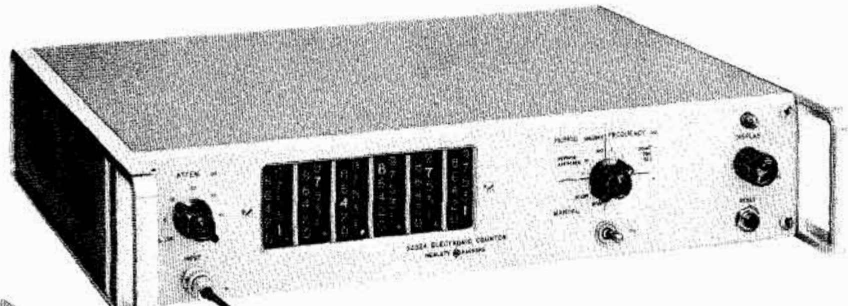
The unique display storage feature of these new counters provides a continuous visual readout of the most recent measurement even while the instrument is gated for a new count. If the new count differs from the "stored" count, the display will shift to the new reading directly. The counter's "inactive time" (when it is not making a new measurement) is completely adjustable from 0.2 to 5.0 seconds and is independent of gate time. This permits a higher sampling rate than is possible with many other counters.

Four-line BCD code output (extra cost option) with assigned weights of 1-2-2-4 is available for systems use or the operation of output devices such as the hp 562A Digital Recorder. *(See pages 116, 117.)* Output impedance is 100,000 ohms for each line; "0" state is indicated by −24 volts, "1" state by −1 volt.

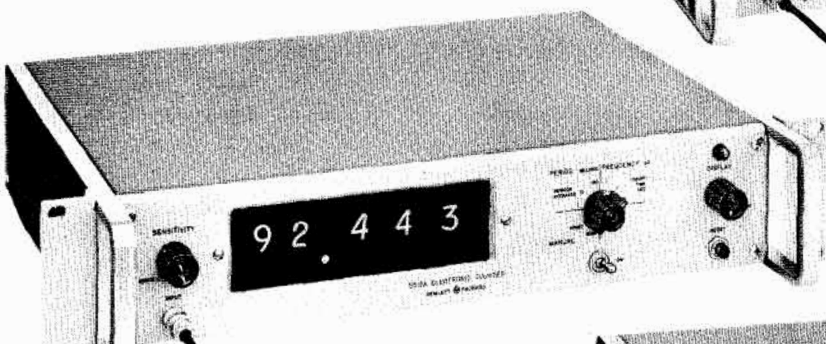
Counter	Max. Counting Rate	Registration		Input		Time Base Stability	Period Measurement			
		No. of Digits	Display	Sensitivity	Impedance		Range	Accuracy*	Reads In	Periods Averaged
5212A	300 KC	5	Column	0.1 v rms sine wave 1.0 v neg pulse, 2.0 μs min. width	1 megohm shunted by 50 pf	0.01% (accuracy)	2 cps to 10 KC in single period; up to 300 KC in multiple period average	± 10 μs ± time base accuracy ± trigger error/ periods averaged	Milliseconds with positioned decimal	1, 10, 10^2, 10^3, 10^4, 10^5
5512A	300 KC	5	In-Line	0.1 v rms sine wave 1.0 v neg pulse, 2.0 μs min. width	1 megohm shunted by 50 pf	0.01% (accuracy)	2 cps to 10 KC in single period; up to 300 KC in multiple period average	± 10 μs ± time base accuracy ± trigger error/ periods averaged	Milliseconds with positioned decimal	1, 10, 10^2, 10^3, 10^4, 10^5
5232A	1.2 MC	6	Column	0.1 v rms sine wave 1.0 v neg pulse, 0.2 μs min. width	1 megohm shunted by 50 pf	± 3 parts in 10^7 per month	2 cps to 10 KC in single period; up to 1 MC in multiple period average	± 1μs ± time base accuracy ± trigger error/ periods averaged	Milliseconds or microseconds with positioned decimal	1, 10, 10^2, 10^3, 10^4, 10^5
5532A	1.2 MC	6	In-Line	0.1 v rms sine wave 1.0 v neg pulse, 0.2 μs min. width	1 megohm shunted by 50 pf	± 3 parts in 10^7 per month	~~2 cps~~ to 10 KC in single period; up to 1 MC in multiple period average	± 1μs ± time base accuracy ± trigger error/ periods averaged	Milliseconds or microseconds with positioned decimal	1, 10, 10^2, 10^3, 10^4, 10^5



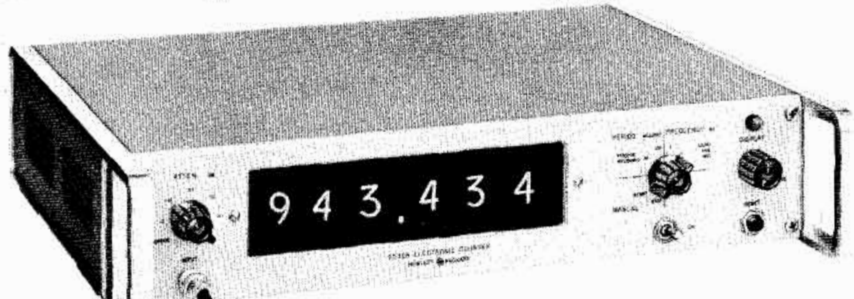
⊕ 5212A



⊕ 5232A



⊕ 5512A



⊕ 5532A

Frequency Measurement				Ratio Measurement						
Range	Accuracy*	Reads In	Gate Time	Reads	Range	Accuracy*	Power Requirements	Dimensions	Net Weight	Price
2 cps to 300 KC	±1 count ± time base accuracy	KC with positioned decimal	10, 1, 0.1, 0.01 sec	(f_1/f_2) x period multiplier	f_1: 100 cps to 300 KC (1 v rms into 1,000 ohms) f_2: Same as period	±1 count of f_1 ± trigger error of f_2	115/230 v ±10%; 50-60 cps, 33 watts	16¾'' wide 3½'' high 11½'' deep	13 lbs.	$ 975.00
2 cps to 300 KC	±1 count ± time base accuracy	KC with positioned decimal	10, 1, 0.1, 0.01 sec	(f_1/f_2) x period multiplier	f_1: 100 cps to 300 KC (1 v rms into 1,000 ohms) f_2: Same as period	±1 count of f_1 ± trigger error of f_2	115/230 v ± 10% 50/60 cps 35 watts	16¾'' wide 3½'' high 11½'' deep	13 lbs.	1,175.00
2 cps to 1.2 MC	±1 count ± time base accuracy	KC with positioned decimal	10, 1, 0.1, 0.01 sec	(f_1/f_2) x period multiplier	f_1: 100 cps to 1.2 MC (1 v rms into 500 ohms) f_2: Same as period	±1 count of f_1 ± trigger error of f_2	115/230 v ± 10% 50/60 cps 38 watts	16¾'' wide 3½'' high 11½'' deep	15 lbs.	1,300.00
2 cps to 1.2 MC	±1 count ± time base accuracy	KC with positioned decimal	10, 1, 0.1, 0.01 sec	(f_1/f_2) x period multiplier	f_1: 100 cps to 1.2 MC (1 v rms into 500 ohms) f_2: Same as period	±1 count of f_1 ± trigger error of f_2	115/230 v ± 10% 50/60 cps 40 watts	16¾'' wide 3½'' high 11½'' deep	15 lbs.	1,550.00

*For a detailed discussion of electronic counter accuracy considerations, see pages 92-95 of this catalog.

hp 5275A TIME INTERVAL COUNTER

10 Nanoseconds to 0.1 Seconds; Compact, Solid-State Construction

Specifications

Range: 10 nanoseconds to 0.1 seconds.

Resolution: 10 nanoseconds.

Accuracy: ± 10 nanoseconds, ± time base accuracy.

Time Base: External 1 MC required. *(See page 125, description of hp 101A).*

Registration: 7 places, direct digital presentation in neon columns.

Read In: Microseconds, with decimal point.

Input Requirements: Start and stop trigger pulses through separate channels.

Input Impedance: 50 ohms.

Minimum Trigger Pulse: 3.0 volts peak, 1.0 volt per nanosecond rise, 5 nsec width at 50% point.

Trigger Polarity: Selectable, positive or negative, for each channel independently.

Reset: Manual from front panel, or remote through rear-mounted terminal.

Standard Frequency Counted: 100 MC.

Power: 115/230 v ± 10%, 50-60 cps, 50 watts.

Operating Temperature Range: −20°C to +65°C.

Dimensions: 19″ wide, 3½″ high, 11½″ deep. Weight 15 lbs.

Optional Equipment: hp 101A 1 MC Oscillator, $500.00. hp 562A Digital Recorder, 4-line BCD (1-2-2-4) Output. Price on request.

Price: hp 5275A. Price on request.

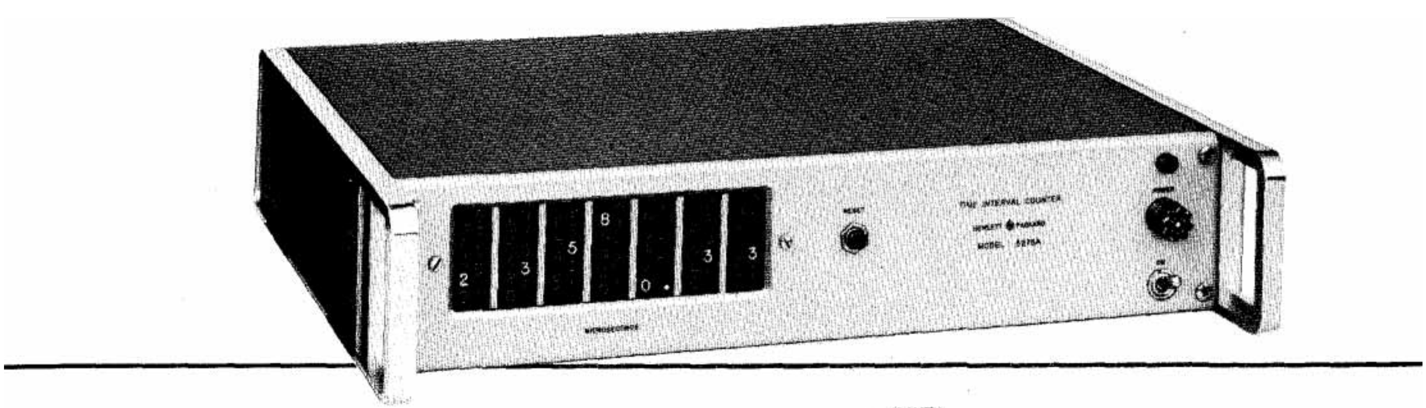
Data subject to change without notice.

Information previously unavailable in digital form can now be measured with electronic counter precision and simplicity with the new hp 5275A Time Interval Counter. 10-nanosecond resolution is achieved in automatic measurements over the full range of the instrument. The counted frequency is 100 MC, obtained from an external 1 MC standard by a 100 to 1 multiplying circuit within the 5275A.

hp 5275A is ideally suited for precise digital measurements of very short time intervals between events that can be represented by suitable electrical pulses. Applications include explosive burning rates, speed and acceleration timing of test vehicles in free-flight wind tunnels, and nuclear measurements.

hp 101A Oscillator *(page 125)* has been specifically designed for use with Model 5275A Time Interval Counter and is capable of supplying the time base for as many as 20 instruments at one time. Using one time base for several counters conserves rack space and reduces system cost.

A 4-line BCD output (optional) permits direct connection to many computers, or may also be used to drive the hp 562A Digital Recorder *(pages 116, 117)*. Other output devices . . . typewriters, card punches, tape punches, magnetic recorders, etc. . . . may be operated through standard output couplers manufactured by Dymec, a division of Hewlett-Packard. *(See page 204.)*



Counting Rates to 1.2 MC; Staircase Printer Output

Three dependable, convenient -hp- AC-4 Decade Counters are offered, with maximum counting rates of 120 KC, 220 KC, and 1.2 MC. Specific characteristics of each decade are given in the table below. Each is of improved design providing high reliability and staircase output voltage for remote register or driving -hp- 560A Digital Recorder. Units may be cascaded for any count capacity; they may be used to totalize, or as scale-of-10 dividers with remainder indicated. Readout is provided by neon lighted numerals.

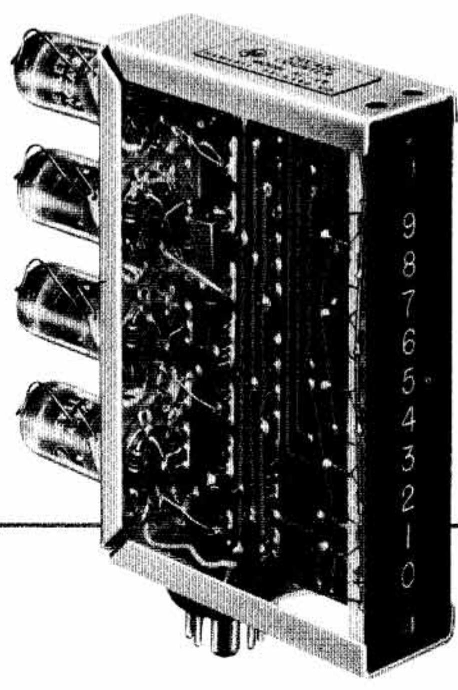
On special order, any Model AC-4 Decade Counter can be supplied with a 4-line binary coded (1-2-2-4) decimal output for direct connection to computors, printers and data reduction equipment.

For replacement in -hp- counters using octal-based Decade Counters, Model AC-4A, 120 KC and Model AC-4B, 220 KC, are available at $42.00 and $77.00, respectively.

Specifications

	AC-4C	AC-4G	AC-4E[1]
Maximum Counting Rate:	220 KC	120 KC	1.2 MC
Double Pulse Resolution:	4 μsec	7 μsec	0.7 μsec
Driving Voltage:	−50 v pulse	−80 v pulse	−20 v pulse 0.2 μsec rise time
Output Voltage:	−80 v pulse	−80 v pulse	−80 v pulse
Reset:	To zero: open base pin connection or apply +90 volt pulse 5 μsec duration. To nine, apply negative pulse.		
Display:	Illuminated numerals in a column.		
Output Code:	Staircase voltage + 135 volts at count of zero, + 55 volts at count of nine.		
Mounting:	12 pin male plug.		
Power:	+ 300 v at 18 ma 6.3 v ac at 1.2 amp.	+ 300 v at 15 ma 6.3 v ac at 1.2 amp.	+ 300 v at 30 ma 6.3 v ac at 1.2 amp.
Price:	$77.00	$42.00	$95.00

[1]Model AC-4D-95 and modification kit is available as a replacement for the AC-4D in -hp- 523B Electronic Counters. Price $100.00.



-hp- AC-4E

540B TRANSFER OSCILLATOR

Measure Frequency to 18 GC (KMC) with Electronic Counter Accuracy

Advantages:

- Extends frequency counter accuracy to microwave region
- Measures to 18 GC (KMC) with new fixed tuned mixers
- Permits measurement of pulsed, FM, CW, AM or noisy signals
- Provides multiple check for positive accuracy
- Measures FM deviation
- Includes self-contained oscilloscope
- Circuit elements usable separately
- Simple to use, compact, eliminates complex set-ups

Uses:

- Fast, accurate determination of CW and AM signal frequencies
- Measuring center frequency or deviation range of FM signals
- Measuring frequency in presence of high noise levels
- High accuracy measurements of pulsed signals

Use of hp 540B Transfer Oscillator with hp counters, frequency converters and fixed tuned mixers permits measurements far into the microwave region with accuracy and simplicity otherwise available only at much lower frequencies.

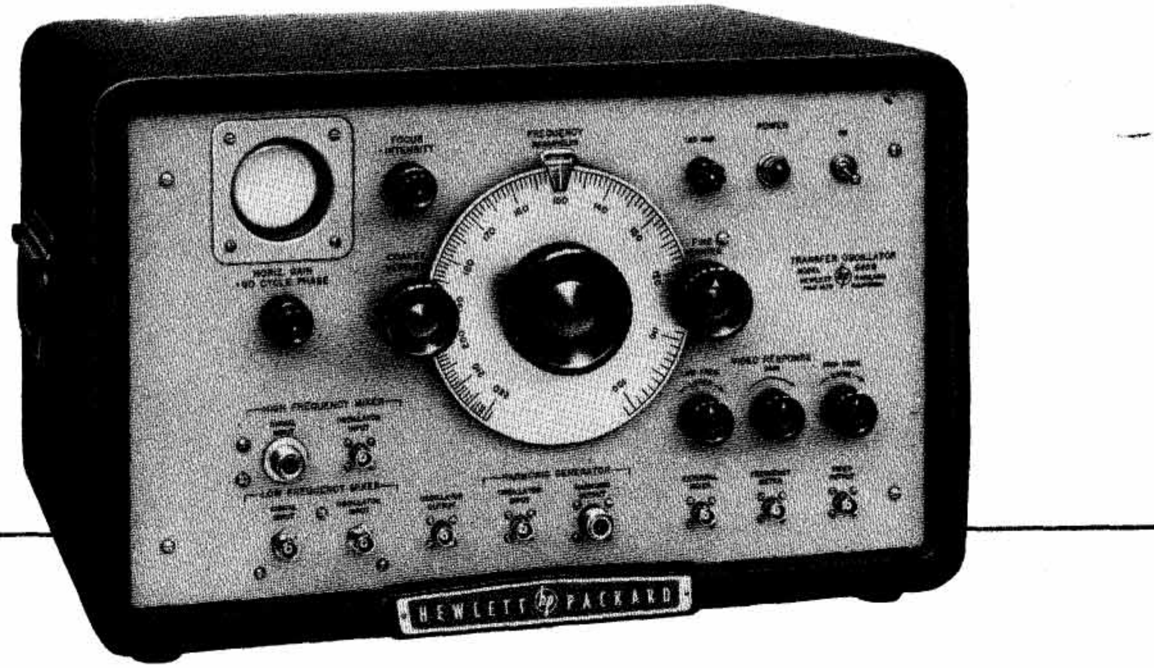
Model 540B contains a highly stable 100 to 220 MC oscillator generating harmonics to at least 12.4 GC (KMC) for comparison. Comparison is made by means of a broadband, untuned, diode mixer system, amplifier and oscilloscope, all within the instrument. In addition, the built-in harmonic generator provides signals for driving external amplifiers and mixers for measurements above 12.4 GC.*

Combined with an hp 524 series Counter with hp 525B Frequency Converter plug-in, the 540B extends the 524's range to 12.4 GC. With the new hp P932A Harmonic Mixer, simple, accurate measurement is available to 18 GC.

In operation, with approximate signal frequency known, the hp 540B is tuned until one of its harmonics beats with the unknown. The multiplying factor is noted. The transfer oscillator frequency is then measured directly on the 524 Counter. The 524 frequency reading, times the multiplying factor, gives the frequency of the unknown signal. When the signal frequency is totally unknown, a convenient calculation employing two or more harmonics is used to determine the multiplying factor.

In measuring carrier frequency of pulsed signals, an external oscillosynchroscope is used to display the detected pulse. Zero beat appears as horizontal lines across the pulses when

*The use of external traveling wave amplifiers and waveguide mixers for measurements in P, K and R bands (12.4 to 40 GC) is described in Application Note No. 2, available on request.



the oscillator is tuned to an exact sub-multiple. Video amplifier frequency response controls can be used to simplify this procedure.

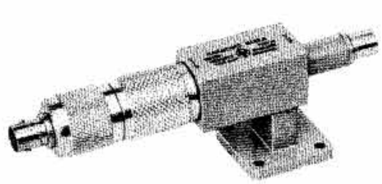
In working with noisy or AM signals, the hp 540B response can be narrowed to obtain a more accurate indication of zero beat.

In signals with appreciable FM, the 540B's oscilloscope presents a characteristic pattern pin-pointing upper and lower frequency deviation limits. If FM deviation is present, center frequency may also be determined.

P-Band Measurements

The hp P932A Harmonic Mixer mounts directly in the waveguide system and operates with either the 540A or 540B, mixing generated harmonics with the unknown waveguide frequency. The mixer's beat frequency output is applied to the 540. The measuring procedure is the same as the procedure using the 540's internal mixer.

An earlier hp Transfer Oscillator, Model 540A is widely used for making measurements to 5 GC. The hp 934A Harmonic Mixer operates from 2 to 12.4 GC, and extends the range of the 540A from 5 GC to 12.4 GC. Both the 934A and P932A are fixed tuned.



hp P932A Harmonic Mixer.

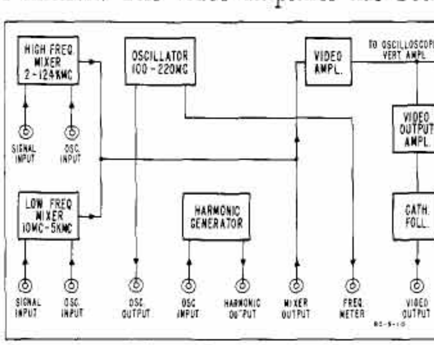
Accuracy

The system's accuracy approaches that of the electronic counter on clean CW signals. On pulsed signals, accuracy is governed by carrier frequency and pulse length. On noisy or intense AM signals, the transfer oscillator system with hp 540B often provides the only means of accurate measurement. Overall system accuracy is greater than 10 times that of the best microwave wavemeters.

A direct-coupled reactance control circuit in the hp 540B allows the oscillator to be locked at a sub-multiple of the measured frequency when it is desirable to measure automatically or record drift characteristics of microwave signal sources.

Quality Features

Each of the circuit elements of hp 540B may be used separately by shifting front panel patch cords. Controls are provided for coarse and fine mechanical tuning. There also is an electrical vernier with range approximately ± 125 parts per million. The video amplifier has both gain and bandwidth controls. Horizontal input to the internal oscilloscope is power line frequency with phase control, or external signals from 20 cps to 5 KC.

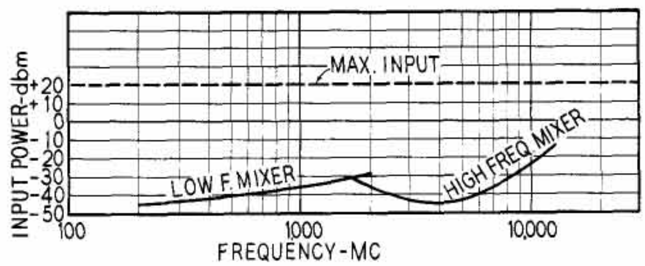


Simplified Block Diagram, hp 540B.

Specifications, Model 540B

General

Frequency Range: 10 MC to 12,400 MC.
Input Signal: CW, FM, AM or pulse.
Input Signal Level: Varies with frequency and individual crystals. *(See chart.)*
Accuracy: CW: Approximately 1/10,000,000 or better.



Typical Sensitivity, Model hp 540B.

Oscillator

Fundamental Frequency Range: 100 MC to 220 MC.
Harmonic Frequency Range: Above 12,400 MC.
Stability: Less than 0.002% change per minute after 30-minute warmup.
Dial: Six inch diameter, calibrated in 1 MC increments. Accuracy: ± 0.5%.
Output: Approximately 2 v into 50 ohms.

Amplifier

Gain: Adjustable. Maximum 40 db or more.
Bandwidth: Variable. High Frequency: 3 db point adjustable approximately 1 KC to 2 MC. Low Frequency: 3 db point switched from 100 cycles to below 10 KC. Adjustable to above 400 KC.
Output: 1 v rms maximum into 1,000 ohms.

Oscilloscope (Self-Contained)

Frequency Range: 100 cps to 200 KC.
Vertical Deflection Sensitivity: 5 mv rms per inch at mixer output.
Horizontal Sweep: Internal, power supply frequency with phase control, or external (connection at rear) with 1 v per inch, 20 cps to 5 KC.

Miscellaneous

Size: Cabinet Mount: 20¾" wide, 12½" high, 15¼" deep. Rack Mount: 19" wide, 10½" high, 14¼" deep behind panel.
Weight: Net 42 lbs. Shipping 53 lbs. (cabinet mount). Net 35 lbs. Shipping 50 lbs. (rack mount).
Power Supply: 115/230 v ± 10%, 50/1,000 cps, approximately 110 w.
Auxiliary Equipment:
hp 524 Electronic Counter, *(see pages 104-106)*.
hp 525B Frequency Converter, $300.00.
Price: hp 540B, $850.00 (cabinet); hp 540BR, $835.00 (rack mount). hp 540B mixer [2 to 12.4 GC(KMC)] available for use with hp 540A; specify Model 934A, $150.00; hp P932A Mixer (12.4 to 18 GC) for use with 540A and 540B, $250.00.

Data subject to change without notice.

ⓗⓟ 560A/561B DIGITAL RECORDERS; 570A/571B DIGITAL CLOCKS

Prints 11-Digit Information at Rates of 5 Lines Per Second

Advantages:

Controllable by electronic or electro-mechanical devices

11-digit parallel entry; primary and supplementary data can be recorded simultaneously

High speed printing rate up to 5 lines/sec.; uses folded or standard roll paper and standard typewriter ribbon

Analog output for strip-chart or X-Y recorder (560A)

Uses:

Recorder for frequency counters, digital voltmeters

Recording of time functions

Digital to analog converter for strip-chart recording

Test, calibration, check-out of telemetering systems

Monitoring, final tabulation and plotting of tests

Investigating drifts in systems and equipment

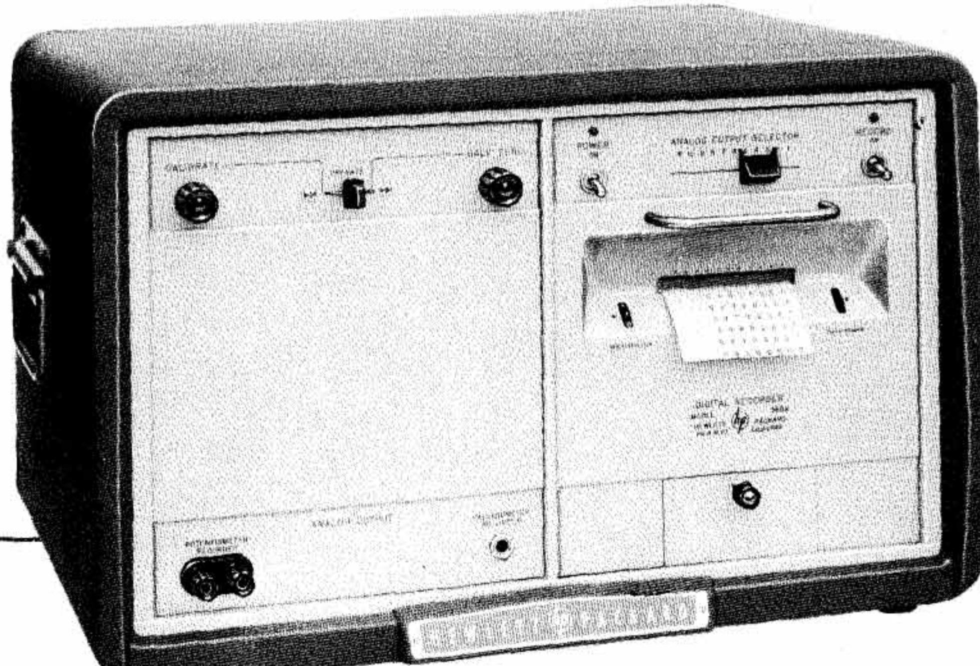
The ⓗⓟ 560 series Digital Recorders, although specifically designed for use with ⓗⓟ electronic counters and voltmeters, are extremely versatile and useful in a wide variety of applications.

Basically, the recorders consist of a motor-driven print mechanism with inked ribbon, printing paper, eleven identical number wheels and eleven circuits which position the number wheels according to the count appearing on an associated electronic counter.

Both Models 560A and 561B have a printing speed of five, 11-digit lines per second. The 11-digit line allows secondary or coding data to be entered simultaneously with primary data. Since each recorder is literally a slave to its associated input, the recorder accuracy is the same as the accuracy of the data gathering input.

Operation—Model 560A

In normal electronic operation, the 11 number wheels are locked in position while the counter is counting. At the end of each counting period, the staircase voltage generated during the count by each decade in the counter comes to rest on the step or voltage level corresponding to the digit displayed by that decade. Each staircase voltage step is sent to the recorder along with a print command pulse which occurs at the end of the count period.



ⓗⓟ 560A

The command pulse then initiates a scanning cycle during which the number wheels are simultaneously positioned according to the staircase voltage levels received from the counter decades and locked in position. At the end of the scan cycle a print of the data is made, and the paper automatically advanced to display the printed count.

Analog Output—Model 560A

Unique features of the ⓗ 560A include an analog output for driving a strip-chart recorder. The analog output available is a voltage or current proportional to the number represented by any three consecutive digits of the recorded data. This feature of the recorder is particularly useful in data reduction work where an expanded scale strip-chart recording of measurements is desired. The strip-chart can never be driven off scale since range variation for the 3-digit scale is 0 to 999. Wider variation results in a repeating of the 0 to 999 sequence.

Specifications—Model 560A/AR

Accuracy: Identical to that of basic counter used.

Printing Rate: 5 lines/sec. max.

Column Capacity: To 11 columns (11 digits per line).

Number Wheels: 12 position, having numerals 0 through 9, a minus, and a blank. Other symbols available.

Data Entry: One wire for each print wheel.

Driving Source: ⓗ and Dymec electronic counters which have recorder kits installed, ⓗ405AR/CR DC Digital Voltmeters with ⓗ 405A-95C Adapter, or other sources providing appropriate input voltages. *(See Counter specifications.)*

Print Command Signal: ± 15 volts peak, 10 μsec or greater in width Manual control with momentary-contact switch.

Paper Required: Standard 3″ roll, or ⓗ #9281-0018 folded paper.

Line Spacing: Zero, single or double, adjustable.

3 Digit Analog Output: 1,000 step staircase directly proportional to count indicated by any three (or the right-hand two) adjacent columns selected by analog output selector switch. (Example: if consecutive digits were 3, 8, and 6; output voltage would be 38.6 millivolts; and 99.9 millivolts if consecutive digits were 999.)

Output Available: 1 ma for galvanometer strip-chart recorders. 100 mv for potentiometer strip-chart recorders.

Power Requirement: 115/230 v ± 10%, 50/60 cps, 250 watts. 4 prints/sec maximum on 50-cycle lines.

Dimensions: Cabinet: 20¾″ wide, 12¾″ high, 18½″ deep. Rack: 19″ wide, 10½″ high, 20½″ required rack depth.

Weight: Cabinet Mount: Net 63 lbs. Shipping 87 lbs. Rack Mount: Net 55 lbs. Shipping 80 lbs.

Accessories Available: Additional comparators to increase print-out of basic 560A from 6 columns to a maximum of 11 columns. These comparators plug into sockets in the 560A. Price: 560A-58 Plug-in Comparator Unit, $25.00 each. No. 9281-0018 Folded Paper Tape, Prices: single packet, $1.00; 24 packet carton, $20.00.

Price: ⓗ 560A, $1,325.00 (cabinet); ⓗ 560AR, $1,310.00 (rack mount). (Includes 6 plug-in comparators.)

For 50-cycle power line operation retaining 5 prints/sec maximum, specify H01 560A (cabinet), H01 560AR (rack), add $15.00. With 570A Digital Clock installed and 11 plug-in comparators, specify E01-560A (cabinet), E01 560AR (rack), add $1,175.00.

Maintenance Kits Available: ⓗ 560A-95AB Basic Tool Kit, for general maintenance exclusive of wheel banks, $31.00. ⓗ 560A-95AC Wheel Bank Maintenance Kit includes small spares, $60.00. ⓗ 560A-95AH Spare Parts Kit for general maintenance exclusive of wheel banks $59.00.

Operation—Model 561B

Model 561B Digital Recorder differs from Model 560A in that input is a 10-line coded decimal entry. The 561B is normally operated from an ⓗ Digital Voltmeter or by a modified Frequency Counter (in-line readout types). Model 561B can also be operated from relays, stepping switches and beam switching tubes because separate connections are made for each wheel position.

The principle of operation is as follows: When a print command is received, the clutch engages, turning the number wheels. Each number wheel turns until its armature contacts a voltage which is negative with respect to the cathode of a tube. A negative voltage on the grid of the tube de-energizes the solenoid and drops the pawl, thus stopping the number wheel in the appropriate position.

Specifications—Model 561B/BR

Same as 560A except:

Column Capacity: 11 columns.

Input: Decimal code, 10 lines plus 2 lines for blank and asterisk for each column.

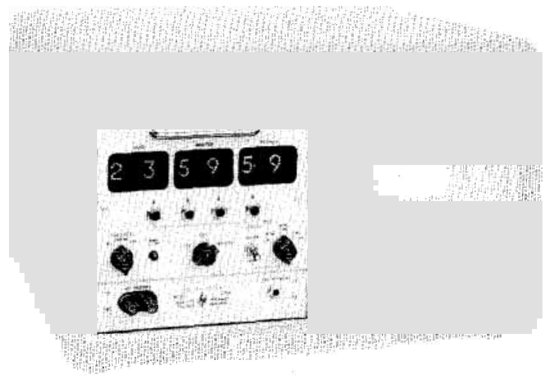
Driving Source: ⓗ In-line readout counters having 561B recorder kits installed. *(See Counter specifications.)* ⓗ Digital Voltmeter. *(See Voltmeter specifications.)* Stepping Switches, Relays, Beam Switching Tubes, contact closure, or −15 to −100 volts connected to appropriate number wire. Operates from 10-line coded systems.

Print Command: ± 15 volts peak or more, 10 μsec minimum width, or external contact closure. Manually controlled by a momentary contact toggle switch. Print commands during scan and print action have no effect.

Power: 115/230 v ±10%, 50/60 cps, approximately 75 watts. 4 prints/sec maximum on 50-cycle lines. For 50-cycle operation retaining 5 prints/sec specify, H03 561B (cabinet); H03 561BR (rack), add $15.00. With 571B Digital Clock installed specify E01 561B (cabinet), E01 561BR (rack), add $950.00.

Price: ⓗ 561B, $1,150.00 (cabinet); ⓗ 561BR, $1,135.00 (rack mount).

ⓗ 570A/571B Digital Clocks



560A with 570A Installed

Models 570A and 571B Digital Clocks mount in the left-hand side of ⓗ 560A and 561B Digital Recorders, respectively. These clocks provide time-of-day information for addition to other recorded data, and can control rates at which measurements are made.

Time is indicated in a 23-hour, 59-minute, 59-second arrangement; display is by bright, in-line indicator tubes with all time digits available for printing.

For maximum flexibility, two operating modes are provided. In the first, ⓗ or Dymec digital counters, digital voltmeters or other external equipment initiate print commands; time is printed along with primary data. In the second mode, (for long-term tests which require infrequent readings) the Digital Clocks determine the rate at which readings are made. Sampling intervals are selected on a front panel switch offering sampling rates of 1/second, 6/minute, 1/minute, 6/hour, 1/hour. Models 570A/571B operate from an internal or external time base.

ⓗ 570A (fits 560A/AR), $1,050.00.

ⓗ 571B (fits 561B/BR), $950.00.

Data subject to change without notice.

562A DIGITAL RECORDER

Flexible Data Input With Information Storage

Advantages:

- Permits increased rate of data collection with information storage; 2 millisecond data transfer
- Parallel entry 4-line BCD input
- Versatile operation; converts to other codes with plug-in cards; can operate with different codes on separate wheels
- Reliable, low maintenance operation with transistorized construction
- Dual input provision to permit simultaneous printing from two unsynchronized data sources.

Uses:

- Record readings of hp Transistor Counters
- Provide permanent record of readings in specialized systems
- Record output from two devices.

Hewlett-Packard Model 562A Digital Recorder is a transistorized 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. 12 digit capacity is available on special order. Model 562A uses the same fast mechanical system pioneered by hp in Models 560A and 561B Digital Recorders.

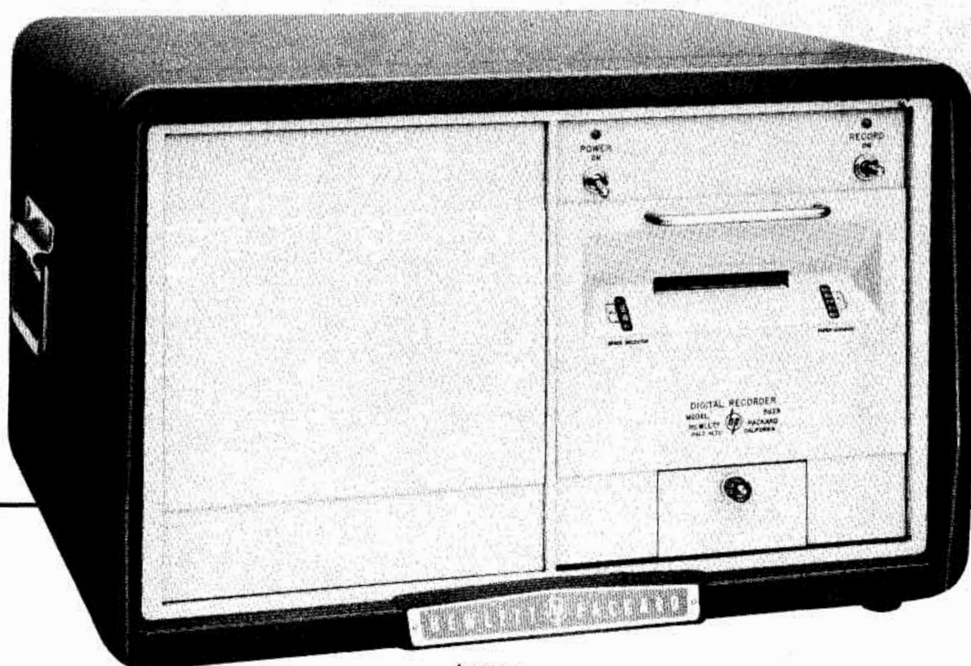
Data Storage

A unique data storage feature allows the driving source to transfer its data to hp 562A in 2 milliseconds. As soon as this data transfer is completed, the driving source is released to gather more information. Reducing the time that the driving source must hold a reading makes possible a higher rate of data collection.

Although designed primarily for use with the new family of hp Transistor Counters, Model 562A is extremely flexible, and can be used in a wide variety of individual and system applications.

Data Entry

Standard input for Model 562A is parallel-entry 4-line BCD code (1-2-2-4). Data enters the unit through two 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. On print command each storage binary unit



hp 562A

assumes the condition of the decade counting unit (or other driving source) connected to it. This data transfer takes place in 2 milliseconds, after which time the driving source is free to accumulate additional information.

The storage binary unit for each column is mounted on a plug-in card with a resistor matrix, which translates the stored data into positioning information for the print wheels. Normally, Model 562A is equipped to translate 1-2-2-4 BCD, but other 4-line codes are accommodated simply by substituting plug-in cards. 10-line code operation is also available by card substitution and the mounting of additional input plugs. However, information storage is not available for 10-line data.

Since each print wheel operates with its own plug-in card, different input codes may be used for separate wheels. For further flexibility, ⓗⓟ 562A is available with dual input coupling to print data simultaneously from two unsynchronized sources.

In addition to the standard print wheels which have numerals "0" through "9," a minus sign and a blank, a wide variety of special character wheels may now be obtained from stock.*

Specifications

Accuracy: Identical to input device used.

Printing Rate: 5 lines/second maximum.

Column Capacity: To 11-columns (12 available on special order).

Print Wheels: 12 position, numerals 0 through 9, a minus, and a blank. Other symbols available.*

Driving Source: Parallel entry 4-line BCD, 1-2-2-4. Other codes available. Source reference voltages establish "0" and "1" states, which may be 100 v above or below ground. "1" state 4 to 75 volts above reference. Driving power approx. 30 μa into 270,000 ohms.

Print Command Signal: Positive or negative pulse, 20 μsec or greater in width, 6 to 20 volts.

Hold Signal: − 7 v to + 15 v and + 15 v to − 7 v (2 signals).

Transfer Time: 2 ms.

Paper Required: Standard 3" roll or folded paper.

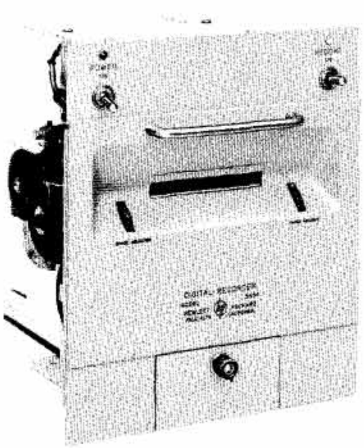
Line Spacing: Single or double, adjustable.

Power Requirement: 115/230 v ± 10%, 50/60 cps, (4 prints/sec maximum at 50 cps).

Dimensions: Cabinet 20¾" wide, 12½" high, 18½" deep. Rack: 19" wide, 10½" high, 16⅞" deep behind panel.

Weight: Cabinet: Net 35 lbs. Shipping 70 lbs. (approx.) Rack: Net 30 lbs. Shipping 63 lbs. (approx.)

Price: ⓗⓟ 562A/562AR, on request.



ⓗⓟ 565A

ⓗⓟ 565A Digital Printer

Model 565A is a fast eleven-column Digital Printer designed specifically for use in custom systems. It is mechanically similar to the printing mechanisms in ⓗⓟ 560/561/562 Digital Recorders.

Model 565A is useful as an output device in computer and data handling systems, as well as other systems involving electronic counters, mechanical counters with an electrical output, stepping switches, relays, beam switching tubes and other digital devices.

Because of the variety of performance characteristics encountered by designers of custom systems, the methods employed to drive Model 565A Digital Printer can vary considerably. For maximum compatibility with the input and control systems encountered, and for simplified field maintenance, all connections are made through connectors at the rear of the instrument.

Specifications

Number of Columns:† 11.

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/sec.

Standard Characters:† 0 through 9, minus sign (−), blank. Dimensions: approximately 0.085" wide, 0.100" high. Column spacing: ¼". Line spacing: 5/32" single space; 5/16" double space.

Print Wheel Position: Controlled by electromagnetically-operated pawls. Wheel position sensed through brush and commutator associated with each print wheel. Maximum commutator current 1 ma. Note: Circuitry for sensing wheel position and operating pawl magnets not included in printer mechanism.

Controls: (1) Front panel POWER switch with pilot light.
(2) Front panel RECORD switch with pilot light. Has momentary position for manual print command.

Power Requirements:† Motor: 115 v ±10%, 60 watts, 50/60 cps (4 prints/sec maximum at 50 cps). Clutch solenoid: 240 volts dc ±10%, 75 ma (operates for approximately 15 msec to initiate printing cycle).

Pawl Magnets: 5.8 volts dc ± 10%, 15 ma (operate when needed during printing cycle).

Dimensions: Front panel: 9¾" high, 8⅜" wide, 9¾" deep behind panel.

Weight: Approximately 15 lbs.

Accessories Furnished: ⓗⓟ 565A-95A Mounting Tracks and Guides. ⓗⓟ 560A-95N Service Kit, contains machine oil, moly oil and type cleaner. 1 packet 1052-24 folded paper tape. 1 1056-6 inked ribbon.

Accessories Available: 125-123 36 pin plug, 1 required, $4.25. 125-125 50 pin plug, 3 required, $5.25 each. ⓗⓟ 560A-95N Service Kit, $3.50. 1056-6 inked ribbon, $3.50. 560A-131A folded paper tape, 24 packet carton, $20.00.

Price: ⓗⓟ 565A Digital Printer, $640.00 each in quantities of 1 to 9; $620.00 each in quantities of 10 to 24; $600.00 each for 25 or more. For 115 v 50 cps operation with 5 prints/sec capability specify H27-565A, $653.00 each in quantities of 1 to 9; $630.00 each in quantities of 9 to 24; $608.00 each for 25 or more. For 230 v 50 cps operation with 5 prints/sec capability specify H24-565A, $655.00 each in quantities of 1 to 9; $632.00 each in quantities of 10 to 24; $610.00 each for 25 or more.

†Others available on special order.

Data subject to change without notice.

The accuracy with which frequency and time intervals may be measured or generated is of vital importance in basic research and in the development, production and maintenance of modern systems and associated instrumentation. In order to provide the performance required in satellite and missile operations, single sideband and time-coded communication, precise navigation systems and similar applications, Hewlett-Packard places major emphasis on the development of high-performance frequency and time standard systems.

Accuracy in the Broad Sense

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 major design objectives at Hewlett-Packard.

The absolute accuracy which you can achieve and maintain with hp systems depends not only upon equipment performance, but also on (1) the accuracy of the reference used and (2) the techniques of comparison and adjustment employed.

By careful use of suitable comparison method, coupled with adequate record-keeping and necessary adjustment, the user may establish and maintain high system accuracy based on the broadcast standards. Two proven comparison techniques available to the user are discussed below.

Necessary equipment characteristics provided by Hewlett-Packard systems are: (1) suitable oscillator stability, (2) high-accuracy comparison capability, (3) reliability and (4) operational simplicity.

Oscillator Stability

Improved long-term stability directly increases the permissible time between oscillator adjustments required to maintain a given absolute accuracy. If an oscillator exhibits long-term stability of + 5 parts in 10^{10} per day, for example, adjustments at twenty-day intervals will permit the user to maintain accuracy of $\pm$ 5 parts in 10^9*; if long-term stability were +5 parts in 10^9 per day, adjustments at two-day intervals would be required for the same accuracy.

Long-term stability of Hewlett-Packard quartz oscillators is conservatively rated at 5 parts in 10^{10} per day and the user may usually expect performance which is substantially better than specification.[1] Such performance results from (1) the use of carefully tested, high-quality crystals, (2) precise control of oven temperature, (3) circuitry which has proven, inherent stability, and (4) AGC action which maintains crystal dissipation level at less than 1/4 microwatt. Careful attention to other details such as shock and vibration isolation, shielding, load isolation, and effects of supply voltage variation are also contributing factors.

The crystal operating level chosen provides the best compromise between long-term stability and short-term stability. The short-term stability specification for the hp 103AR, for example, is $\pm$ 5 parts in 10^{10}, and this specification is based on the average of the frequency over one-second intervals. This specification includes effects of variations in ambient temperature from 0-50°C, variations in dc supply voltage from 22-30 v, variations in load impedance from a few ohms to several hundred ohms, and other variations in environmental conditions. As a result, the user can usually expect short-term stability on the order of one part in 10^{10} (averaged over one second) when the oscillator is operating under normal laboratory conditions. *(See Figure 1.)*

[1]See Hewlett-Packard JOURNAL, Vol. 12, No. 3, November, 1960.

*This assumes no error in the broadcast standard and comparison error small enough to be neglected.

Spectral Purity

For applications which require extreme spectral purity, hp 104AR is offered. This oscillator is similar to Model 103AR, but has an additional 5 megacycle output which can provide a spectrum only a few cycles wide when multiplied to the gigacycle region.

Comparison Methods For High Accuracy

I. Frequency Standards

a. Time Comparison Method

Frequency standards may be calibrated and monitored by means of time comparisons with broadcast standard time signals as shown in Figure 2. Transmissions from WWV (WWVH, MSF, JJY or any other station transmitting precise time signals) are received and their "time ticks" are connected to the vertical input of the oscilloscope. The hp 113BR Frequency Divider and Clock derives "local ticks" from the output frequency of the 103 AR Quartz Oscillator. The "local ticks" are used to trigger the oscilloscope.

At the beginning of a test, the "time ticks" and "*local ticks*" may be as much as ½ second apart. By successive adjustment of the 113BR or the 114BR, *(see pages 122, 123)* and oscilloscope sweep speed, a reference condition is established in which the time between the two ticks is very short and is accurately known. The amount by which the TIME REFERENCE control must be adjusted to re-establish

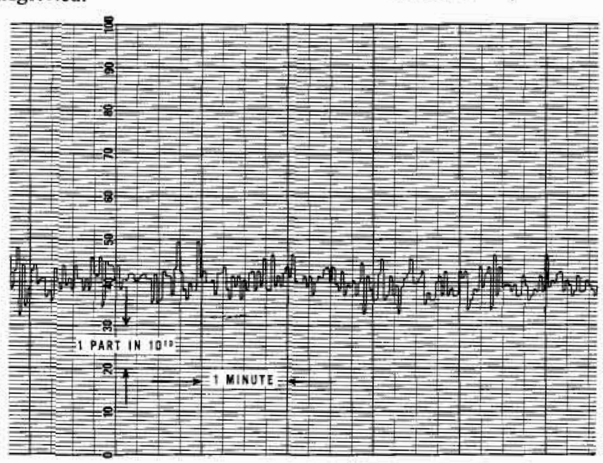


Figure 1. Typical short-term stability, hp 103AR.

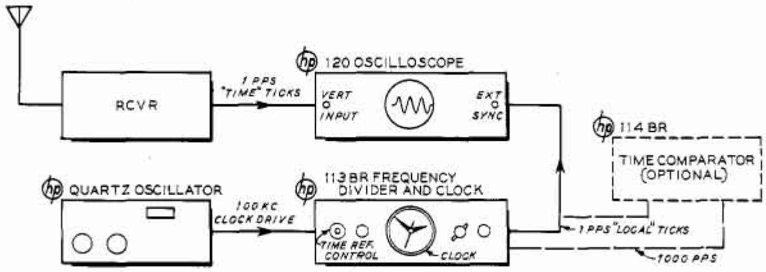


Figure 2. Time Comparison for Frequency Standard Calibration.

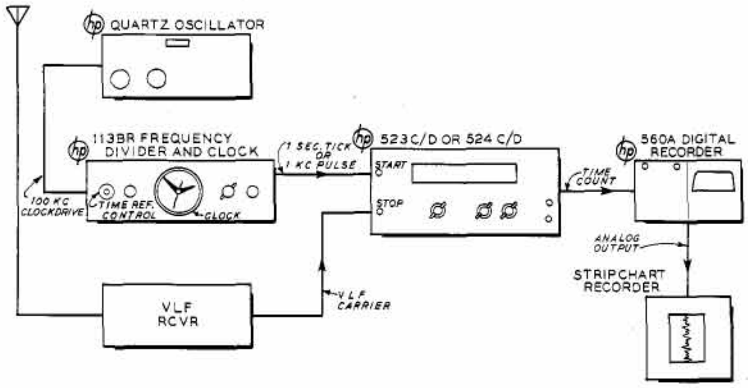


Figure 3. VLF Comparison System[3]

the reference condition in subsequent tests indicates the time drift of the oscillator under test. By plotting the data obtained over a period of time, drift rate and frequency error may be determined very accurately and oscillator frequency can be readjusted to keep it within predetermined accuracy limits. Time comparisons made over several days can yield comparison accuracy of a few parts in 10^{10}.[2]

b. Frequency Comparison Using VLF Transmissions

Since vlf transmissions are virtually free of the propagation problems encountered with hf signals, an alternate method for calibration of frequency standards is based on frequency comparisons with the vlf standard stations such as NBA and WWVL. By this method, comparison accuracy of one part in 10^9 may usually be achieved in less than one hour. Tests conducted for longer periods will increase the comparison accuracy proportionally.[3] Equipment for vlf comparison is shown in Figure 3.

Output from the 113BR Clock is used to start the time interval counter and the next cycle of the vlf carrier is used as the "stop" signal. Trigger level and slope controls on the time interval counter permit selecting given and repeatable points on the start and stop signals. The resulting time-interval readings are printed by the ⓗⓟ 560A Digital Recorder and continuously plotted on a strip chart recorder using the 560A analog output. This analog record gives the relative time drift of the oscillator under test compared to the vlf carrier. From the time drift record, the user may determine frequency error and rate of frequency drift for his oscillator.

2. Time Standards

Maintenance of maximum time accuracy generally requires that oscillator frequency be maintained within close limits by some method such as those discussed above. In addition a suitable technique is required for synchronizing time signals from the system. The method most commonly employed for time synchronization of widely separated clocks is one-way transmission of time signals using hf propagation.[4] Time signals carried by the standard broadcasts from WWV, WWVH and others are locked to the frequency of the transmissions and may be used to synchronize the ⓗⓟ time standard with national standards.

This method of synchronization requires precise knowledge of propagation time length between the standard broadcast transmitter and the local receiver. From longitude and latitude data, the great circle distance can be calculated and from this, ground-wave propagation time is easily determined. The next step is to calculate propagation times for a given mode sky-wave signal. These calculations are simplified by published curves for assumed layer heights and propagation modes.

Once propagation time is known, the 113BR Clock is set to agree with the time information contained in the standard broadcast transmissions. Corrections, as required, can then be made to the Quartz Oscillator and to the 113 BR Clock itself to maintain the required time accuracy.

To date, information bandwidth characteristics have limited the use of vlf for time-of-day information and for time comparison measurements.

Reliability and Fail-Safe Operation

It is important to minimize downtime of a frequency or time standard but, far more important, the accuracy which may be attained in the system is directly dependent upon continuity of operation. Further, the system must be fail-safe to prevent the accumulation of insidious frequency or time errors. Hewlett-Packard frequency and time

[2]Dexter Hartke, "A New Clock for Improving the Accuracy of Local Frequency and Time Standards," ⓗⓟ Journal, Vol. 11, No. 3-4, November-December, 1959.

[3]For a complete discussion of vlf frequency comparison measurements with ⓗⓟ laboratory equipment, Application Note 50 is now available from Hewlett-Packard upon request.

[4]See NBS Technical Note No. 22, "Precise Time Synchronization of Widely Separated Clocks" by A. H. Morgan.

standards employ simplified, optimized designs which display a high order of inherent dependability. Premium components are used with substantial derating to provide large safety margins. Development has been considered complete only when all component values have been optimized and rigid environmental tests have been passed. Before release for production, pilot run quantities of each type of instrument must pass independent evaluations, generally including additional environmental testing to commercial as well as military specifications. Testing prior to shipment is a meticulous, unhurried procedure which continues until performance significantly better than specification has been clearly established.

Fail-safe operation results mainly from three Hewlett-Packard equipment characteristics: (1) The Standby Power Supply employs a standby battery to provide continued operation in event of line failure, (2) Dividers used in ⓗⓟ Quartz Oscillators and in the 113BR Frequency Dividers and Clocks will not respond to spurious signals, and (3) Output from the dividers will stop and remain stopped upon any interruption of driving signal or supply power.

Power Supply Considerations

Interruptions in primary power to any quartz oscillator can cause serious changes in output frequency. In addition, if the power interruption is of sufficient length, cooling causes strains in the crystal which result in an increased 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. Since the accuracy attained in time comparison measurements is directly dependent upon the length of time over which the measurements are made, power interruptions to comparison equipment, such as the ⓗⓟ Frequency Divider and Clock, are also undesirable.

Hewlett-Packard Standby Power Supplies operate over wide ranges of ac line voltage and frequency and supply regulated dc to operate the Quartz Oscillator and Frequency Divider and Clock. These supplies are designed to operate with standby batteries which assume the load immediately without switching or undesirable transients whenever ac line power fails. When line power is restored, the supplies immediately reassume the load and automatically recharge the standby batteries. Alarm systems include local indication of operating conditions and provisions for remote alarms.

Fail-Safe, Regenerative Dividers

To assure the user that output signals can neither gain or lose time with respect to the driving source ⓗⓟ Frequency and Time Standard Systems utilize regenerative frequency dividers of a non-self-starting design with simple push button starters. Small gains or losses of time, which could be difficult to detect, would not only degrade accuracy of generated time signals but would also impair the accuracy of comparisons utilizing those signals.

Sharp tuning makes ⓗⓟ regenerative dividers virtually invulnerable to noise bursts or other spurious signals which would cause pulse counters or phantastron dividers to "gain" in time. 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.

Operational Simplicity

For convenience and speed in making time comparisons, both the 113BR Frequency Divider and Clock and the 114BR Time Comparator are calibrated directly in milliseconds and microseconds. Controls on all system components are simple and clearly identified. Front panel meters facilitate monitoring important voltages and currents in the system.

To simplify oscillator frequency adjustments, the fine frequency controls on ⓗⓟ quartz oscillators are calibrated directly in parts in 10^{10} frequency change. The time indicated by the 113-BR Clock may be reset without affecting the position of time signals generated by the system.

Use of the specially designed standby power supplies and associated standby batteries eliminates concern over operating problems such as line voltage variations and power interruptions.

ⓗⓟ Frequency and Time Standard systems are well suited for use in sea-going vessels, aircraft and trucks, as well as for general laboratory and field use. They are characterized by small size, moderate weight, low power requirement, extended standby operation and ability to withstand a wide range of environmental conditions.

Systems Concept

Since most users prefer to have one company assume overall responsibility for a frequency and time standard system, Hewlett-Packard has developed systems capability suited to the most exacting requirements. ⓗⓟ maintains large, well equipped research, development and manufacturing facilities in order to meet stringent requirements in performance, quantity and delivery time. This program is supported by the ⓗⓟ Precision Components Division which provides quartz crystal research and production, and by the ⓗⓟ Quality Assurance Department which includes such services as components evaluation and environmental test.

The instruments described on the following pages constitute an integrated family of precision devices which may be combined with other Hewlett-Packard and Dymec (a division of Hewlett-Packard) instruments to meet a wide variety of requirements.

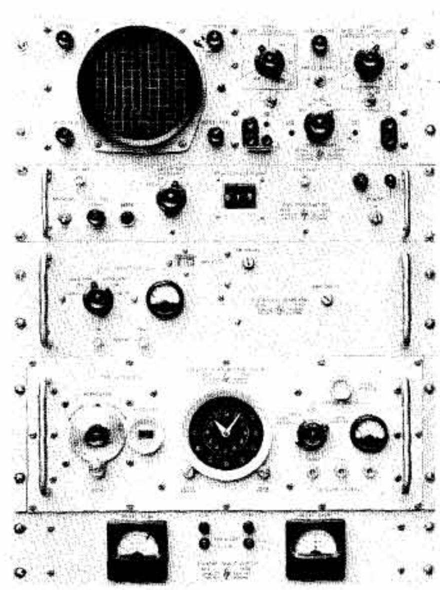


Figure 4. ⓗⓟ Frequency Standard System.

hp 103AR/104AR QUARTZ OSCILLATORS

5 Parts in 10^{10}/Day Stability; Short-Term Typically 1 Part in 10^{10}*

hp 103AR and 104AR Quartz Oscillators make possible improved accuracy in Primary Frequency and Time Standard systems because they provide increased stability, maximum reliability and are easy to adjust.

Long-term stability of hp 103AR and 104AR is conservatively rated at 5 parts in 10^{10}/day. Short-term stability, specified as 5 parts in 10^{10}*, includes effects of variations in supply voltage, load resistance, ambient temperature and other environmental conditions. Models 103AR and 104AR typically display short-term stability of one part in 10^{10} when operated in a reasonably constant environment.

Model 103AR provides two sinusoidal output signals, 1 MC and 100 KC, from a low source impedance at a power level well suited for distribution over 50-ohm systems. A separate 100 KC output is available for driving hp 113BR Frequency Divider and Clock for time comparison measurements and for generating time signals.

Proportionally-controlled double ovens house the crystal and all critical frequency-determining elements and maintain their temperature constant within a few hundredths of a degree. Crystal dissipation level is kept constant at less than ¼ microwatt by AGC action. Frequency changes due to variations in supply voltage and load impedance are virtually eliminated as a result of internal voltage regulation and excellent buffering.

Completely transistorized, hp 103AR and 104AR Quartz Oscillators are compact and rugged, withstand severe environmental conditions and operate for extended periods from standby batteries of moderate size.

Model 104AR has the same high stability as hp 103AR and in addition provides a 5 MC output of extreme spectral purity. Spectra only a few cycles wide in the gigacycle region may be obtained by multiplication of this 5 megacycle output.

*Averaged over 1 second intervals.

Specifications

Overall Stability: Long-Term: 5 parts in 10^{10} per day. Short-Term: Better than 5 parts in 10^{10} averaged over 1-sec. intervals.

Output Frequencies: 103AR 1 MC, 100 KC, 1 v rms into 50 ohms; 100KC for driving hp 113.
104AR 5 MC, 1 MC, 100 KC, 1 v rms into 50 ohms; 100 KC for 113.

Harmonic Distortion: At least 40 db below rated output.

Non-Harmonically Related Output: At least 80 db below rated output.

Output Terminals: 103AR and 104AR: 1 MC, 100 KC, front and rear BNC connectors. Clock drive 100 KC, rear BNC.
104AR: 5 MC front and rear BNC connectors.

Frequency Adjustments: Coarse: Screwdriver adjustment with range of approximately 1.5 parts in 10^{6}. Accessible through front panel by removing threaded plug.
Fine: Front panel control with range of approximately 600 parts in 10^{10}. Accessible through front panel by removing threaded plug. Digital indicator calibrated directly in parts in 10^{10}.

Monitor Meter: Ruggedized front-panel meter and associated selector switch monitors:
103AR and 104AR: SUPPLY voltage, OSC voltage, INNER OVEN current, OUTER OVEN current, 100 KC output, 1 MC output. 104AR: BIAS, 5 MC output.

Temperature Range: 0 to 50°C.

Size: Rack Mount: 5¼″ high, 19″ wide, 14″ deep behind panel, including cable allowances. 16″ deep overall.

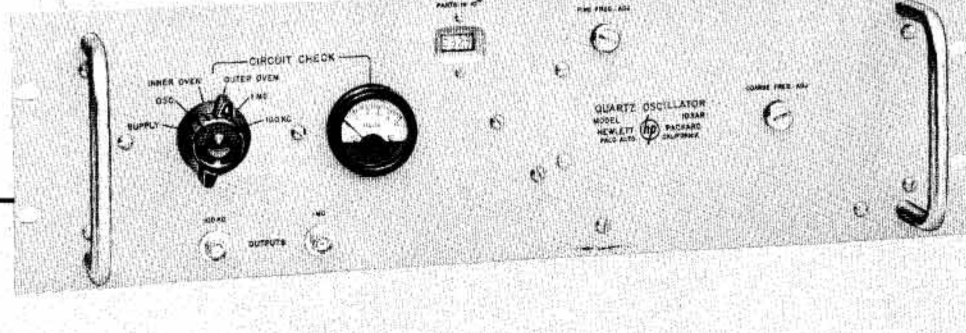
Weight: 103AR, net approx. 17 lbs. 104AR, net approx. 17 lbs.

Power Requirements: 22 to 30 v dc, approx. 5 watts operating, approx. 10 watts during warmup. Dual power connectors at rear.

Accessories Furnished: 6 ft. power cable for connecting Quartz Oscillator to hp 724 or 725AR Standby Power Supply.

Price: hp 103AR, \$2,500.00 (rack mount); hp 104AR, \$3,250.00 (rack mount).

Data subject to change without notice.



hp 103AR

113BR FREQUENCY DIVIDER AND CLOCK

Increased Accuracy From Frequency/Time Standards

Specifications

Input Frequency: 100 KC for solar time, input bandwidth ± 300 cps. 100.3 KC for sidereal time, on special order.

Accuracy: 1) Accuracy of output pulse and sine-wave signals determined by accuracy of input frequency. 2) Time reference dial linearity ± 10 μsec.

Input Voltage: 0.5 to 5 volts rms.

Input Impedance: 300 ohms nominal.

Tick Pulse Output, positive: 1 pps with amplitude of 10 volts or more into minimum recommended load impedance of 4,700 ohms and 200 pf. Rise time, 2 μsec maximum; duration 20 μsec minimum; jitter 1 μsec maximum. Rear BNC connector.

Tick Pulse Output, negative: 1 pps with amplitude of 10 volts or more into minimum recommended load impedance of 1 Megohm and 100 pf. Rise time, 2 μsec maximum; duration 20 μsec minimum; jitter 1 μsec maximum. Front BNC connector.

Auxiliary Pulse Output, 1 pps: At least 2 volts positive into minimum recommended load of 50 ohms and 5,000 pf. Rise time, 1 μsec maximum; duration 200 μsec; jitter, 1 μsec maximum. Rear BNC connector.

Auxiliary Pulse Output, 1,000 pps: At least 4 volts positive into minimum recommended load of 1,000 ohms and 1,000 pf. Rise time, 2 μsec maximum; duration 20 μsec minimum; jitter, 1 μsec maximum. Rear BNC connector.

Auxiliary Output: 100, 10 and 1 KC sinusoidal, 0.25 volts rms, min. Source Impedance 1,200 ohms nominal. Front panel BNC connectors.

Time Reference: Continuously adjustable. Directly calibrated in 10 microsecond increments on dial and in milliseconds on mechanical counter.

Frequency Divider: Manually starting, regenerative type, fail-safe.

Effect of Transients: Will not gain or lose time because of: 1) ±300 volt step function on 100 KC input. 2) 0 to ±50 volt pulses, 0 to 500 pps, 1 to 10 μsec duration on 100 KC input. 3) ± 4 volt step in 26 v dc input.

Clock Mechanism: 24-hour dial; minute hand adjustable in 1 minute steps; second hand continuously adjustable. Manual start. Front panel adjustment of clock hands does not affect tick output. (12-hour dial on special order.)

Monitor Meter: Ruggedized meter and selector switch on front panel for checking supply voltage, divider operation (100 KC, 10 KC, 1 KC) and total clock current.

Increased accuracy from frequency and time standard systems is possible by use of the new hp 113BR Frequency Divider and Clock. Precise comparisons between local standards and hf or vlf broadcasts based on national standards of time and frequency may be made simply and conveniently. Model 113BR also generates precise, adjustable time signals with accuracy determined by the driving oscillator.

Use of the 113BR simplifies recording drift rates, determining time or frequency differences in widely separated systems and permits adjustment of systems for maximum accuracy. By averaging out the effect of hf propagation path errors, use of the 113BR can reduce comparison error to a few parts in 10^{10} within several days. Model 113BR also simplifies vlf comparisons, especially where ICW transmissions are involved.

The hp optical gating system (no contacts, no wear, cannot add jitter) and a directly-calibrated, precision phase shifter make possible the unique accuracy of the 113BR and provide time comparison capability of ± 10 microseconds, where signal conditions permit.

Fail-safe dividers and clock motor reduce the possibility of error, since (1) neither dividers nor motor can respond to spurious signals, (2) interruptions in driving signal or supply power stop all outputs.

Model 113BR is fully transistorized and meets performance requirements of MIL-E-16400.

Power Required: 22-30 v dc, approximately 2 watts. Recommended supply hp 724BR, 725AR.

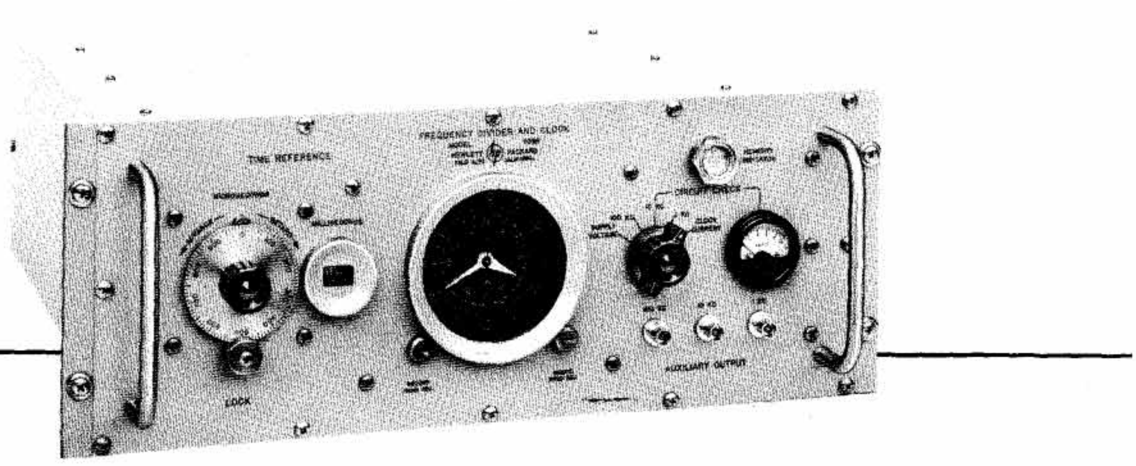
Dimensions: 19" wide, 7" high, 19½" deep behind panel.

Weight: Net 10 lbs. Shipping approximately 21 lbs.

Accessories Furnished: hp 113A-16E Cable, 6 ft. long, connects 113BR to 724BR or 725AR Standby Power Supply.

Price: hp 113BR, $2,750.00.

Data subject to change without notice.



Speed, Simplify Frequency or Time Standards Comparisons

The new hp 114BR Time Comparator provides additional speed and flexibility in making time comparisons between stable oscillators and standard time signal transmissions such as those from WWV. Model 114BR is an auxiliary unit used in conjunction with the hp 113BR Frequency Divider and Clock and an oscilloscope in primary frequency or time standard systems. If time signals generated by the hp 113BR Frequency Divider and Clock are to be used with computers or for system timing signals or similar purposes, the 114BR provides a method of making time comparisons without disturbing outputs from the 113BR.

The hp 114BR Time Comparator consists of an adjustable preset digital delay generator, a sweep generator and a marker generator. An oscilloscope such as hp 120AR is used as an indicator. All critical controls on the 114BR are detented selector switches, and time markers are automatically adjusted to sweep speed. As a result, time comparison by means of the 114BR is simple and fast. Adjustment of the 114BR will not affect operation of the frequency or time standard in any way.

The time difference between the received one-per-second standard time signal and the tick output from the hp 113BR can be resolved to $\pm$ 10 microseconds, where signal conditions permit. The data thus accumulated over a period of days, weeks or months may be used to determine the long-term drift of the stable frequency source or for time checks in time standard systems.

Specifications

Sweep Delay Range: 0 to 999 msec in 1 msec steps with direct reading, in-line front panel switches.

Sweep Output: 1,000, 100, 10, or 1 msec duration as selected by front panel switch. Sweep may be delayed from 0 to 999 msec in 1 msec steps with direct reading front panel switches. Amplitude 1 volt peak-to-peak, dc coupled. Front panel vernier horizontal position control provides fine adjustment of dc level. Recommended display unit, hp 120A/AR Oscilloscope.

WWV Tick Output: WWV Tick, gated at 1-second intervals to provide stable base line for intensity markers between ticks, appears at VERTICAL AXIS BNC connector on front panel.

Z-Axis Output:

Intensity Markers: Marker intervals automatically adjusted to 1/10 of the sweep duration; length automatically adjusted with sweep time. Markers may be switched on or off by front panel switch.

Unblanking Voltage: 50 KC unblanking square wave synchronized with standard frequency for interpolation to 10 μsec or better. Amplitude 40 volts peak-to-peak.

Input Requirements: 1 KC positive pulses from hp 113BR; 1 pps positive pulses from hp 113BR: WWV Tick, 0.1 to 10 volts peak-to-peak to BNC connector on rear.

Self Check: Each digit of delay setting may be checked by means of front panel pushbutton.

Power Requirements: 115/230 $\pm$10% volts ac, 50-1,000 cps; approximately 7 watts.

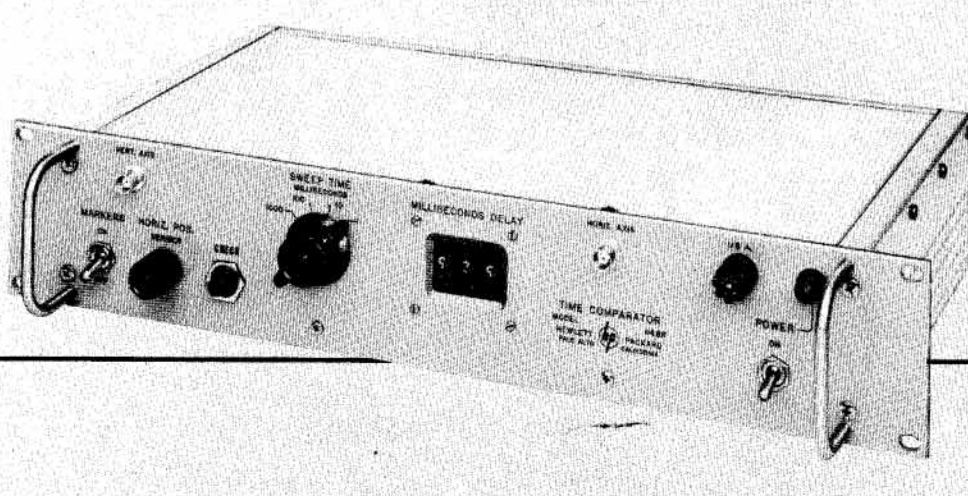
Dimensions: 3½" high, 19" wide, 13½" deep overall, 11½" deep behind panel, including cable allowance.

Weight: Net, approximately 11 lbs.

Accessories Furnished: hp 114BR-16A power cable, 6 feet long, with NEMA line plug; hp 114BR-16B Z-axis cable, 3 feet long; hp 114BR-16C Horizontal axis cable, 6½" long; hp 114BR-16D Vertical axis output cable, 10" long.

Price: hp 114BR, $1,200.00 (rack mount).

Data subject to change without notice.



ⓗⓟ 724BR/725AR STANDBY POWER SUPPLIES

Avoid AC Problems in Frequency, Time Standard Systems

Specifications

Output Voltage: 24 ±1 volts dc.

Rated Current (total external load): 300 ma, nominal.†

Over-Current Protection: Current limiter provides short-circuit protection, eliminates need for load fuses.

Alarm Indicators: Panel lamps indicate (1) OPEN AC LINE FUSES, or (2) AC OFF, indicating ac is not reaching power transformer and load is being supplied by standby battery.

Remote Alarm Provisions: DPDT relay contacts (form C) provided at rear terminals for operating remote alarm from separate power system. Contacts rated at 3 amperes (resistive) at 115 volts ac or 28 v dc.

Panel Meters: Voltmeter and ammeter indicate battery voltage and battery charge/discharge current.

Power Requirements: 115/230 ±10% v ac, 50-1,000 cps.

Output Connectors: MS type female connectors at rear mate with ⓗⓟ 103AR/104AR, 113BR power cables.

Battery (supplied): ⓗⓟ 724BR, Vented Nickel-Cadmium, 16 ampere hour: ⓗⓟ 725AR, Sealed Nickel-Cadmium, 2 ampere hour.

Additional (external) Battery Provision: MS 3106E-14S-2S female connector, with cap, at rear. Mating connector supplied.

Weight: ⓗⓟ 724BR, net 75 lbs., including battery.
ⓗⓟ 725AR, net 20 lbs., including battery.

Dimensions: ⓗⓟ 724BR, 19" wide, 7" high, 14" deep behind panel, including allowance for cables. ⓗⓟ 725AR, 19" wide, 3½" high, 12" deep behind panel, including allowance for cables.

Accessories Furnished: Power cable, 6 feet long.

Price: ⓗⓟ 724BR, including battery, $850.00 (rack mount).
ⓗⓟ 725AR, price on request (rack mount).

†Suitable for operating ⓗⓟ 113BR and 103AR or 104AR at any temperature from 0 to 50°C.

Data subject to change without notice.

ⓗⓟ Standby Power Supplies, Models 724BR and 725AR, improve performance and reliability of frequency and time standard systems by assuring continued operation in the event of ac line power failure. Also, with these standby supplies you can use a standard at various locations, since the system can be kept in operation for extended periods during transport.

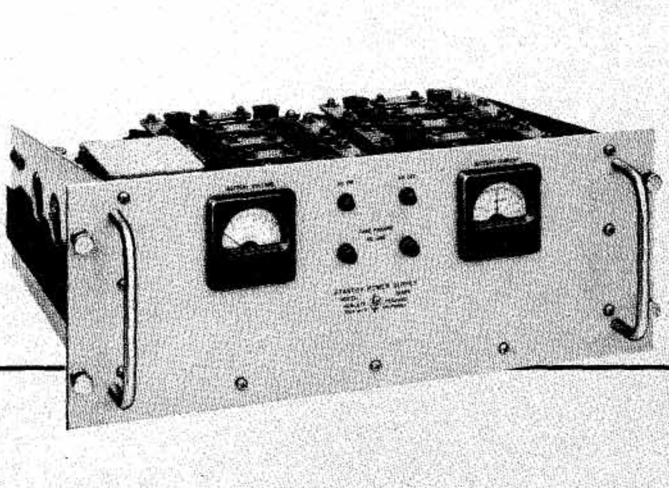
Models 724BR and 725AR are completely automatic, solid-state supplies specially designed to power the ⓗⓟ 113BR Frequency Divider and Clock and ⓗⓟ 103AR or 104AR Quartz Oscillators.* These supplies are designed to operate with standby batteries. The standby battery is kept charged and instantly assumes the load, without switching, in case of ac failure. When line power is restored the supply reassumes the load and automatically recharges the battery.

After a week of operation ⓗⓟ 724BR provides a minimum of 48 hours standby operation at an average temperature of 25°C for an ⓗⓟ Quartz Oscillator and a 113BR Frequency Divider and Clock. Under similar conditions, Model 725AR provides at least six-hour standby operation. A switch at the rear of the 724BR increases standby period at least 50%.

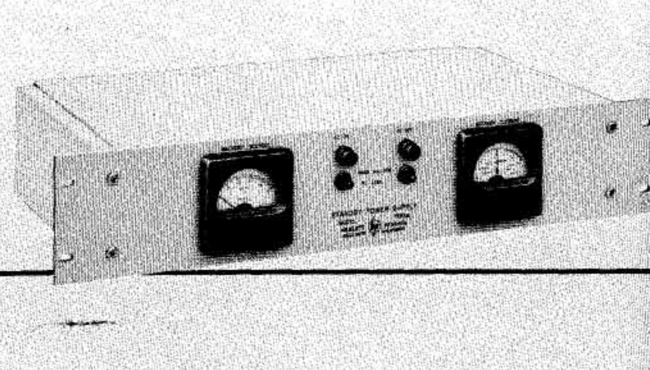
Output is voltage-regulated and current-limited, eliminating the need for output fuses. Operating aids include alarm lamps, contacts for remote alarms and connectors for additional standby batteries.

Both supplies will withstand severe environmental conditions. Model 724BR is equipped with heavy-duty chassis tracks. Models can be supplied to meet performance requirements of MIL-E-16400, Class 4.

*ⓗⓟ 724AR, required for operation with ⓗⓟ 113AR Frequency Divider and Clock, available on special order.



ⓗⓟ 724BR



ⓗⓟ 725AR

100E FREQUENCY STANDARD

5/10⁸ Stability, Multiple Outputs For Test, Production or Lab Use

Good stability and the versatility of a wide variety of outputs are offered by the hp 100E Frequency Standard.

This compact instrument provides six standard sine and four pulse signals for use at many different stations on a production line or in the laboratory.

A particularly useful feature of 100E is a timing comb providing output pips at 100, 1,000, and 10,000 μsec intervals to simplify sweep and time interval measurements.

Model 100E includes a built-in oscilloscope which may be used to calibrate external equipment such as oscillators through use of Lissajous figures or to check the Standard's internal frequency division.

Specifications

Stability: Short term ± 3 parts in 10^8. Long term ± 5 parts in 10^8 per week.

Output Frequencies: Sinusoidal, 10 cps, 100 cps, 1 KC, 10 KC, 100 KC and 1 MC. Pulse 10 cps, 100 cps, 1 KC and 10 KC.

Output Voltages: Sinusoidal 5 v rms minimum into rated load. Pulse approx. 15 v peak-to-peak. Harmonics to 5 MC from 10 KC pulses.

Rated Load: 50 ohms nominal, 100 KC and 1 MC. 5,000 ohms nominal, 10 cps, 100 cps, 1 KC and 10 KC.

Source Impedance: Approx. 50 ohms, 100 KC and 1 MC. Approx. 300 ohms, 10 cps, 100 cps, 1 KC and 10 KC.

Distortion: (Sinusoidal) Less than 4% into rated load.

Timing Comb: Marker pips at 100 μsec intervals. Double amplitude pips at 1,000 μsec, triple amplitude pips at 10,000 μsec intervals.

Oscilloscope: Vertical sensitivity adjustable approx. 3 v rms/inch. Vertical bandwidth approx. 100 cps to 1 MC. Horizontal sensitivity adjustable approx. 2 v rms/inch. Horizontal bandwidth approx. 20 cps to 150 KC.

Frequency Shifter: Panel pushbutton lowers oscillator frequency approx. 0.1 cps at 1 MC to aid in frequency comparisons.

Power: 115/230 v ±10%, 50/1,000 cps, 140 watts.

Dimensions: Cabinet Mount, 11¼" high, 20¾" wide, 18¾" deep. Rack mount, 8¾" high, 19" wide, 16⅝" deep behind panel.

Weight: Net 35 lbs. Shipping 50 lbs.

Price: hp 100E, $925.00 (cabinet); hp 100ER, $900.00 (rack mount).

101A 1 MC OSCILLATOR

5/10⁸ Stability For Electronic Counter Time Base

Designed specifically to be the time base for hp 5275A Electronic Time Interval Counters, the high precision capabilities and low cost of hp 101A make it useful for many other applications as well. This 1 MC oscillator can be used directly to obtain increased accuracy from counters such as hp 523C/D. An optional 100 KC output is available for use with counters such as hp 524B, FR-38U, AN/USM-26, and for other suitable applications.

Model 101A provides an output of at least 1 volt into a 50 ohm load, sufficient to drive a number of electronic counters. Model 101A has a long-term stability of 5 parts in 10^8 per week and is a transistorized version of the proven oscillator used in hp 524C/D Electronic Counters and hp 100E Frequency Standard.*

*hp Journal, Vol. 10, No. 3-4, Nov.-Dec., 1958, "5×10^{-8}/Week Time Base Accuracy in the 10 MC Frequency Counter."

Specifications

Stability: Short term, ±3 parts in 10^8. Long term, ±5 parts in 10^8 per week.

Output Frequencies: Sinusoidal, 1 MC (100 KC optional), BNC connectors.

Output Voltages: 1 v rms minimum into 50 ohm load.

Source Impedance: Approx. 15 ohms.

Distortion: Less than 4% into rated load.

Oven Temperature Indicator: Front panel dial thermometer.

Frequency Adjustment: Front panel screwdriver adjustment with range of approximately 1 part per million for calibration from primary standards.

Power: 115/230 v ±10%, 50/1,000 cps, approx. 9 watts average.

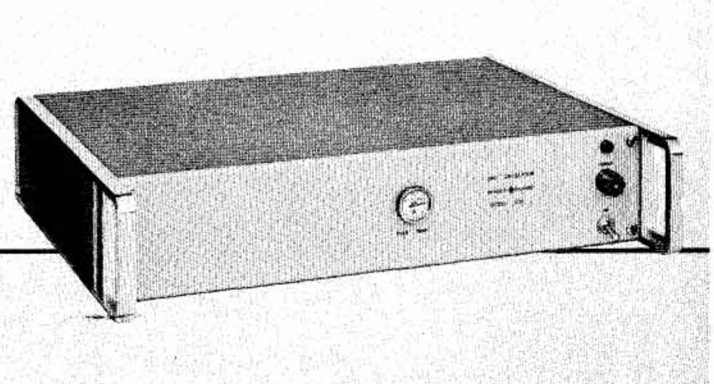
Dimensions: 3½" high, 16¾" wide, 11½" deep behind panel.

Weight: Net: Approximately 10 lbs.

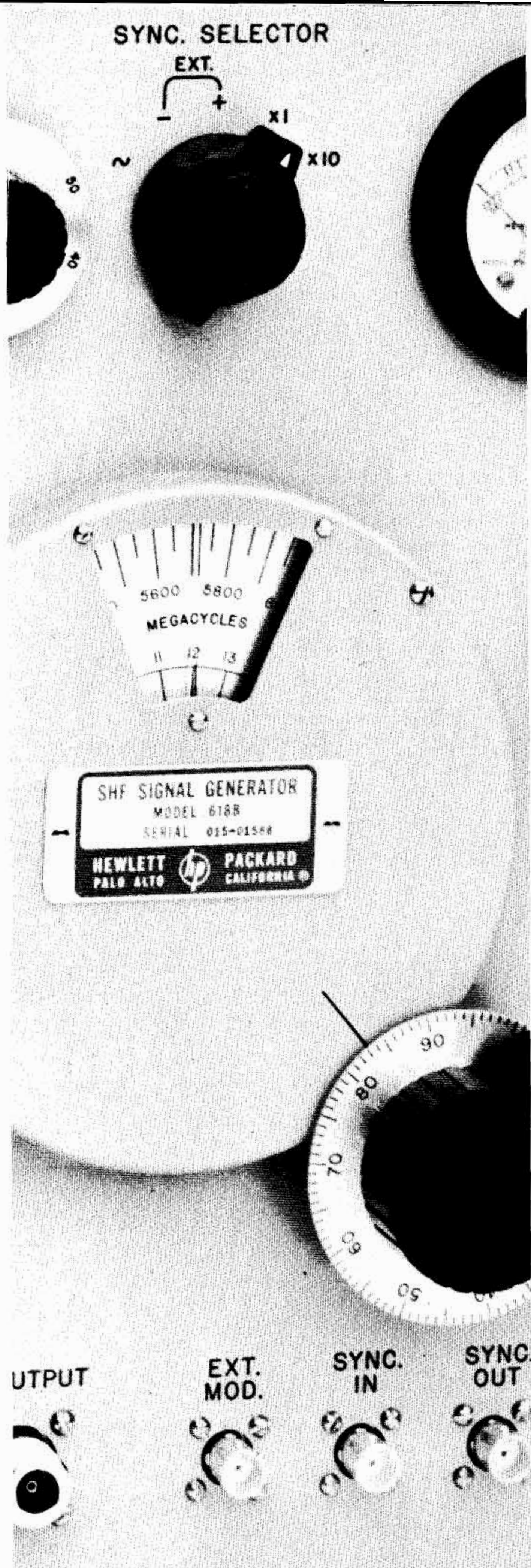
Price: hp 101A, $500.00.

Data subject to change without notice.

hp 100E



hp 101A



SIGNAL GENERATORS

A signal generator is an oscillator calibrated to provide output signals of precisely known frequency and power. Signal generators are essential to many different types of measurement, and in order to adequately serve their purpose, they must meet certain minimum requirements, viz: (1) accurate frequency calibration, (2) accurate and variable output, (3) constant output impedance, (4) varied modulation capabilities, (5) low leakage, (6) low harmonic content, and (7) freedom from spurious or incidental modulation.

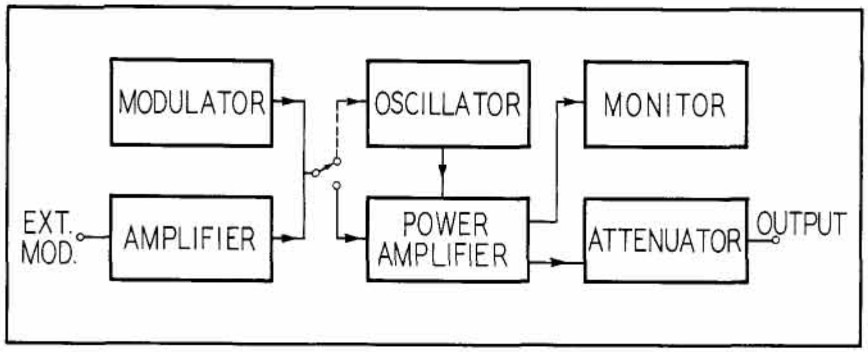


Figure 1. Block diagram of Signal Generators in Group I.

Hewlett-Packard offers a complete easy-to-use line of hf, vhf, uhf, and shf signal generators, 12 precision instruments operating at frequencies between 50 KC and 40,000 MC. Each generator incorporates every basic requirement listed above and is designed so that both frequency and power output are direct reading. This assures utmost convenience and accuracy for all kinds of measurements, including receiver sensitivity, selectivity or rejection, signal noise ratio, gain-bandwidth characteristics, conversion gain, antenna gain, transmission line characteristics; or for driving bridges, slotted lines, filter networks, etc.

Oscillator Types

hp signal generators can be divided into three different groups according to their oscillator circuit design. Signal generators in Group I have master oscillator-power amplifier circuits, those in Group II have reflex klystrons in external cavities, and the signal generators in Group III utilize broadband crystal harmonic generators with low conversion loss to provide rf power at twice the driving frequency. Table 1 shows the important characteristics of these units. Figures 1, 2 and 3 show the basic circuit diagram of each group. Tubes for the oscillator section of hp signal generators are carefully selected for optimum performance over the range of each generator.

Group I signal generators (except hp 612A) are capacitively tuned, and Group II signal generators (including hp 612A) are tuned by adjusting a shorting element that tunes the cavity resonator associated with the oscillator tube. Group III generators depend on the driving generator for tuning and frequency accuracy.

A number of special-purpose signal generators using techniques similar to those of hp instruments are manufactured by Dymec, a division of Hewlett-Packard. See page 209 for specifications.

Modulator Section

Hewlett-Packard generators, in addition to CW emission, also provide amplitude and frequency modulated output. The type of amplitude modulation (pulse, square-wave or sine wave) varies with each signal generator, and it is described in detail in Table 1.

Group II signal generators include internal pulse circuitry which is used for pulse modulation. Considerable care has been taken to achieve a modulating pulse that has good waveform and does not undergo deterioration in

Group	Generator	Frequency Range (MC)	Frequency Accuracy	Calib. Output Range	Output Accuracy	Max. SWR of Output	Modulation: Internal	Modulation: External
I	606A	0.05 - 65	± 1%	0.1 µv to 3 v	± 1 db	1.2	Sine 400 cps ±5% 1,000 cps ±5%	Sine wave, pulse sq. wave
I	608C	10 - 480	± 1%	+ 13 to −127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine wave, pulse sq. wave
I	608D	10 - 420	± 0.5%	+ 7 to −127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine wave, pulse sq. wave
I	612A	450 - 1,230	± 1%	+ 7 to −127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine wave, pulse sq. wave
II	614A	800 - 2,100	± 1%	−10 to −127 dbm	± 1 db −10 to −127 dbm	1.6	Pulse, FM	Pulse, sq. wave
II	616B	1,800 - 4,200	± 1%	0 to −127 dbm	± 1.5 db −7 to −127 dbm	1.8	Pulse, FM	Pulse, sq. wave
II	618B	3,800 - 7,600	± 1%	0 to −127 dbm	± 2 db −7 to −127 dbm	2	Pulse, FM, sq. wave	Pulse, sq. wave, FM
II	620A	7,000 - 11,000	± 1%	0 to −127 dbm	± 2 db −7 to −127 dbm	2	Pulse, FM, sq. wave	Pulse, sq. wave, FM
II	626A	10,000 - 15,500	± 1%	+ 10 to −90 dbm	± 1 db ± 2% of attenuation in db	2.5 at +10 dbm 1.2 at 0 dbm	Pulse, sq. wave FM	Pulse, sq. wave, FM
II	628A	15,000 - 21,000	± 1%	+ 10 to −90 dbm	± 1 db ± 2% of attenuation in db	2.5 at +10 dbm 1.2 at 0 dbm	Pulse, sq. wave FM	Pulse, sq. wave, FM
III	938A	18,000 - 26,500	That of driving source	0 to −100 dbm	±2, 3 db ± 2% of attenuation in db	2.0 at 0 dbm 1.5 at −10 db	Depends on Driving Source	
III	940A	26,500 - 40,000	That of drivng source	0 to −100 dbm	± 1.5 db ± 2% of attenuation in db	2.0 at 0 dbm 1.5 at −10 db	Depends on Driving Source	

Table 1. Characteristics of hp Signal Generators.

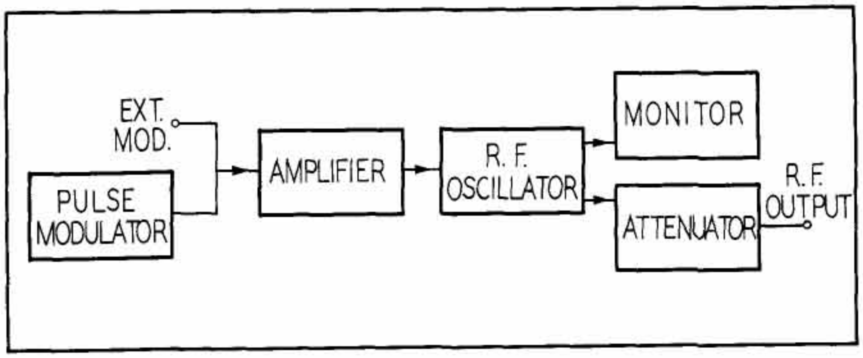


Figure 2. Block diagram of Signal Generators in Group II.

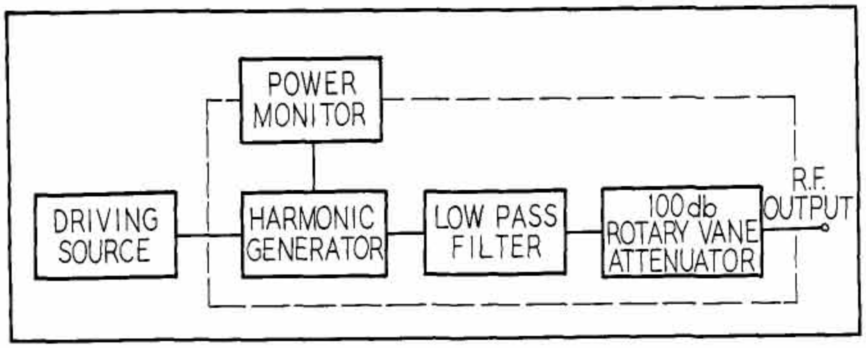


Figure 3. Block diagram of Signal Generators in Group III.

the modulating system. Spurious FM, AM and harmonic content have been kept to a minimum by incorporating well regulated power supplies, good circuit design and excellent construction techniques.

Frequency modulation with variable amplitude and phase is generated internally in signal generators of Group II. The particular type of FM varies with the instrument and may be generated by power line voltage, by a sawtooth generator (40-4000 cps) or by a 1000 cps modulator. In addition, signal generators in Group II (except ⓗⓟ 614A and 616B) can be frequency modulated by signals applied to a front panel jack. These FM features are achieved by taking advantage of the voltage-tuning characteristics of reflex klystrons.

External Modulation Techniques

There are many cases where it is desirable to modulate a signal generator with external signals. The type of modulation used must be applied to the generator in such a way as not to detract from the stability or accuracy of generation. Further, incidental or spurious modulation should not be introduced. Certain precautions, different for different signal generators, should be observed when applying external modulation.

Almost any type of amplitude modulation may be applied to ⓗⓟ 606A, 608C/D and 612A (which employ master oscillator-power amplifier circuits) as long as the modulation bandwidth of the particular instrument is not exceeded.

All modulation in the 606A and 608C/D is accomplished in the amplifier section, and either sine wave, pulse or square wave modulating voltages can be employed. Because the amplifier section of the 608C/D employs a grounded grid circuit, the power is not completely cut off between pulses. The reduction in power output between the time the pulse is on and off is better than 20 db since interelectrode capacity provides some coupling even though the tube is cut off.

In the ⓗⓟ Model 612A, provision is made for applying pulse and square wave modulation directly to either the oscillator or the amplifier section. When modulation is applied to the oscillator section the signal is completely cut off between pulses. It is advisable to apply only square waves or pulses for amplitude modulation to the oscillator section. Other types of modulation should be applied to the amplifier section, the bandwidth limitation of which is 5 MC. The types of modulation employed (with due consideration to above restrictions) will not seriously affect the stability or spurious signal content. There is no provision for FM modulation in Models 606A, 608C/D and 612A signal generators.

In Group II generators utilizing klystron oscillators, it is desirable to use pulse or square wave modulation of sufficient magnitude to completely cut off the generator between pulses. This is necessary to eliminate spurious signals and harmonics. If a square wave generator is not available, a high voltage sine wave may be used. The use of this sine wave will tend to overload the modulator and the sine wave will become heavily clipped — thus applying an approximation of a square wave to the oscillator. Since the grids of the modulator tubes are ac coupled, high level signals drawing grid current will develop a clamp voltage on the grid of the tube. Damage to tubes is thus prevented. The amplitude of the modulating voltages should be approximately 50 volts.

Models 618B, 620A, 626A, and 628A, in addition to external amplitude modulation, have provision for external frequency modulation. Modulation capability depends on the reflex klystrons in each individual generator, and magnitude of the applied modulating voltage should be limited so that the reflector will not be swept into undesired oscillating modes.

Output Section

The output sections of ⓗⓟ generators are designed to achieve high monitor accuracy, high attenuator accuracy and to minimize mismatch between generator and load.

In Models 606A, 608 C/D and 612A, a high order of monitor accuracy is achieved by employing a crystal detector at a low power level. Calibration is performed at a fixed level so monitor detector laws will not cause error in measurement. On other ⓗⓟ generators, accuracy is maintained through use of a thermistor bridge. In these instruments, drift compensating networks are employed to reduce zero drift and sensitivity variations with ambient temperature changes.

Attenuators in the output systems are the waveguide-beyond-cutoff type, (except ⓗⓟ 606A, 626A and 628A), and operate on magnetic coupling for the lowest order mode. This type of attenuator is characterized by linear relation between the attenuation (in db) and displacement (in length units) of the coupling elements. The linear relationship holds except for approximately the first 7 db of attenuation. As long as the attenuator waveguides are well below cutoff, the attenuation will be independent of frequency and will be dependent only upon tube size and type of coupling employed. Attenuator waveguides are accurately sized, and this, in conjunction with magnetic coupling assures that once the relation between attenuator movement and attenuation in db becomes linear, it will stay linear down to the lowest value desired.

Thus accurate measurements are easily obtained whether working into a standard 50-ohm load or into a load adjusted to match exactly with generator characteristics.

Sources of Error

Harmonic Content: In hp signal generators every effort has been made to minimize harmonic content, which is at least 20 db down. Nevertheless for some measurements (as for example, measurements involving filters, slotted lines or pre-selectors) even this residual harmonic content may cause error. Such errors may be eliminated by employing hp 360 or 362A low pass filters *(page 186)* between the signal generators and equipment following the generator.

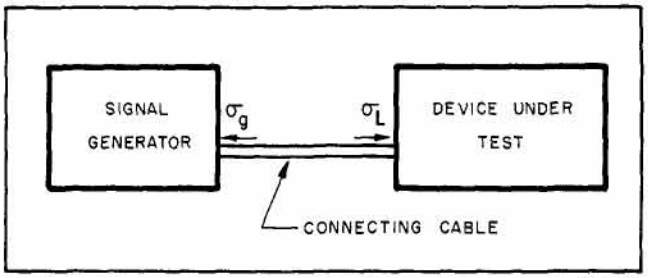


Figure 4. Typical setup for making measurement on Signal Generators.

The Model 606A output attenuator is a series of 4 resistive π networks switched with cam-controlled microswitches for a total of 120 db range. It is similar to the Model 355A/B vhf attenuators on page 64.

Models 626A and 628A employ rotary waveguide attenuators which have an extremely flat frequency response. These attenuators are similar to hp 382A Waveguide Attenuators *(page 180)*.

Signal generator output impedance is held close to 50 ohms by utilizing pads in the attenuator and output connectors. This type of output system has certain advantages which contribute greatly to the accuracy and usefulness of a signal generator. The monitoring circuit sets a reference calibration level and also serves as a continuous monitor on the oscillator level. Changes of oscillator level due to loading, etc., are immediately apparent. At any level the maximum available power from the generator can be determined quickly and accurately from monitor readings and attenuator settings. It is not necessary to return the output to a high level for monitoring.

hp generators are calibrated in terms of their maximum available power.

Power Loss Due to Mismatch: Another source of error in determining power output is mismatch between a signal generator output impedance and the instrument following the generator. Hewlett-Packard generators have an output impedance of 50 ohms which matches the nominal impedance of most cables and connectors. The deviation of output impedance from 50 ohms is designated Standing Wave Ratio (SWR) and it is less than 2.5 for all hp generators. With a knowledge of the value of SWR of both generator and load, the limits of the power loss can be calculated. It is necessary to know the phase of the reflection coefficient to determine the exact power loss.

A typical setup for making measurements on signal generators is shown in Figure 4. To determine the amount of error due to mismatch, the values of SWR of the signal generator and the load should be measured. Maximum and minimum power loss is then obtained by substituting the values of SWR in the equation below:

^{P}max—the maximum power loss in db is given by:

$$^{P}\text{max} = \left(20 \log \left[\sqrt{\sigma_g \sigma_L} + \frac{1}{\sqrt{\sigma_g \sigma_L}}\right] - 6\right) \text{db}$$

And ^{P}min—the minimum power loss in db is given by:

$$^{P}\text{min} = \left(20 \log \left[\sqrt{\frac{\sigma_g}{\sigma_L}} + \sqrt{\frac{\sigma_L}{\sigma_g}}\right] - 6\right) \text{db}$$

Where σ_g = SWR of signal generator
Where σ_L = SWR of device under test

NOTE: These losses are with respect to the maximum available power output. (Calibration of the signal generator.)

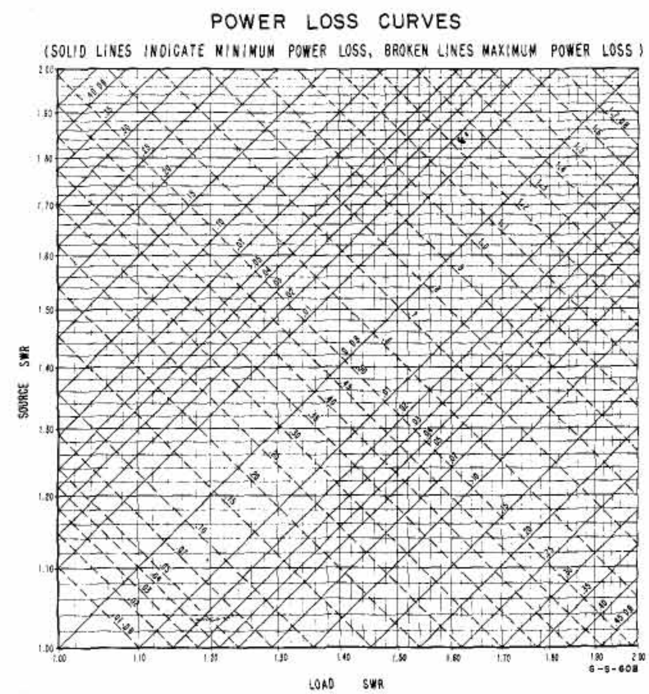


Figure 5. Power loss curves. Solid lines indicate ^{P}max; broken lines ^{P}min. (Courtesy Sperry Gyroscope Co.)

These formulas can be drawn up in chart form as shown in Figure 5. As an example, let it be assumed that on a measurement the attenuator setting is −30 dbm, the SWR of the generator is 1, and the SWR of the load is 3. Then using the above formulas or chart, it can be shown that ^{P}max equals 1.28 db, and ^{P}min equals 1.28 db. Here it should be noted that because the generator is matched, the ambiguity of error is eliminated and power loss can be calculated exactly.

Assuming the same data as before with the exception that the generator has an SWR of 1.5, it can be shown that ^{P}max equals 2.28 db, and ^{P}min equals 0.52 db. In this last example the power actually being delivered to the load lies somewhere between −30.52 dbm and −32.28 dbm. Without further information concerning the relative phase of the reflection coefficients, it is impossible to obtain this value more accurately. With some form of tuner, the load may be matched to the generator. Then the attenuator reads accurately as maximum power is transmitted to the load. For most measurements, it will be found that an average value of the power loss will adequately meet the accuracy requirements.

Loss in Cables: Another source of error in power output determination is loss in the cables connecting the generator to the load. This loss may become significant, particularly at higher frequencies. To minimize this error, ⓗⓟ generators which may be most affected by cable loss, (614A, 616B, 618B and 620A) are calibrated in terms of power at the end of the 6 ft. cable which is furnished with the generator. If cables of different lengths are used, consideration should be given to the differences in attenuation presented by such cables. Nominal attenuation for several different types of cables is shown in Figure 6.

ⓗⓟ 606A HF Signal Generator

The Model 606A High Frequency Signal Generator *(pages 132, 133)* has been specially designed for new convenience and accuracy in hf measurements. It features feedback circuitry around the power amplifier section of the generator which provides constant output levels on all bands and at any frequency within a band. This eliminates the tedious, error-producing retuning and resetting of output power levels normally found in generators of this type. Furthermore the feedback circuitry is wide band so that a constant modulation level is obtained with negligible envelope distortion, even up to 100% modulation. Output is high and is continuously adjustable from 0.1 microvolts to 3 volts into 50 ohms.

Covering the high frequency spectrum (which includes the 30 and 60 megacycle radar IF bands) the new 606A is exceptionally useful in driving bridges, antennas and filters, and measuring gain, selectivity, and image rejection of receivers and hf circuit elements.

Output is constant within ± 1 db over the full frequency range and is adjustable from + 20 dbm (3 volts rms) to −110 dbm (0.1 microvolts rms). No level adjustments are required during operation; the instrument has a minimum of controls and high accuracy results are assured because of the constant internal impedance.

The 606A may be modulated by sine waves and complex wave forms from dc to a maximum of 20 KC with the percentage modulation indicated on an internal meter. An internal crystal calibrator circuit provides check points at 100 KC and 1 megacycle intervals with errors of less than 0.01% to insure maximum accuracy of frequency setting.

New ⓗⓟ 938/940A Frequency Doubler Sets

The new ⓗⓟ 938A/940A Frequency Doubler Sets *(pages 146, 147)* extend the Hewlett-Packard signal generator range up to 40 GC (KMC). These versatile frequency doubler sets consist of broadband crystal harmonic generators with low conversion loss to provide up to 1 milliwatt of power throughout the frequency range from 18 to 40 GC.

In each frequency doubler set, a broadband crystal harmonic generator is suitably mounted in a waveguide flange and is provided with an input matching section so that input drive power may be applied directly to the crystal element. Signal generators in the 9 to 20 GC range supply power to this input flange and thence to the crystal element which generates harmonics with very low conversion loss. The desired second harmonic signal is separated from higher harmonics by use of a low pass filter which follows the harmonic generation section. This low pass filter is specifically designed for broad stop band characteristics and is similar to the ⓗⓟ Models K/R362A *(page 186)*.

To provide accurate attenuation capabilities and true signal generator action, a 100 db dual rotary vane attenuator follows the low pass filter. This attenuator allows the desired rf power to be reduced 100 db and results in convenient power setting for many measurements.

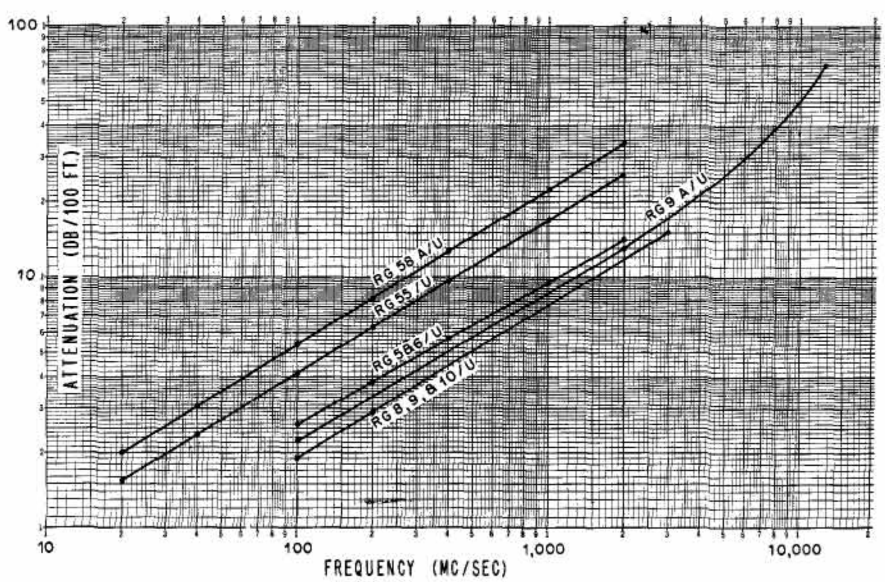


Figure 6. Attenuation vs. frequency curves for several cables.

A power monitor section consists of a meter calibrated in dbm which responds to the harmonic generation crystal current. This meter provides for monitoring the rf output power level within ± 1.5 db to ± 3 db, depending on the frequency range involved. The power monitor is set to the desired reference by using the level attenuators in the driving source.

Model 938A/940A Frequency Doubler Sets are specially designed to be driven with ⓗ 626 or 628A Signal Generators and, since their conversion loss is between 17 and 18 db, output power typically runs between 0.5 milliwatts and 1 milliwatt when these driving signal generators are run at full output. Furthermore, since the doubler sets are broadband devices they will convert swept frequency signals as well as CW to higher frequencies. Thus ⓗ Models 686C and 687C BWO Sweep Oscillators may also be used as the driving source. This capability provides for extremely useful swept frequencies in the 18 to 40 GC frequency range.

Modulation characteristics of the driving source are preserved and the doubler set output may be CW, pulse modulated, square wave modulated or frequency modulated.

Swept frequency output, of course, gives the capability of making reflectometer measurements in K and R bands hitherto not possible because of a lack of swept sources in the 18 to 40 GC range.

Sweep Oscillators

In addition to precision signal generators, ⓗ offers six sweep oscillators covering the frequencies in the range 1.0 to 18.0 GC. These oscillators have voltage-tuned backward wave tubes which generate CW and swept frequencies with a wide variety of modulation capabilities. Most provide high output levels of at least 10 milliwatts (50 milliwatts for the 682C, 5 mw for the 687C) into a matched load. The rf output frequency sweeps linearly with time and both the desired frequency sweep, Δf, as well as the rate of change of frequency are selectable individually in direct reading switch positions on the front panel. 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.

Swept frequency techniques are usable for a wide variety of waveguide instrument and component testing. The ⓗ pioneered reflectometer system *(pages 172, 173)*, depends on swept frequency sources for its fast, wide band presentation of SWR measurements. These swept frequency test techniques are used extensively in the Hewlett-Packard waveguide testing department for both speedy and comprehensive tests on all microwave components. X–Y recorder plots of SWR and of attenuation versus frequency are just two of the typical measurements made. Reflectometer techniques assure that no hidden spurious responses will slip through unnoticed on a microwave component. Broadband insertion loss tests on flap attenuators, for instance, assure that the attenuation versus frequency curve does not go out of specification.

ⓗ sweep frequency generators are used extensively in the ⓗ microwave development laboratories for broadband, "quick look" information on the new components under development. They eliminate many of the tedious point-by-point measurements previously required in a waveguide component development program.

Level Output From Sweep Oscillators

A new feature of the "C" series of ⓗ 680 sweep oscillators, which contributes to their general usefulness, is a simple open loop control system which maintains the rf output nearly constant. This practical system varies the anode voltage of the backward wave tube in accordance with the changing helix voltage so that the typical rf output variations of the backward wave oscillator are removed. Only the minor variations, which are usually less than ± 1.5 db are left. The curves in Figure 7 show the effectiveness of this inexpensive control system in a typical ⓗ 682C.

Models 686C and 687C are additionally useful now with the introduction of the 938/940A frequency doubler sets, since their output power is sufficient to provide up to ½ milliwatt output from the frequency doubler sets in the 18 to 36 GC region. For maximum power output to drive the doubler sets at best efficiency, a front panel switch on the 686C and 687C permits the open loop leveler to be turned off. A cathode current control further provides for reducing cathode current of the backward wave oscillator tube when the full output is not required.

The new backward wave oscillators feature a direct connection to the backward wave tube grid which can provide extremely fast rf rise and decay times for many fast pulse requirements. Typical rise times on the order of 50 nanoseconds and decay times on the order of 100 nanoseconds may be obtained by the use of this external modulation capability. Using this external modulation allows extremely narrow pulses to be generated.

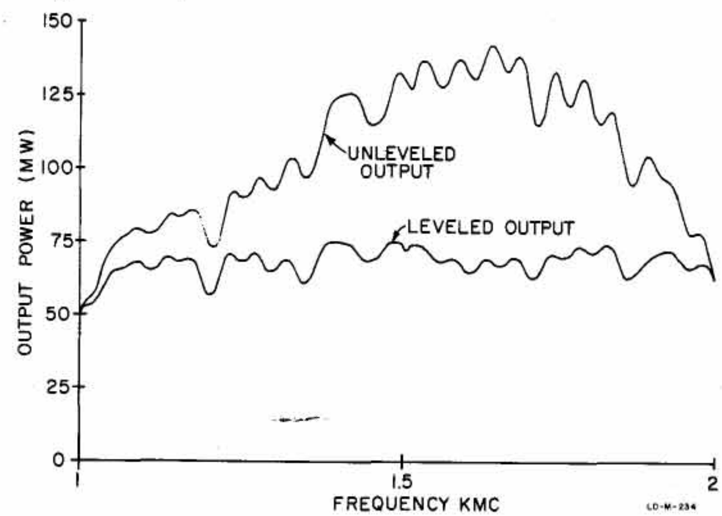


Figure 7. Typical output characteristics of ⓗ 682C.

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
- Measuring harmonic distortion of AM receivers

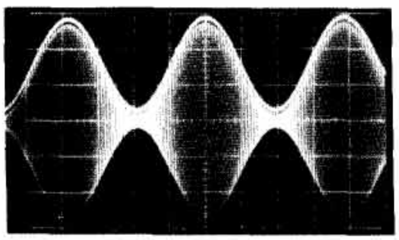


Figure 1. Dual-trace presentation comparing modulated output from ⓗⓟ 606A with internal 1 KC modulating waveform (positioned closely above rf envelope).

Here in the ⓗⓟ 606A is the most convenient and versatile signal generator ever manufactured. Its wide frequency and output range and excellent modulation characteristics fit the 606A for many measurements.[1]

Constant Output—Modulation

A feedback circuit maintains both output level and percent modulation essentially constant over the entire frequency range. Thus, it is usually unnecessary to readjust either the output level or modulation controls when conducting measurements at various frequencies. Even the output level can be varied without seriously affecting percent modulation. Another advantage provided by the feedback circuit is the reduction of envelope distortion during modulation.

Low Distortion

Because envelope distortion is low, overall distortion measurements may be made on high-fidelity AM receivers by applying the ⓗⓟ 606A output to the receiver's antenna terminals *(see Figure 1)*.

Broad Modulation Bandwidth

ⓗⓟ 606A may be modulated with signals from dc to 20 KC, by square waves and other complex signals. Square wave

[1]See Arthur Fong, "Special Purpose Performance in a General Purpose 50 KC to 65 MC Signal Generator," Hewlett-Packard Journal, Vol. 10, No. 8, April, 1959.

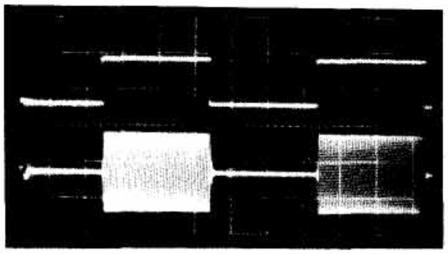


Figure 2. Dual-trace presentation showing carrier in the broadcast band-modulated by a 1 KC square wave.

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.

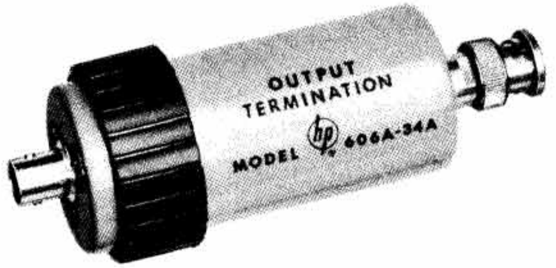
hp 606A - 34A Output Termination (10:1) and IRE dummy antenna. See "Accessories Available" under "Specifications."

This multipurpose termination further 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 IRE standard characteristics for receiver measurements.



Specifications hp 606A

Frequency Range: 50 KC to 65 MC in six bands:

50 - 170 KC	1.76 - 6.0 MC
165 - 560 KC	5.8 - 19.2 MC
530 - 1800 KC	19.0 - 65.0 MC

Frequency Accuracy: Within $\pm$ 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 from 0.1 μv to 3 volts into a 50 ohm resistive load. Calibration is in volts and dbm (0 dbm is 1 milliwatt or 0.223 volts rms into 50 ohms).

Output Accuracy: Within $\pm$ 1 db into 50 ohm resistive load.

Frequency Response: Within $\pm$ 1 db into 50 ohm resistive load over entire frequency range at any output level setting.

Output Impedance: 50 ohms, SWR less than 1.1 on 0.3 volt range; on 1 v and 3 v ranges, less than 1.1 to 20 MC and less than 1.2 to 65 MC. BNC output connector mates with UG-88A/B/C/D.

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 $\pm$ 0.5 db regardless of carrier frequency and output level changes.

Internal Modulation: 0 to 100% sinusoidal modulation at 400 cps $\pm$ 5% or 1,000 cps $\pm$ 5%. Internal modulation voltage appears at modulation jack.

Modulation Bandwidth: DC to 20 KC maximum, depends on carrier frequency, f_c, and percent modulation as shown in the following table:

Max. Mod. Frequency	*30% Mod.*	*70% Mod.*	*Squarewave Mod.*
	$0.06 f_c$	$0.02 f_c$	$0.003 f_c$ (3 KC max)

External Modulation: 0 to 100% sinusoidal modulation dc to 20 KC. 4.5 volts peak produces 100% modulation at modulating frequencies from dc to 20 KC. Input impedance is 600 ohms. May also be modulated by square waves and other complex signals.

Envelope Distortion: At output levels of 1 v or less, less than 1% at 30% modulation, less than 3% from 0 to 70% modulation using internal 400/1,000 cps source.

Modulation Meter Accuracy: Within $\pm$ 5%, 0 to 90%.

Incidental FM: At 1 v or less output and 30% amplitude modulation: 0.0025% or 100 cps, whichever is greater.

Spurious FM: Less than 0.0001% or $\pm$ 20 cps, whichever is greater.

Spurious AM: Hum and noise sidebands are 70 db below carrier down to thermal level of 50-ohm output system.

Frequency Drift: Less than 0.005% or 5 cps, whichever is greater, for a 10-minute period after warmup or restabilization at frequency of use.

Power: 115/230 v $\pm$ 10%, 50 to 1,000 cps, 135 watts.

Dimensions: Cabinet Mount: 20¾" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13⅜" deep behind panel.

Weight: Net 46 lbs. Shipping 57 lbs. (cabinet mount). Net 43 lbs. Shipping 58 lbs. (rack mount).

Accessories Available: hp 606A-34A Output Termination with 50 ohms termination, 5 ohms termination (10:1 voltage division), and IRE standard dummy antenna (10:1 voltage division). $70.00.

Price: hp 606A, $1,350.00 (cabinet); hp 606AR, $1,335.00 (rack mount).

Data subject to change without notice.

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 μv to 0.5 v 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 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 the front panel meter

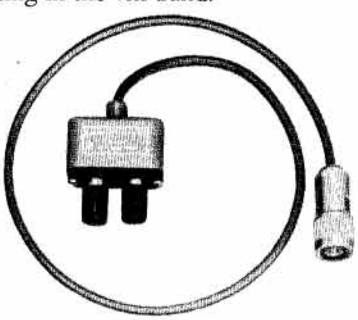
Finest Construction

An important feature of 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 hp and feature electrically welded Invar low temperature steel plates to minimize drift. Sealed transformers are used throughout, and construction is militarized.

hp 608C vhf Signal Generator

The hp 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 may be AM modulated to 95% and provides high quality pulses as short as 1 μsec at rf output frequencies above 100 MC. As in hp 608D, rf leakage is negligible, and the rf attenuator is calibrated to 0.1 μv.

hp 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.



hp 608A-16D

Accessories

Terminated Output Cable, hp 608A-16D, is designed for use with hp 608D and 608C vhf Signal Generators. It provides an accurate termination which may be directly connected to the point of a circuit at which the signal voltage is to be injected.

Another accessory, the hp 608A-95A 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

hp 608D

Frequency Range: 10 to 420 MC, 5 bands.

Tuning Control: Main dial calibrated in MC. Vernier interpolation dial. 45″ scale length. Calibrated every other MC, 130 to 270 MC; every 5 MC, above 270 MC.

Frequency Calibration: Accuracy: ± 0.5% full range.

Resettability: Better than ± 0.1% after warmup.

Crystal Calibrator: 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 warmup (15° C 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 bandswitching, 10 minutes are required to restabilize.

Output Level: 0.1 μv to 0.5 v into 50-ohm resistive load. Attenuator dial calibrated in volts and dbm. (0 dbm equals 1 mw.)

Voltage Accuracy: ± 1 db full range.

Generator Impedance: 50 ohms, maximum SWR 1.2.

Modulation Percentage: 0 to 95% at output of 0 dbm and below.

Envelope Distortion: Less than 5% at 30% sine wave modulation; less than 10% at 50% sine wave modulation.

Internal Modulation: 400 cps ± 10% and 1,000 cps ± 10%.

External AM 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 15,000 ohms.

External Pulse Modulation: Positive 5 volt peak pulse required. 40 MC to 220 MC; combined rise and decay time of rf pulse less than 4 μsec.

220 MC to 420 MC: combined rise and decay time of rf pulse less than 1 μsec.

Residual level at least 20 db below 0.5 volt peak pulse output.

Modulation Meter Accuracy: ±10% of full scale, 30% to 95% modulation.

Incidental FM: Less than 1,000 cycles at 50% AM for rf output frequencies above 100 MC; less than 0.001% below 100 MC.

Leakage: Negligible; permits sensitivity measurements to at least 0.1 μv.

Filament Regulation: Provides high oscillator and amplifier stability for line voltage change.

Power: 115/230 v ± 10%, 50/1,000 cps, 220 watts.

Dimensions: Cabinet Mount: 13¼″ wide, 16⅜″ high, 21″ deep. Rack Mount: 19″ wide, 14″ high, 18⅜″ deep behind panel.

Weight: Net 62 lbs. Shipping 74 lbs. (cabinet). Net 62 lbs. Shipping 91 lbs. (rack).

Accessories Available: 608A-16D Output Cable, $18.00; AC-16K Video Cable Assembly, $6.50; AC-16F rf Cable Assembly, $15.00; 360A Low Pass Filter, $60.00; 608A-95A Fuseholder, $25.00.

Price: hp 608D, $1,200.00 (cabinet); hp 608DR, $1,220.00 (rack mount).

hp 608C

Same as hp 608D, except:

Frequency Range: 10 to 480 MC, 5 bands.

Frequency Calibration Accuracy: ± 1% full range.

Crystal Calibrator: In Model 608D only.

Output Level: 0.1 μv to 1.0 v into 50 ohm resistive load.

Incidental FM: Less than 0.0025% at 30% amplitude modulation for rf output frequencies 21 to 480 MC.

Price: hp 608C, $1,100.00 (cabinet); hp 608CR, $1,120.00 (rack mount).

Data subject to change without notice.

612A UHF SIGNAL GENERATOR

All-Purpose Uhf Signal Generator 450 to 1230 MC

Advantages:

Output 0.5 v over full range

Uhf-TV modulation characteristics

Direct calibration

CW, AM and pulse output

Low incidental FM

Constant internal impedance

Microsecond pulsing

No charts or interpolation

Use To:

Measure gain, selectivity, sensitivity
and image rejection of receivers and amplifiers

Drive bridges, slotted lines, antennas
and filter networks

Test uhf-TV equipment under actual
modulation conditions

Here is an all-purpose, precision signal generator particularly designed for utmost convenience and applicability in measurements throughout the important uhf-TV frequency band. It is ideally suited for measurements in uhf television broadcasting, studio-transmitter links, public service communications, citizen's radio, marine communication systems, and aeronautical radio-navigation networks. In the laboratory it is also a convenient power source for driving bridges, slotted lines, antennas and filter networks.

MO-PA Circuit

The master oscillator-power amplifier circuit in 612A provides a high output power of 0.5 v into 50 ohms over the full frequency range of 450 to 1,230 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 instrument may be modulated internally or externally, amplitude modulated, or pulse modulated (good rf pulses 0.2 μsec or longer). Pulse modulation may be applied to the amplifier, or direct to the oscillator when high on-off

signal ratios are required. (Signal may be completely cut off during pulses.) A dc restorer circuit allows modulation up or down from preset level to simulate TV modulation characteristics accurately. The large, easily read percentage modulation meter responds to peak value, indicating degree of pulse modulation.

Advanced Design

The oscillator-amplifier circuit in ⓗⓟ 612A employs high frequency pencil triodes in a cavity-tuned circuit for precise tracking over the entire band. The tuned cathode, tuned-plate oscillator drives a double-tuned power-amplifier of 15 MC bandwidth. (This circuitry produces the high modulation percentages to 5 MC and minimum incidental FM which characterize the instrument.)

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 μv. The attenuator is calibrated over a range of 131 db. It has been carefully designed to provide a constant impedance versus frequency characteristic. The SWR of the output system is less than 1.2 over the complete frequency range when used into a 50 ohm impedance.

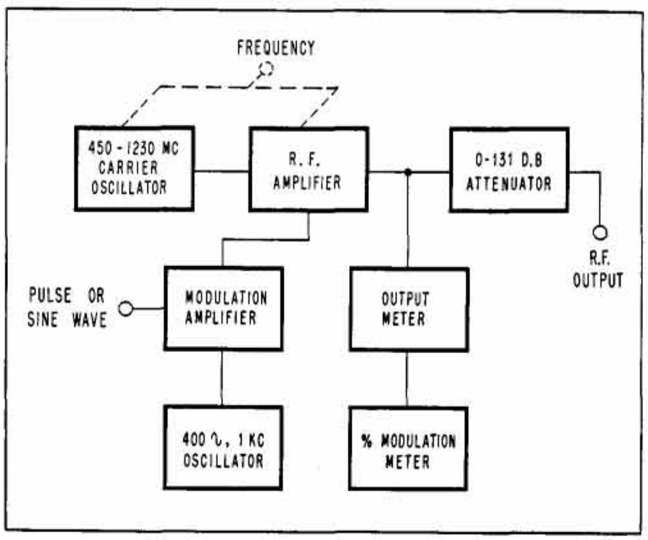


Figure 1. Block diagram, ⓗⓟ 612A Signal Generator.

The ⓗⓟ 612A covers the 450 to 1,230 MC band in one continuous range. The tuning dial has an expanded scale that covers 15 inches and is calibrated every 5 megacycles. The dial can be read to approximately 1 megacycle and is accurate within 1%.

Specifications

Frequency Range: 450 to 1,230 MC in one band. Scale length approximately 15 inches.

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 volts and dbm (0 dbm = 1 mw).

Output Accuracy: ± 1 db, 0 to −127 dbm over entire frequency.

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 cps and 1,000 cps ± 10%. Envelope distortion less than 2% at 30% af 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, 1.0 μsec.

Power: 115/230 v ± 10%, 50/1,000 cps, 215 watts.

Dimensions: Cabinet Mount: 13½″ wide, 16½″ high, 21½″ deep. Rack Mount: 19″ wide, 14″ high, 20¼″ deep behind panel.

Weight: Net 57 lbs. Shipping 69 lbs. (cabinet mount). Net 57 lbs. Shipping 93 lbs. (rack mount).

Accessories Available: AC-16F rf Cable Assembly, $15.00; AC-16K 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), $60.00.

Price: ⓗⓟ 612A, $1,300.00 (cabinet); ⓗⓟ 612AR, $1,320.00 (rack mount).

Data subject to change without notice.

614A/616B UHF SIGNAL GENERATORS

Direct Reading, Direct Control 800 to 2,100 MC, 1.8 to 4.2 GC (KMC)

Advantages:

- Direct frequency control
- Direct voltage readings
- CW, FM or pulsed output
- Variable pulse rate
- Synchronized pulsing
- Wide frequency range
- High stability
- Rugged, compact, dependable

Use To Measure:

- Receiver sensitivity
- Signal-to-noise ratio
- Conversion gain
- Standing wave ratios
- Antenna gain
- Transmission line characteristics

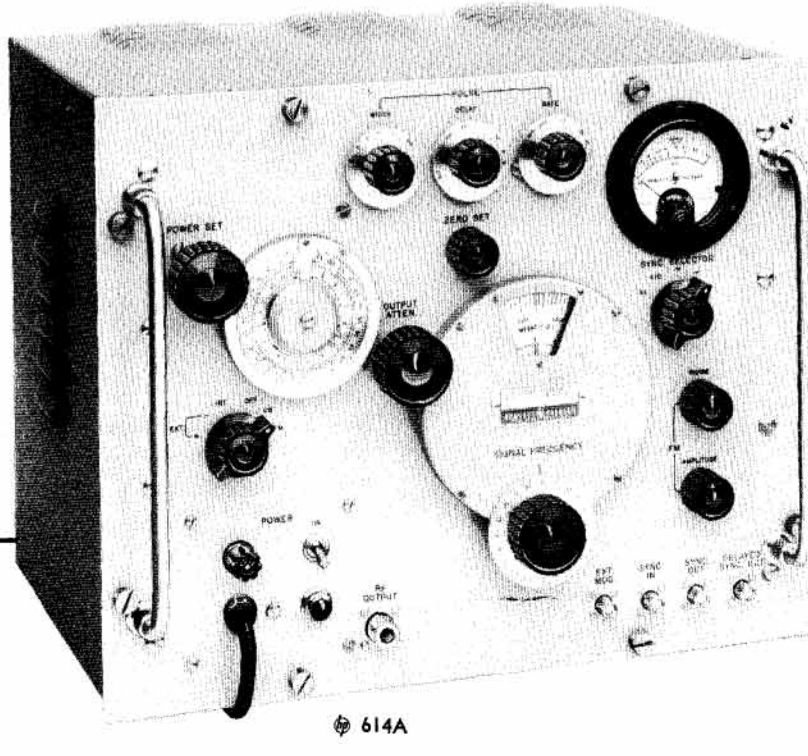
Ease of operation, direct reading without calibration charts, one-dial frequency control, high stability, accuracy and broad frequency coverage—all are outstanding advantages of these two widely-used hp signal generators.

hp 614A covers frequencies from 800 to 2,100 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.

hp 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 supply 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 hp 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 ther-



hp 614A

mistor bridge circuit which is virtually unaffected by ambient temperature conditions. Voltage output is read directly on the scale. A logging scale on the frequency dial provides a resettability of 0.1%.

A piston attenuator in the power monitor circuit is mechanically coupled to the cursor of the output attenuator dial to compensate for variations in klystron output as frequency is changed. Output power is passed through another identical piston attenuator which is linear over a range of 120 db or more.

Because of their wide range and great stability, ℎ𝑝 614A and 616B Signal Generators are ideal for almost all precision uhf measurements. They are compact in size and ruggedly built of highest quality components for long, trouble-free service.

Specifications

hp 614A

Frequency Range: 800 to 2,100 MC directly calibrated.

Frequency Calibration: Accuracy ± 1%

Frequency Stability: 0.005%/°C change in ambient temperature. Line voltage changes of ± 10% cause less than 0.03% frequency change.

Attenuator Range: 0 dbm to −127 dbm (0.223 v to 0.1 μv) calibrated directly in volts and dbm.

Attenuator Accuracy: ± 1 db from −10 dbm to −127 dbm.

Output Power: At least 0.5 mw.

Internal Impedance: 50 ohms. SWR less than 1.6.

Modulation: Internal or external pulse or FM.

Internal Pulse Modulation: Pulse repetition rate variable from 40 to 4,000 per second; 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, pos. or neg. peak amplitude 40 to 70 v, width 1.0 μsec to 2,500 μsec. May be square wave modulated.

Trigger Pulses Out: (1) Simultaneous with rf pulse. (2) In advance of rf pulse, variable 3 to 300 μsec. (Both approx. 1 μsec rise time, amplitude 10 to 50 v.)

External Sync Pulse Required: Amplitude from 10 to 50 v of either pos. or neg. polarity; and 1 to 20 μsec width. May also be synchronized with sine waves.

FM Modulation: Oscillator frequency sweeps at power line frequency. Phasing and sweep range controls provided. Max. deviation approx. ± 3 MC.

Power: 115/230 v ± 10%, 50/1,000 cps, 150 watts.

Dimensions: Cabinet Mount: 17¼″ wide, 13⅝″ high, 13½″ deep. Rack Mount: 19″ wide, 14″ high, 12⅛″ deep behind panel.

Weight: Net 58 lbs. Shipping 82 lbs. (cabinet mount). Net 57 lbs. Shipping 80 lbs. (rack mount).

Accessories Furnished: 1 AC-16F rf Cable Assembly.

Accessories Available: 360C Low Pass Filter, $50.00. AC-16K Video Cable Assembly, $6.50.

Price: hp 614A, $1,950.00 (cabinet); hp 614AR, $1,970.00 (rack mount).

hp 616B

Frequency Range: 1.8 to 4.2 GC (KMC), directly calibrated.

Frequency Calibration Accuracy: ± 1%.

Frequency Stability: 0.005%/°C change in ambient temperature; line voltage changes of ± 10 v cause less than 0.03% frequency change.

Output Range: 1 milliwatt or 0.223 v to 0.1 μv (0 dbm to −127 dbm). Directly calibrated in microvolts and dbm; continuously monitored.

Attenuator Accuracy: Within ± 1.5 db from −7 dbm to −127 dbm without correction charts.

Internal Impedance: 50 ohms, nominal. SWR less than 1.8.

Modulation: Internal or external pulse or FM.

Internal Pulse Modulation: Repetition rate variable from 40 to 4,000 per second; pulse length variable from 1 to 10 μsec; and delay variable from 3 to 300 μsec (between synchronizing signal and rf pulse).

External Pulse Modulation: Pulse requirements: Amplitude from 40 to 70 v positive or negative, width 1 μsec to 2,500 μsec. May be square wave modulated.

Trigger Pulses Out: (1) Simultaneous with rf pulse. (2) In advance of rf pulse, variable 3 to 300 μsec. (Both approximately 1.0 μsec rise time, amplitude 10 - 50 volts.)

External Sync Pulse Required: Amplitude from 10 to 50 volts of either positive or negative polarity and 1 to 20 μsec width. May also be synchronized with sine waves.

FM Modulation: Oscillator frequency sweeps at power line frequency. Phasing and sweep range controls provided. Maximum deviation approximately ± 3 MC.

Power: 115/230 v ± 10%, 50/1,000 cps, 160 watts.

Dimensions: Cabinet Mount: 17¼″ wide, 13⅝″ high, 13½″ deep. Rack Mount: 19″ wide, 14″ high, 12⅛″ deep behind panel.

Weight: Net 58 lbs. Shipping 79 lbs. (cabinet mount). Net 59 lbs. Shipping 80 lbs (rack mount).

Accessories Furnished: 1 AC-16F rf Cable Assembly.

Accessories Available: 360D Low Pass Filter, $50.00. AC-16K Video Cable Assembly, $6.50.

Price: hp 616B, $1,950.00 (cabinet); hp 616BR, $1,970.00 (rack mount).

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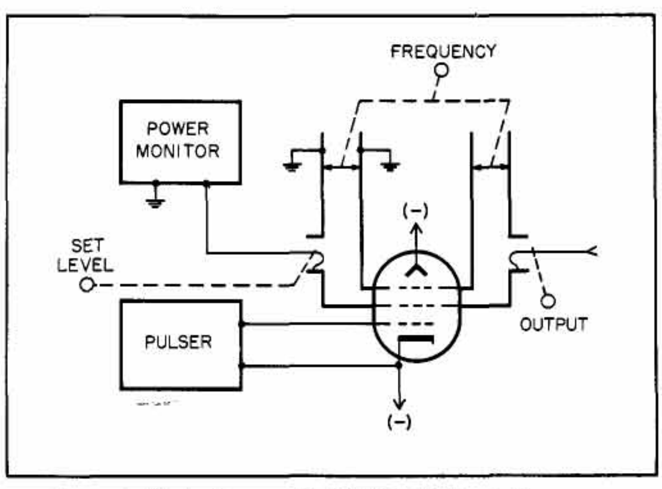


Figure 1. Block diagram, hp 614A/616B Signal Generator.

hp 618B/620A SHF SIGNAL GENERATORS

Widely Varied Pulsing Capabilities for Measurements 3,800 to 11,000 MC

Advantages:

- Direct reading frequency control
- Direct output voltage control
- Internal FM, CW, pulsed or square wave modulation
- Broad pulsing capabilities
- Wide frequency range
- High stability, high accuracy
- Sturdy, compact, precision built

Use To Measure:

- Receiver sensitivity
- Selectivity or rejection
- Signal-to-noise ratio
- Conversion gain, SWR
- Antenna gain
- Transmission line characteristics

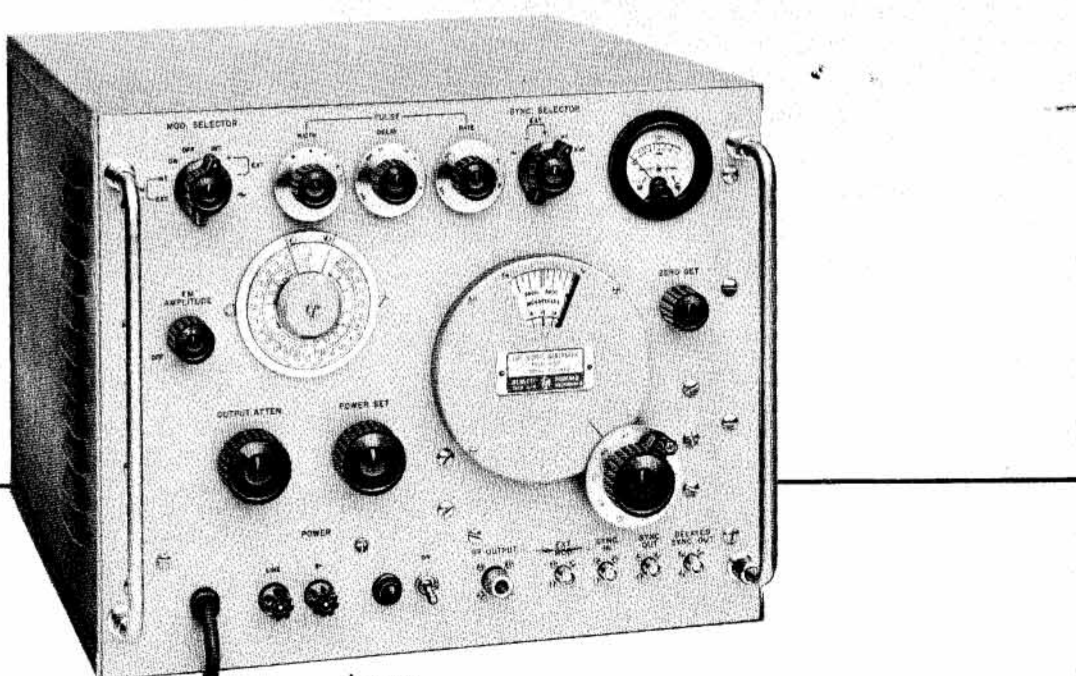
Hewlett-Packard 618B and 620A shf Signal Generators bring the simple yet versatile operation and the varied pulsing capabilities of hp uhf Signal Generators to the 3,800 to 11,000 MÇ frequency range.

These generators offer internal or external pulse modulation, internal square wave modulation, and FM. The repetition rate is continuously variable from 40 to 4,000 pps, and pulse width is variable from 0.5 to 10 miscroseconds. 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.

Saw-tooth Sweep

For internal frequency modulation, both hp 618B and 620A have a saw-tooth voltage variable from 40 to 4,000 cps providing a frequency deviation variable up to $\pm$ 3 MC. For external FM, the instruments provide capacitive coupling to the repeller of the klystron oscillator. Maximum deviation is approximately $\pm$ 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



hp 618B

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 ⓗⓟ developed coupling device which causes oscillator repeller voltage to track frequency changes automatically. RF output is also set and read directly; no calibration charts are needed either for 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

ⓗⓟ 618B

Frequency Range: 3,800 to 7,600 MC 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 volts 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 into 50 ohms.

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 4,000 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 1,000 ohm load.)

External Synchronization: (1.) Sine wave: 40 to 4,000 cps, amplitude 5 to 50 volts rms. (2.) Pulse signals: 0 to 4,000 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.

Internal Square Wave Modulation: Variable 40 to 4,000 cps, controlled by "pulse rate" control.

Internal Frequency Modulation: Saw-tooth sweep rate adjustable between 40 to 4,000 cps. Frequency deviation up to ± 3 MC.

External Pulse Modulation: Pulse requirements: amplitude from 20 to 70 volts positive or negative, width 0.5 to 2,500 μsec.

External Frequency Modulation: Provides capacitive coupling to repeller of klystron. Max. deviation approx. ± 5 MC.

Power: 115/230 v ±10%, 50/60 cps, 250 watts.

Dimensions: Cabinet Mount: 17½" wide, 14" high, 19½" deep. Rack Mount: 19" wide, 14" high, 17⅜" deep behind panel.

Weight: Net 95 lbs. Shipping 118 lbs. (cabinet mount). Net 96 lbs. Shipping 119 lbs. (rack mount).

Accessories Furnished: 1 AC-16Q rf Cable Assembly.

Accessories Available: AC-16K Video Cable Assembly, $6.50.

Price: ⓗⓟ 618B, $2,250.00 (cabinet); ⓗⓟ 618BR, $2,270.00 (rack mount).

ⓗⓟ 620A

(Same as ⓗⓟ 618B except as follows:)

Frequency Range: 7,000 to 11,000 MC covered in a single band. Repeller voltage automatically tracked and proper mode automatically selected.

Output Range: 1.0 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 from —7 dbm to —127 dbm; within ±3 db from 0 to —7 dbm, at panel connector, terminated in 50 ohm load.

Price: ⓗⓟ 620A, $2,250.00 (cabinet); ⓗⓟ 620AR, $2,270.00 (rack mount).

Data subject to change without notice.

hp 626A/628A SHF SIGNAL GENERATORS

Direct Reading, High Power 10 to 15.5 GC (KMC), 15 to 21 GC

Advantages:

Direct reading frequency control

Direct reading output control

10 mw output over full range

CW, FM or pulsed output

Internal square wave modulation

Broad pulsing capabilities

Low internal SWR

High stability, high accuracy

Sturdy, compact, precision-built

With hp 938/940 Frequency Doubler Sets operates to 40 GC (KMC).

Use To Measure:

Receiver sensitivity

Selectivity or rejection

Signal-to-noise ratio

Conversion gain, SWR

Antenna gain

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 (KMC). The hp 626A covers frequencies 10,000 to 15,500 MC, and the hp 628A covers frequencies 15,000 to 21,000 MC.

In design and operation, the instruments are similar to hp generators for lower frequency ranges. Operation is very simple. Carrier frequency in MC 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 is also 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 pages 146, 147)* retain the modulation of the driving source and have accurate power monitors and attenuators.

Versatile Modulation

Both hp 626A and 628A offer internal and external pulse modulation as well as internal squarewave modulation and

hp 628A

FM. Pulse repetition rate is continuously variable from 40 to 4,000 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 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 $\pm$ 5 MC. For external FM, the generators have capacitive coupling to the klystron oscillator repeller.

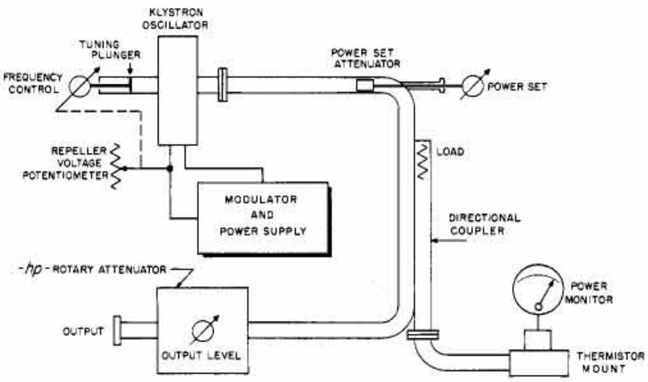


Figure 1. Basic circuit, hp 626A/628A.

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 directional coupler through an attenuator which is adjusted to provide a fixed reading on the 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 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 effects 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) guides suitable for the 10 to 21 GC range.

Data subject to change without notice.

Specifications

Frequency Range: 626A, 10,000 to 15,500 MC; 628A, 15,000 to 21,000 MC.

Frequency Calibration: Dial direct reading in megacycles. 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 $\pm$ 1 db.

Output Attenuator Accuracy: Better than $\pm$ 2% of attenuation in db introduced by output attenuator.

Leakage: Less than minimum calibrated signal generator output.

Modulation: Internal or external pulsed, FM, or square wave.

Internal Pulse Modulation: Repetition rate variable from 40 to 4,000 pps. Pulse width variable 0.5 to 10 μsec.

Internal Square Wave Modulation: Variable 40 to 4,000 cps controlled by "pulse rate" control.

Internal Frequency Modulation: Power line frequency, deviation up to $\pm$ 5 MC.

External Pulse Modulation: Pulse Requirements: Amplitude 15 to 70 volts peak positive or negative; width 0.5 to 2,500 μsec.

External Frequency Modulation: Provided by capacitive coupling to repeller of klystron. Maximum deviation approximately $\pm$ 5 MC.

Sync Out Signals: Positive 20 to 50 volts peak into 1,000 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 4,000 cps, amplitude 5 to 50 volts rms.
(2) Pulse signals 0 to 4,000 pps, 5 to 50 volts amplitude, positive or negative. Pulse width 0.5 to 5 μsec. Rise time 0.1 to 1 μsec.

Power: 115/230 v $\pm$ 10%, 50/60 cps, approx. 200 watts.

Dimensions: Cabinet Mount: 17″ wide, 14″ high, 15″ deep. Rack Mount: 19″ wide, 14″ high, 12-13/16″ deep behind panel.

Weight: Net 65 lbs. Shipping 83 lbs.

Accessories Furnished: hp 626A (a) MX 292A Waveguide Adapter, WR-75 to WR-90 guide. (b) MP 292A Waveguide Adapter, WR-75 to WR-62 guide.
hp 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: hp AC-16K Video Cable Assembly, \$6.50. For hp 626A: M362A Low Pass Filter, \$350.00. For hp 628A: N362A Low Pass Filter, \$350.00.

Price: hp 626A or hp 628A, \$3,400.00 (cabinet).
hp 626AR or hp 628AR, \$3,420.00 (rack mount).

682C/687C ELECTRONIC SWEEP OSCILLATORS

Electronic Sweeping for Simple, Comprehensive Full-Band Measurements

Advantages:

Electronic sweep
1 to 18 GC (KMC)
Simple to operate, direct reading
Continuously adjustable sweep width and rate
10 mw output minimum
Frequency sweep linear with time
Slow sweep for mechanical recorders; fast sweep for non-flickering oscilloscope presentation
Single sweep manually started or externally triggered
External FM or AM modulation

Uses:

Convenient source of cw and swept rf frequencies for:
- Reflectometer measurements
- Slotted line measurements
- Antenna checks

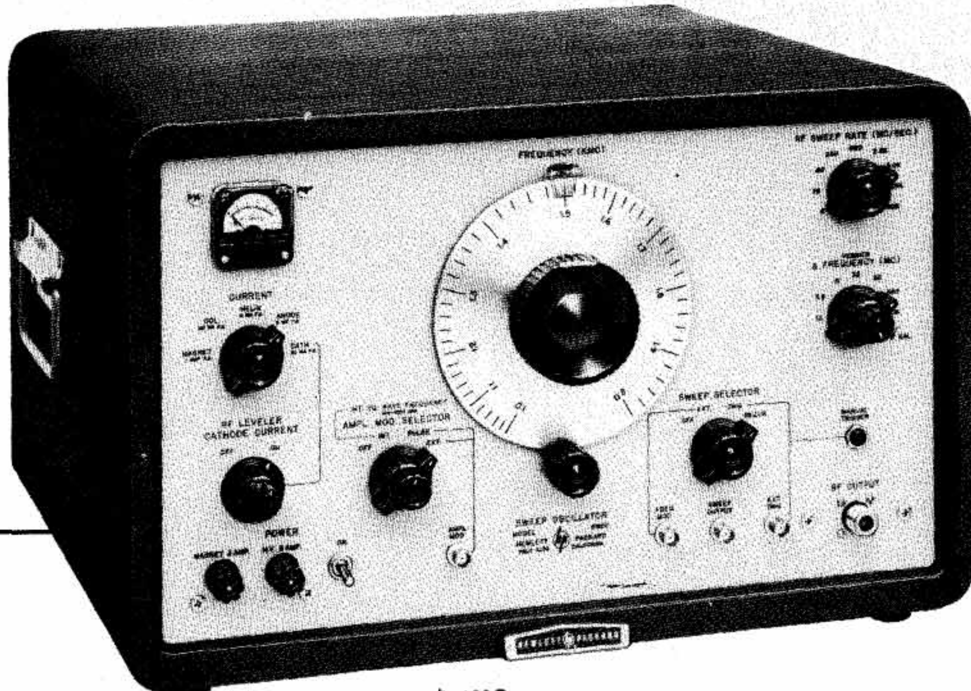
Transfer characteristics of:
- Networks
- Filters
- Attenuators
- Amplifiers
- Ferrite devices

Hewlett-Packard offers six backward-wave sweep oscillators that eliminate sweep motors, tuning plungers, previous range limitations and mechanical problems . . . *and cover all or part of a given band with a simple, flexible, broadly adjustable, quiet electronic sweep!*

With these instruments, you have complete freedom of sweep combination—both sweep width and rate of change of frequency (sweep rate) are independently controlled and direct reading. CW or swept rf frequencies may be obtained over any part of the range; sweep width may be adjusted instantly without interrupting operation. The full range can be covered in periods slow enough for high resolution mechanical recording or fast enough for flickerless oscilloscope presentations *(see Specifications)*. Sweep rate is adjustable in nine steps over various ranges as indicated under Specifications.

Linear Frequency Sweep

A unique means is used to achieve a swept frequency that is a linear function of time. Output frequency of a backward wave oscillator tube is an exponential function of the voltage applied to its helix, so by making the sweep voltage applied to the helix the proper exponential function of time, a frequency sweep results which is linear.



682C

For greatest convenience the sweep may be operated recurrently, triggered manually by means of a pushbutton or by an externally generated voltage for operation of the instrument in synchronism with other equipment. To facilitate oscilloscope and mechanical recordings, a 20 volt peak saw-tooth sweep voltage concurrent with the frequency sweep is supplied at a front panel connector. This saw-tooth sweep voltage has a fly-back so short that no blanking signal is required during oscilloscope retrace.

Broad Modulation Capabilities

In addition to their swept frequency output, the oscillators may be internally or externally AM modulated, externally pulse modulated and externally FM modulated.

Internal amplitude modulation is produced by a square wave variable 400 to 1,200 cps. During modulation, peak power is the same as the unmodulated cw output.

External amplitude modulation is produced by a signal applied to the backward wave oscillator through a built-in amplifier. Pass band of this amplifier is dc to 300 KC, and −20 volts or more reduces the output level from rated to zero.

Pulse modulation is also available. In this case there is no output from the instrument except during the pulse. The peak pulse power will be equal to the cw level if the input pulse is 10 volts peak or larger. Pulses up to 5 milliseconds long may be used for this modulation.

Frequency modulation is achieved by varying with externally generated signals the voltage supplied to the helix of the backward wave tube. These signals are capacitively coupled to the helix modulator. When FM'd externally in this manner, the instrument's frequency deviation is both above and below the frequency set on the main tuning dial.

Specifications

Model	Freq. GC (KMC)	Sweep Range	RF Sweep Rate of Change	Sweep Time	Output Power Variation	Residual FM	Spurious Signal	Output Connector	Price	
									Rack	Cabinet
682C	1 - 2	1.1 MC to 1.1 GC, seven steps, continuous control between steps	8 MC/sec to 80 GC/sec in nine steps	0.0138 sec to 138 sec for full band sweep, determined by sweep range and rate	Less than ± 1.5 db over entire frequency range[1]	Less than 50 KC pk	Less than −20 db	Type N (Female)	$3,075.00	$3,090.00
683C	2 - 4	2.1 MC to 2.1 GC, seven steps, continuous control between steps	16 MC/sec to 160 GC/sec in nine steps	0.0135 sec to 135 sec for full band sweep, determined by sweep range and rate	Less than ± 1.5 db over entire frequency range[1]	Less than 100 KC pk	Less than −20 db	Type N (Female)	2,985.00	3,000.00
684C	4 - 8.1	4.1 MC to 4.1 GC, seven steps, continuous control between steps	32 MC/sec to 320 GC/sec in nine steps	0.0135 sec to 135 sec for full band sweep, determined by sweep range and rate	Less than ± 2 db over entire frequency range[1]	Less than 200 KC pk	Less than −20 db	Type N (Female)	2,885.00	2,900.00
HOI 686C	C 7 - 11	4.4 MC to 4.4 GC in seven steps, continuous control between steps	32 MC/sec to 320 GC/sec in nine steps	0.0139 sec to 139 sec for full band sweep, determined by sweep range and rate	Less than ±3 db over entire frequency range[1]	Less than 200 KC pk	Less than −30 db	Type N (Female)	2,985.00	3,000.00
686C	8.2 - 12.4	4.4 MC to 4.4 GC, seven steps, continuous control between steps	32 MC/sec to 320 GC/sec in nine steps	0.0139 sec to 139 sec for full band sweep, determined by sweep range and rate	Less than ± 1.5 db over entire frequency range[1]	Less than 200 KC pk	Less than −30 db	X-band cover flange (UG-135/U)	2,885.00	2,900.00
687C	12.4 - 18	6 MC to 6 GC, seven steps, continuous control between steps	44 MC/sec to 440 GC/sec in nine steps	0.0136 sec to 136 sec for full band sweep, determined by sweep range and rate	Less than ±2 db over entire frequency range[1]	Less than 200 KC pk	Less than −30 db	P-band cover flange (UG-419/U)	3,385.00	3,400.00

[1]with leveler operating.

For All Models:

Sweep Mode: Recurrent; externally triggered; manually triggered. RF frequency sweep is linear with respect to time and is downward from frequency dial setting.

Sweep Output: + 20 volt (approx.) peak sawtooth provided concurrently with swept rf output for recorder and oscilloscope sweeping. Source impedance approximately 10,000 ohms and 20 pf in parallel.

Power Output: 10 milliwatts or greater into load (50 ohms for Type N output) having an SWR of 1.25 or less. Output continuously adjustable to zero.

Maximum SWR: 3 or less for 687C, 2.5 or less for other models.

Dial Accuracy: ± 1%.

Residual AM: Less than −40 db.

Modulation:

Internal AM: Square wave modulation continuously adjustable from 400 - 1200 cps; output peak rf output power is within 1 db of the cw setting.

External AM: Direct coupled dc to 300 KC/sec: −20 volts or more reduces rf output level from rated cw output to zero. Input impedance: 150 ohms.

External FM: Approximately 150 volts peak-to-peak required to modulate full frequency range of instrument. 10 cps to 60 cps. Modulating voltage must be decreased with modulating frequencies higher than 60 cps. Input impedance: 43,000 ohms shunted by 100 pf; ac coupled.

External Pulse: + 10 volts or greater pulse required; 5 millisecond maximum pulse length. Peak rf pulse level within 1 db of cw setting. Pulse rise and decay times less than 1 μsec. Input impedance: 390,000 ohms shunted by 25 pf; ac coupled.

Power: 115/230 volts ± 10%, approximately 540 watts.

Dimensions: Width 20 - 9/16", height 12¾", depth 18" (cabinet mount). Width 19", height 10½", 16¾" deep behind panel (rack mount).

Weight: Net 105 lbs. Shipping 134 lbs. (cabinet mount). Net 104 lbs. Shipping 134 lbs. (rack mount).

938A/940A FREQUENCY DOUBLER SETS

Now! Generate Precise Signals to 40 GC (KMC) with New Doublers!

Advantages:

Cover 18 to 40 GC (KMC) with accuracy, versatility, simplicity

Increases usefulness of 9 to 20 GC signal generators

Versatile output capability identical to driving source

Use with swept signal sources, signal generators, klystrons

Uses:

Usable power in K and R bands, 18 to 40 GC

Inexpensive method for high-frequency work

Useful for testing waveguide components

Ideal for reflectometer applications in K and R bands

Increase sweep oscillator versatility

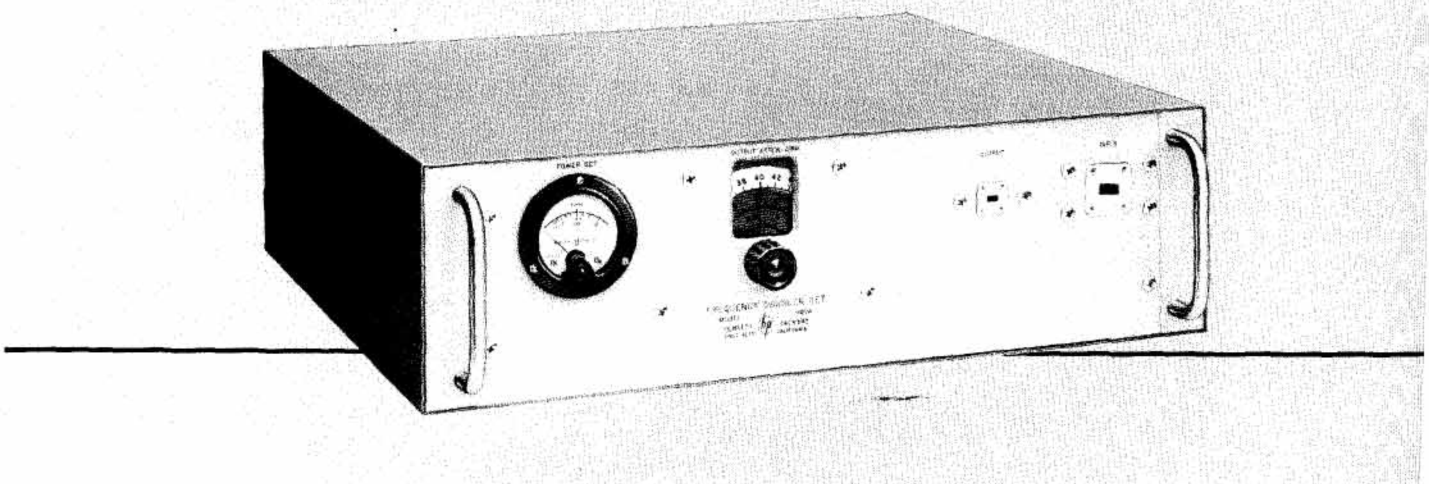
Convenient, economical, reliable signal generation to 40 GC (KMC) is possible with the new hp 938A/940A Frequency Doubler Sets used in conjunction with a wide variety of existing signal sources or one of the dependable, bench-proven hp signal generators or sweep oscillators listed in this catalog.

hp Model 938A supplies power from 18 to 26.5 GC when driven by a 9 to 13.25 GC source; hp Model 940A supplies power from 26.5 to 40 GC when driven by a 13.25 to 20 GC source.

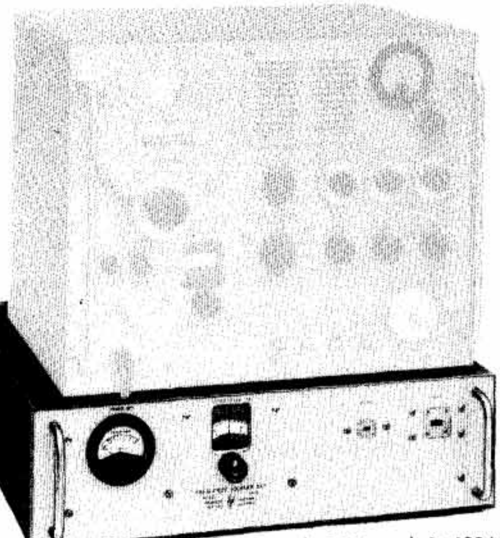
The 938A and 940A have the same output versatility as the driving source. These broadband instruments accept CW, pulsed or swept input signals from signal generators, swept signal sources or klystrons.

Each contains a broadband crystal-harmonic generator, plus a dual rotary vane attenuator, for generating and accurately setting the output level 0 to -100 db. Output power depends on input power and is typically 0.5 to 1.0 mw when the driving source is an hp 626A or 628A Signal Generator or an hp 686C or 687C Sweep Oscillator. *(See paragraph on Swept Frequency Output, next page.)* Output power is known, even though an uncalibrated signal source is used, since the output monitor is accurate to ± 2 db.

Typical of the output versatility of these Frequency Doubler sets is the fact that an hp 938A driven by an hp 626A will provide CW output, pulse modulated output with a repetition rate from 40 to 4,000 pps, square wave modulated



hp 940A



ⓗ 940A and ⓗ 628A

output with modulation frequencies from 40 to 4,000 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.

Swept Frequency Output

Swept frequency output may be obtained by driving the frequency doubler set with an ⓗ 686C or 687C *(see pages 144, 145)*. The 686C and the 687C provide a simple, flexible, broadly adjustable electronic sweep. Multiplying the sweep oscillator settings by 2 yields sweep rate and width. Both sweep width and rate of change of frequency are independently controlled. CW or swept rf frequencies may be obtained over any part of the range, and sweep width may be adjusted instantly without interrupting operation.

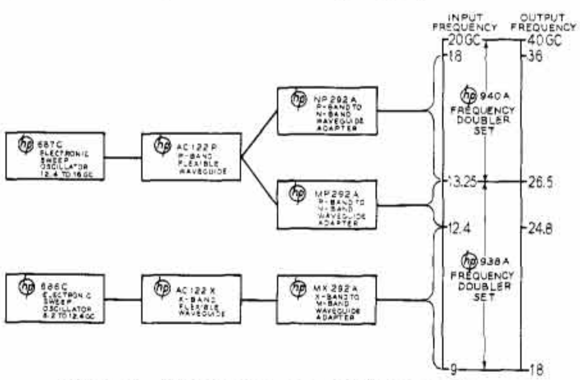


Figure 1. Driving sources, swept frequency.

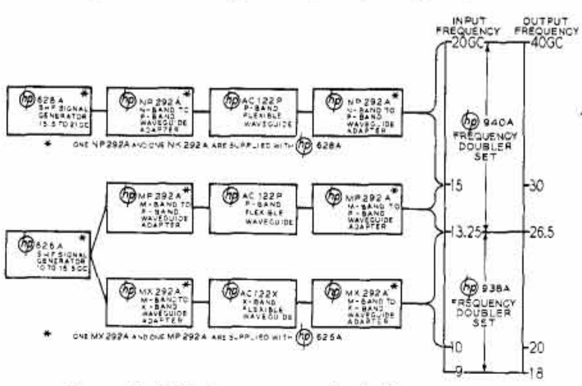


Figure 2. Driving sources, single frequency.

Specifications

ⓗ Model 938A Frequency Doubler Set

Frequency Range: 18-26.5 GC (KMC).

Conversion Loss: Less than 18 db at 10 mw.

Output Power: Depends on input power supplied. Approx. 0.5 to 1.0 mw when used with typical ⓗ Model 626 Signal Generator.

Saturation Output Power: 3 mw.

Input Power Required: 10 mw design center.

Maximum Input Power: 100 mw.

Output Monitor Accuracy: ± 2 db.

Output Attenuator Accuracy: $\pm 2\%$ of reading or ± 0.2 db whichever is greater.

Attenuator Range: 100 db.

Output SWR: Approx. 2 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.

Input Flange: M-Band flat cover flange for WR-75 waveguide.

Output Flange: UG-595/U flat cover flange for WR-42 waveguide.

Dimensions: 5″ high, 19″ wide, 18″ deep.

Weight: Net 20 lbs. Shipping 26 lbs.

Accessories Available: Waveguide Adapters MP292A, MX292A (one each furnished with ⓗ Model 626A). AC-122X, X-band flexible waveguide.

Price: ⓗ 938A, $1,500.00.

Complementary Equipment: ⓗ Model 626A Signal Generator. ⓗ Models 686C and 687C Electronic Sweep Oscillators.

ⓗ Model 940A Frequency Doubler Set

Frequency Range: 26.5 to 40 GC.

Conversion Loss: Less than 18 db at 10 mw input.

Output Power: Depends on input power supplied. Approximately 0.5 mw when used with typical ⓗ 626A and 628A Signal Generators.

Saturation Output Power: 2 mw.

Input Power Required: 10 mw design center.

Maximum Input Power: 100 mw.

Output Monitor Accuracy: $\pm$ 1 db.

Output Attenuator Accuracy: $\pm 2\%$ of reading or $\pm$ 0.2 db whichever is greater.

Attenuator Range: 100 db.

Output SWR: Approx. 2:1 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.

Input Flange: N-Band flat cover flange for WR-51 waveguide.

Output Flange: UG-599/U flat cover flange for WR-28 waveguide.

Dimensions: 5″ high, 19″ wide, 18″ deep.

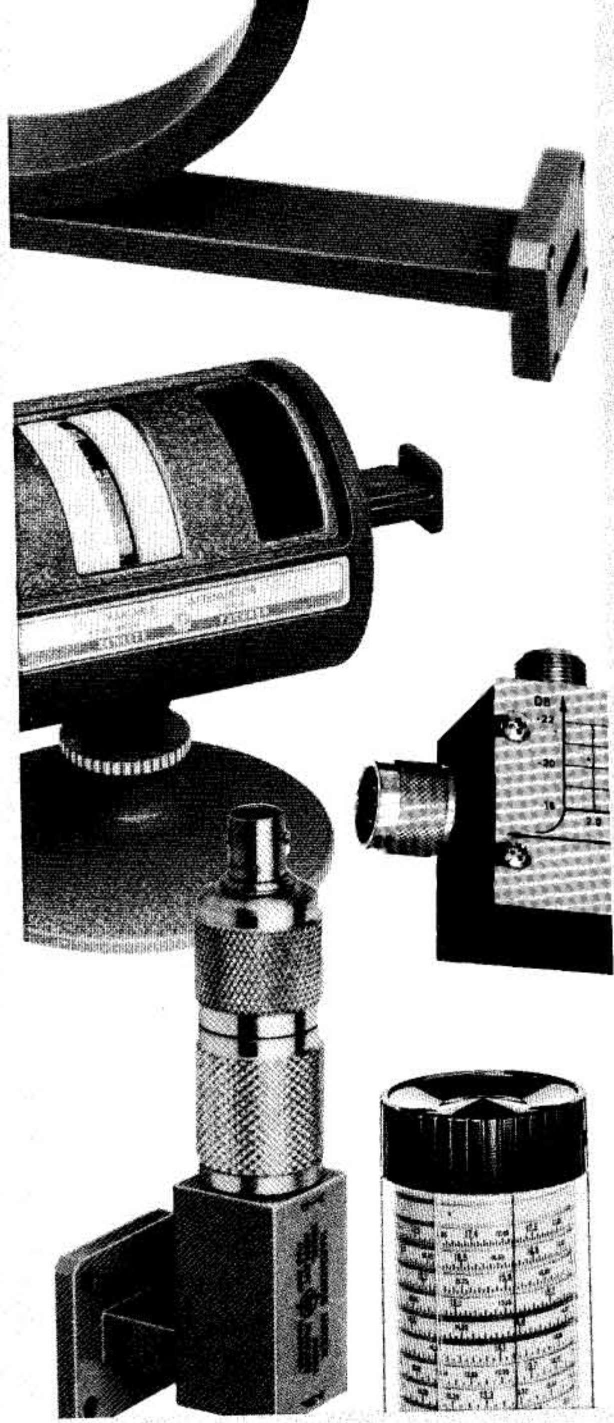
Weight: Net 20 lbs. Shipping 26 lbs.

Accessories Available: Waveguide Adapter NP292A, NK292A (one each furnished with ⓗ 628A), MP292A, AC-122P, P-Band flexible waveguide.

Price: ⓗ 940A, $1,500.00.

Complementary Equipment: ⓗ 626A and 628A Signal Generators. ⓗ 687C Electronic Sweep Oscillator.

Data subject to change without notice.



MICROWAVE

Hewlett-Packard microwave test equipment is designed to provide a complete set of high-quality, low-cost instruments for measurement of microwave parameters including power, impedance, noise figure, attenuation, and frequency. In addition to a wide variety of coaxial slotted lines, bridges, detectors, mounts, etc., the equipment includes complete instrumentation in the waveguide field. Each instrument has been designed for broad band coverage, high stability, broadest applicability, convenient size, and simplest possible operation. Highest quality metals, alloys, components and dielectrics have been used in construction; and utmost care is taken during manufacture. All units are thoroughly tested before leaving the factory and are warranted to conform with, or exceed, specifications.

Letter Designations

Model numbers of hp waveguide components are normally preceded by a prefix letter. This letter designates the waveguide size and frequency band of the instrument. Each hp waveguide instrument of a given band will have this same prefix in its model number. Eleven designator prefixes are used:

Band	Fits Waveguide Size (In.)	Freq. Range GC (KMC)
"S"	3" x 1½"	2.6 to 3.95
"G"	2" x 1"	3.95 to 5.85
"C"	1.718" x .923"	4.9 to 7.05
"J"	1½" x ¾"	5.3 to 8.2
"H"	1¼" x ⅝"	7.05 to 10.0
"X"	1" x ½"	8.2 to 12.4
"M"	.850" x .475"	10.0 to 15.0
"P"	.702" x .391"	12.4 to 18.0
"N"	.590" x .335"	15.0 to 22.0
"K"	.500" x .250"	18.0 to 26.5
"R"	.360" x .220"	26.5 to 40.0

Thus, an hp 370 Fixed Waveguide Attenuator designed for use with 3" x 1½" guide is designated S370. The same instrument designed for the .702" x .391" guide is designated P370.

Many Hewlett-Packard instruments also have suffix letters in the complete model number. Normally an "A" suffix is used to identify the original instrument while "B," "C" and other suffixes indicate a revised, modified or special version of the basic model.

However, in the case of certain hp microwave elements, the *suffix* letter indicates specific attenuation or coupling factors. Six designator letters are used:

"A"	3 db	"D"	20 db
"B"	6 db	"E"	30 db
"C"	10 db	"F"	40 db

Thus, the 20 db coupling version of hp 750 Cross-Guide Coupler will be designated as hp 750D.

The model of the 750 built for 1" x ½" waveguide systems will, of course, have the size *prefix* designator "X." Therefore, the complete model number of a 750 series Coupler with 20 db coupling for use with 1" x ½" equipment is hp X750D Cross-Guide Coupler. Use of this prefix and suffix code will simplify and speed inquiries and ordering.

Flanges

All hp waveguide equipment is equipped with plain AN cover flanges. When it is desired to connect between Hewlett-Packard instruments and a choke flange system under actual operating conditions hp 290A Cover to Choke Flange Adapters may be used.

K band (18 to 26.5 GC) and R band (26.5 to 40.0 GC) waveguide equipment is normally supplied with rectangular flanges. However, when specified, circular flanges may be obtained on most K- and R-band instruments at no extra charge.

Waveguide Equipment

Hewlett-Packard Broad Band Waveguide Instruments are based on a time-proven design approach. The fundamentals of this concept are:

1. Each instrument is of simplest construction consistent with its basic function and covers the entire frequency range of its waveguide size.
2. An integrated set of instruments is available for each commonly used waveguide frequency from S to R band.
3. Simple mechanical design, incorporating novel electrical circuitry, insures high accuracy, stability, and quality, and yet makes possible quantity production at low cost.

With hp waveguide equipment, you select the exact instruments you need. Each is designed in its most fundamental form, yet is integrated mechanically and electrically with the complete hp waveguide line. You are assured maximum operating flexibility, efficiency, convenience, and economy.

Power, Impedance, Noise Figure Measurements

General information and techniques for the use of Hewlett-Packard microwave test equipment in making power measurements are presented on pages 151 to 153. A similar discussion concerning microwave impedance measurements appears on pages 163 to 165. A discussion on noise figure measurements appears on page 176. Instruments appropriate to each type of measurement are shown on the pages immediately following the discussion of that type of measurement.

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 system in which 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 attenuation at the output indicator is a measure of the attenuation. This measurement requires first, that the law of the detector be known over the complete frequency range of the measurement; and second, that reflection effects in the system be essentially the same both with and without the attenuator.

The type of detecting equipment used will depend on the range of the attenuation measurement. A range of attenuation measurement up to 30 to 40 db can be achieved with a detector mount employing a barretter, and hp 415B 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 attenuation in decibels may be read directly from the Model 415B.

To eliminate effects of reflections between generator and attenuator, and attenuator and load, it is desirable to use pads. Pads should be well matched to the transmission system.[1]

The homodyne method permits measuring attenuation as high as 100 db. In this system a signal generator furnishes local oscillator power to a mixer and at the same time drives a TWT amplifier which is modulated to produce an offset frequency. The offset frequency is fed through the attenuator to be measured, and combined with the local oscillator frequency. The difference frequency is amplified in a tuned amplifier and applied to an indicating meter. Because the TWT amplifier is serrodyne modulated, the difference frequency from the mixer is constant and a narrow-band tuned amplifier such as ⓗ 415B may be used even though the signal generator frequency drifts.[2]

RF substitution depends on substituting an RF attenuator of known characteristic for the unknown. For instance, a signal generator attenuator may be used. When using this method the output of the signal generator is fed to the attenuator being measured and then into the detector. The attenuator being measured is removed, and a reading is obtained upon the detector. The setting of the signal generator attenuator is noted. The attenuator is then inserted, and the signal generator output is adjusted to obtain the same reading as before. The difference between the signal generator attenuator settings is the attenuation of the attenuator in db. Since the detector is always operated at the same level, detector law is no problem. The attenuator measurement may similarly be performed with an ⓗ 382A Precision Attenuator and a signal source.

The IF substitution method offers the highest accuracy in attenuation measurements since its substitution standard is a precise 30 MC cutoff attenuator. 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.[1]

Cable Characteristics

Two cable characteristics that frequently must be measured are attenuation and characteristic impedance. The following discussion indicates appropriate procedures for these measurements.

The measurement of large values of cable attenuation can be made by the previously described methods. The amount of attenuation for a given length of cable is measured in the same manner as described in the foregoing discussion of attenuation measurement.

The measurement of small values of cable attenuation requires a different technique. In this case, attenuation is calculated by measuring SWR of a shorted cable and substituting into a formula which relates SWR, cable length and attenuation. A recommended arrangement for this measurement is shown in Figure 1.

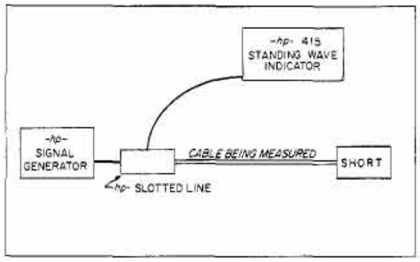


Figure 1. Suggested instrument arrangement for measuring small values of cable attenuation. Unknown cable is placed between slotted line and short.

In measurements on 50-ohm coaxial cable with this instrumentation, the procedure is as follows:

1. Measure cable length.
2. Measure SWR of shorted cable.
3. Compute attenuation from this formula:

$$\text{Tanh}\ \alpha = \frac{1}{\text{SWR}}\ \text{Nepers}$$

If αL is much smaller than 1, Tanh αL is approximately αL, and this formula reduces to

$$\alpha L = \frac{1}{\text{SWR}}\ \text{Nepers or}\ \frac{8.686\ \text{db}}{\text{SWR}}$$

For cables with a characteristic impedance of other than 50 ohms, a special technique must be employed which is beyond the scope of this discussion. See Terman & Pettit, "Electronic Measurements," 2nd edition, page 189.

Characteristic Impedance

The value of the characteristic impedance of a cable can be computed from impedance measurements made with a bridge such as ⓗ 803A VHF Bridge *(page 174)*. Suggested procedure is as follows:

At some specific frequency, measure the input impedance to the line with the output end of the line open. At the same frequency, measure the input impedance of the line with the output end shorted. Then compute the characteristic impedance with the formula:

$$Z_0 = \sqrt{Z_s\ (\text{op})\ Z_s\ (\text{sh})}$$

where Z_0 = characteristic impedance
Z_s (op) = input impedance with output end open
Z_s (sh) = input impedance with output end shorted

(Reference: Skilling, "Electric Transmission Lines," 1951, page 163.)

Another useful method of determining characteristic impedance in a coaxial cable is through the measurements of two constants of the cable—capacitance and velocity of propagation. The characteristic impedance is then computed as follows:

$$Z_0 = \frac{101{,}000}{VC}$$

where Z_0 = characteristic impedance
V = velocity of propagation
C = capacity in pf/foot

The suggested procedure is as follows:

1. Measure cable capacitance at low frequencies with a standard capacitance bridge.
2. Measure velocity of propagation at some frequency (above 50 MC to prevent "skin effect" errors).

Figure 2 indicates equipment appropriate to the measurement of velocity of propagation.

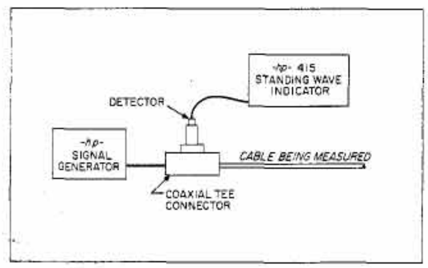


Figure 2. Arrangement of instruments for measuring velocity of propagation.

To measure velocity of progagation,

a. Vary frequency of the signal generator to obtain successive nulls on the standing wave indicator. Record frequencies of the nulls, f_1 and f_2.
b. Measure length of the cable in feet to the center of the tee connector.
c. Compute velocity of propagation from the formula:

$$V = \frac{Lf_1}{2.46K}$$

where L = cable length in feet
f_1 = recorded frequency
$K = \frac{2f_1}{f_2 - f_1}$

3. Substitute the values of capacitance and velocity of propagation in the formula:

$$Z_0 = \frac{101{,}000}{VC} = \text{characteristic impedance}$$

(See Terman & Pettit, "Electronic Measurements," 2nd edition, page 135.)

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[1]Request ⓗ Application Note #38, *Microwave Measurements for Calibration Laboratories,* for further information.

[2]See or Request ⓗ Application Note #6, *Homodyne Generator and Detection System.*

In the microwave region, power measurements are considered to be more basic than current or voltage measurements. This is because power is invariant with position of measurement, while current and voltage (because of the distributed nature of the transmission system at these frequencies) are not.

In the power range up to 10 milliwatts power measurements are customarily made by use of temperature-sensitive elements, such as bolometers. A bolometer is an element which converts rf power to heat, which in turn varies the resistance in proportion to the temperature change of the element. Bolometers are normally used in a bridge configuration which allows the change of resistance in the bolometer to be determined by external audio or dc techniques. Unbalanced bridge configurations are used occasionally. However, the more accurate bridges use ac substitution techniques which allow the resistance of the bolometer to remain at a fixed value (100 or 200 ohms) at all values of rf power. The audio power, which is removed to rebalance the bridge and keep the bolometer resistance constant, is a measure of the rf power being applied.

In the range above 10 watts, power measurements are generally made using calorimeter techniques. Either a dry calorimeter or a water flow calorimeter is usually used.

Between these low and high power ranges, measurements can be made using attenuators and low power bolometers. However, these measurements are somewhat clumsy and inaccurate.

The hp 434A Calorimetric Power Meter makes direct, convenient and accurate measurements in the 10 mw to 10 watt range. This unique oil flow calorimeter fills the need for a convenient measuring device having high accuracy and wide bandwidth.

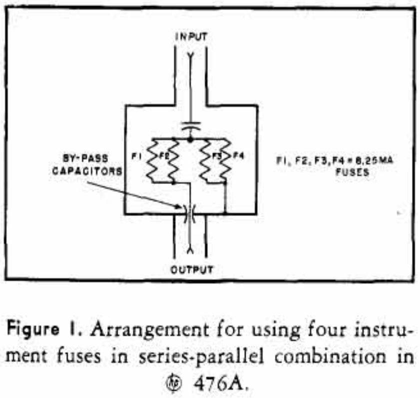


Figure 1. Arrangement for using four instrument fuses in series-parallel combination in hp 476A.

Conventional Bridge Techniques

Bolometers used for microwave measurements are of two general types: barretters—metallic wire or film in which the temperature coefficient of resistance is positive, and thermistors—semi-conductor material in which the temperature coefficient is negative. Both barretters and instrument fuses are used as positive temperature coefficient bolometers. Barretters consist of a short length of very fine platinum wire suitably capsulated. Negative temperature coefficient bolometers (thermistors) consist of a small bit of semi-conductive material suspended between two fine wires.

In general, barretters are delicate, and readily burned out by too much power. Even if the overload is insufficient to burn out a barretter, it may still increase its cold resistance to the point where a self-balancing bridge meter cannot be zero set. Thermistors are much more rugged. Although they are rated at 25 mw maximum, they generally burn out at about 400 mw and their characteristics change only slightly, if at all, upon overload.

The bolometer element is used in conjunction with a power meter such as the hp Model 430C *(pages 158, 159)*. This power meter is designed to operate with bolometer impedances of either 100 or 200 ohms.

The bolometer element itself must be mounted and well matched to the rf transmission system used and to the power meter. hp bolometer mounts feature low SWR through their operating range and are available for coaxial and waveguide systems. Barretters are usually operated at 200 ohms, while thermistors usually operate at 100 or 200 ohm levels. Series-parallel combinations of the bolometer elements are used in hp coaxial mounts. hp 476A Bolometer Mount, for example, uses four instrument fuses, each operating at 200 ohms and arranged to present 200 ohms to a microwave power meter but only 50 ohms to the rf energy. *(Fig. 1.)*

The power measured by a bolometer mount also depends upon the relationship between the load and the source impedance. To obtain maximum available power the load should present a conjugate match to source impedance. This can be achieved by properly adjusting a double-stub tuner, a line stretcher, an E-H tuner, or a slide-screw tuner. These tuners transform the magnitude and phase of the source impedance in order to conjugate match it to the load impedance. Errors that result from generator and load mismatch have been discussed under the section of this catalog dealing with Signal Generators.

hp 430C Microwave Power Meter will give direct instantaneous readings of microwave power when connected with a suitable bolometer mount. The bias current necessary to bring the bolometer to the correct operating resistance is furnished by the 430C Power Meter. This power meter circuit includes a self-balancing bridge and an audio voltmeter to indicate the magnitude of the bridge amplifier output, *(Figure 2)*. The self-balancing bridge uses the external bolometer element (a non-linear resistor) as one of the bridge arms. A high gain amplifier is connected across the bridge as a detector, and the output of the same amplifier is connected as the driving source for the bridge. With sufficient gain, the bridge oscillates and audio power is furnished at an amplitude such that the bridge is almost balanced. When the rf power is applied to the element, the amplitude of oscillation decreases an amount necessary to maintain the element's resistance constant. This audio power decrease is equal to that power added by the rf source and can be read on the voltmeter which is calibrated in power units.

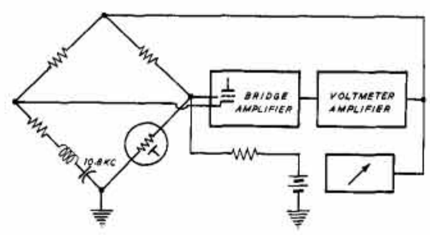


Figure 2. Basic Circuit of Power Meter.

ⓗⓟ bolometer mounts have been designed for both coaxial and waveguide systems at frequencies between 10 MC and 40.0 GC(KMC). These mounts are extremely simple to use, have low SWR, and may be used with ⓗⓟ 430C Power Meter to provide direct reading measurements. ⓗⓟ bolometer mounts may be classified according to the type of bolometer element employed—thermistor, or barretter—and whether the mount is untuned (broadbanded) or tunable.

ⓗⓟ fixed tuned thermistor mounts are exceptionally broad band bolometers. Model 477B Coaxial Thermistor Mount *(page 160)* covers the frequency range of 10 MC to 10 GC, while ⓗⓟ 487B *(waveguide series, page 162)* are available from 2.6 to 40.0 GC. No tuning is required and an extremely low SWR is maintained throughout frequency bands.

Model 485B Detector Mounts *(page 161)* employ a single tuning control to match the applicable waveguide to a barretter power detection element. In general, their SWR is less than 1.25 over the rated frequency range when using barretters. This provides an excellent match to the rf line and very low mismatch losses.

ⓗⓟ 476A Universal Bolometer Mount *(page 160)* is a fixed tuned bolometer in the frequency range from 10 to 1,000 MC. The bolometer element consists of 8.25 ma fuses.

In general, squarewave or pulse modulated power can be measured accurately with either a barretter, fuse, or thermistor, subject to certain limitations which depend upon the characteristics of the bolometer elements in conjunction with the bridge oscillator. However, in ⓗⓟ 430C Power Meter, these limitations are not serious.

New Temperature Compensated Power Bridge

Conventional bolometer bridge techniques have a serious limitation in the lower power sensitivity regions because of thermal drift in the mount itself. Since the bolometer is a temperature sensitive element, power of all types, including ambient temperature change, causes a resistance change in the mount. In fact, typical power sensitivity of a thermistor mount to temperature change is such that 0.005° Centigrade is approximately equivalent to 1 microwatt. Such a high temperature sensitivity seriously limits the low power sensitivity unless special techniques are employed.

The new ⓗⓟ 431A Temperature Compensated Power Meter *(pages 156, 157)* represents a significant advance in stability and accuracy in power measurements. The power meter utilizes a dual bridge, temperature-compensated circuit arrangement which allows power measurements to be made down to a full scale sensitivity of 10 microwatts. Operation is essentially drift-free.

Under laboratory conditions, for instance, long-term drift on the most sensitive range of 10 microwatts full scale, is typically 1 or 2 microwatts per 4 hour period. This extreme stability makes for a truly satisfying power measurement in the high sensitivity region and opens a new area of convenience to power meter users. Furthermore, power up to 10 milliwatts may be measured directly on the same bridge.

Time savings on zero setting alone are appreciable and further time savings are made by providing that the zero set be carried over for all power ranges. Previous conventional bridge techniques required that new zeroing be done whenever the power range switch was turned to a different range.

Operation of the temperature compensated power meter depends on the use of two identical thermistor bridges. Thermally sensitive elements, the thermistors, are located in close thermal proximity to each other, but one element is placed so that it absorbs rf power from a transmission line while the other element is free from any rf influence. Special mount design and thermistor mounting procedures provide the nearly identical thermal environment, the coupling of rf power to one thermistor and the shielding of the other.

An increase or decrease of ambient temperature tends to change the operating resistance of both thermistors. The unbalance, sensed by the temperature compensating thermistor bridge, is amplified and in turn reduces the audio power applied to both bridges, keeping both in balance. Thus, as long as the temperature sensitivity of the two thermistors tracks with temperature, and they are both maintained in close thermal proximity, temperature effects are essentially cancelled out. The rf power applied to the rf mount, however, reduces the audio power drive to both bridges and, to maintain the temperature compensating bridge in balance, a dc power is supplied from the electronics of the power meter. It is this dc power which is metered to indicate the rf power input. One feature of this bridging system is that both bolometer elements are maintained in a balanced condition, and since they are identical thermally there is a 1 to 1 translation between the rf power supplied to the rf bridge and the dc rebalance power supplied to the compensating bridge. Thus, both elements are maintained at the same impedance over all power ranges. One of the advantages obtained from operating both bridges in a balanced condition is that 10 milliwatts of rf power can be measured. This is not true of some temperature compensated power meters which utilize an unbalanced bridge as the metering drive.

The 431A features a "zero carry over" which means that the power meter may be balanced on the lowest range of 10 microwatts, and as the range is switched upward to 10 milliwatts no re-zoning need be done.

High accuracy is realized in this meter by careful attention to switching resistors and bridge determining resistors. In addition, terminals are provided on the rear of the unit for a dc calibration input to calibrate the mounts with precise dc standards for even higher accuracy. For better readability commensurate with the increased accuracy that can be obtained with precise dc calibration, a recorder output is provided. A 3 or 4 digit digital dc voltmeter may be connected to the recorder output and, in combination with precise dc calibration, improves resolution and accuracy of power measurements. Hence, Model 431A provides an extremely convenient automatic balancing bridge with excellent readability for use in Standards laboratories.

The special bridge balancing arrangement in Model 431A achieves a new convenience in pulsed power measurements. Conventional bridges respond to the audio drive voltage and mathematically convert this to indicate power. At low repetition rates the bridge tends to follow the rf modulation, with the meter responding to average voltage rather than average power. Since Model 431A meters a dc rebalance voltage proportional to power, true power averaging is obtained on amplitude modulated rf waves.

A special series of coaxial and waveguide thermistor mounts has been designed for use with this temperature-compensated power meter, and these mounts must be used because of the inherent thermal matching problems in the mounts. These mounts are presently available in coax and X-band. The Model 478A *(page 157)*, which covers the frequency range from 10 megacycles to 10.5 GC, is an extremely compact thermistor mount which contains both thermistor elements in close thermal contact. It utilizes a dual set of rf thermistors, each operating at 100 ohms so that it presents 200 ohms to the temperature compensated power meter while presenting 50 ohms to the rf line. The compensating elements are constructed in a similar manner.

A second temperature compensated mount, Model X486A *(page 157)*, is available in X-band waveguide, which covers the frequency range from 8.2 to 12.4 GC. Other waveguide mounts from 2.6 to 40 GC are being made available. Write for information.

10 mw to 10 Watts

The Model 434A Calorimetric Power Meter *(see pages 154, 155)* automatically measures average power from 10 milliwatts to 10 watts. The instrument operates from dc to 12.4 GC. The operator simply connects the source to the 434A and reads the power. Power above 10 watts may be measured by reducing it to the range of the 434A with calibrated attenuators or directional couplers.

Model 434A is ideally suited for highly accurate measurements because its overall accuracy is 5% which includes rf efficiency and substitution error. Also, it allows direct measurement of intermediate powers and thus eliminates the error in the power reducing attenuator which is required in bolometer techniques.

The Model 434A, shown simplified in Figure 3, 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.

To provide swift balancing, an efficient heat transfer from the loads to the temperature gauges is accomplished by immersing the components in an oil stream. This gives full scale deflection in less than 5 seconds.

The power measurement is accurate, because the flow rates through the two heads are the same and the head characteristics are the same. To insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger prior to entering the heads.

The accuracy of Model 434A is one of its unique attributes. Since the power meter represents the most accurate method available for measuring high-frequency power the 434A may find much use as a laboratory standard power meter. Nominal accuracy is 5%. However, higher accuracies can be achieved by employing techniques to minimize frequency and impedance mismatch effects.

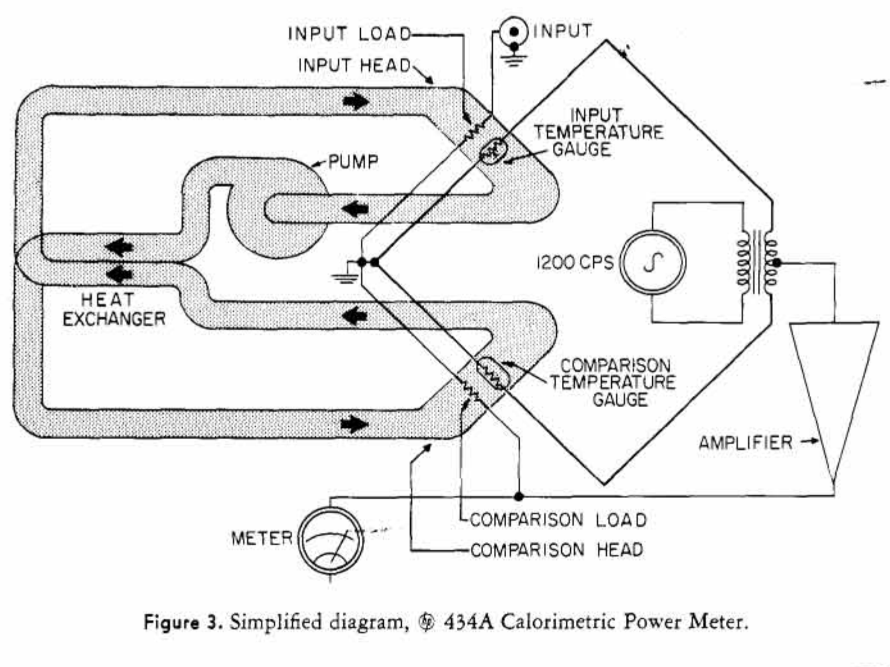


Figure 3. Simplified diagram, ⓗ 434A Calorimetric Power Meter.

hp 434A CALORIMETRIC POWER METER

Just Connect, Read Power 10 mw to 10 Watts

Advantages:

Simplest power measurements, 10 mw to 10 watts, dc to 12.4 GC (KMC)

No barretter or thermistor needed

No external terminations or plumbing

Compact, entirely self-contained

Direct reading in watts and DBW

Uses:

Measures power to 10 watts average, 1 KW peak

AM power measurement

Pulsed, ac and video power

Measure dc powers

Stated simply, the hp 434A Calorimetric Power Meter offers you this:

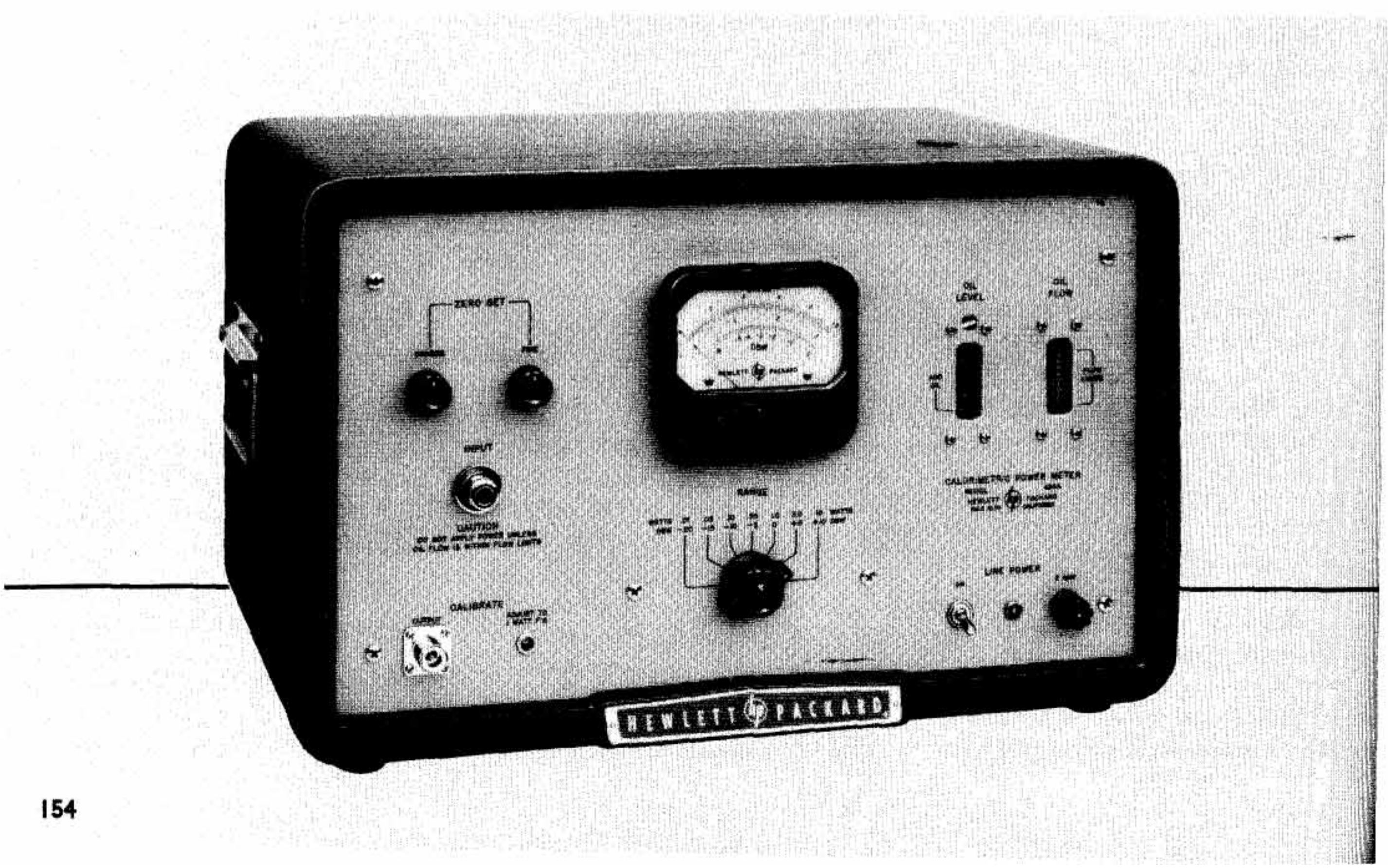
The fastest, easiest means yet devised to measure powers accurately from 10 milliwatts to 10 watts between dc and 12.4 GC (KMC).

With the new 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 431A (pages 156,157) 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 or plumbing of any type.

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 adjustments in input tuning circuits. Further, the use of twin power sensitive elements in one oil stream plus a feedback system makes the accuracy virtually independent of variations in oil flow rate or ambient temperature, and prevents fluctuations because of changes in oil temperature.

Circuit Description

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.

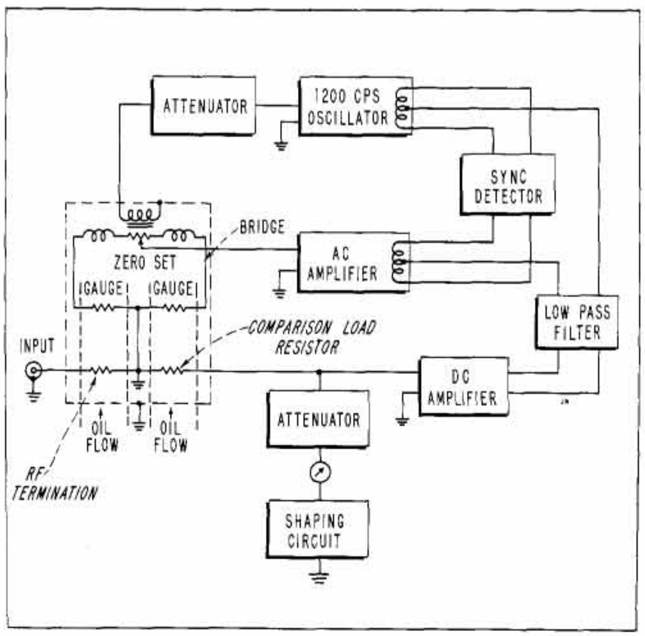


Figure 1. Basic arrangement of instrument circuitry.

Specifications

Input Power Range: Seven meter ranges. Full-scale readings of 0.01, 0.03, 0.1, 0.3, 1.0, 3.0 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.

Peak Input Power: 1 kilowatt, maximum.

Frequency Range: DC to 12.4 GC (KMC).

DC Input Impedance: 50 ohms ± 5 ohms at type N input jack.

Input SWR: DC to 5 GC, less than 1.3. 5 to 12.4 GC, less than 1.5.

Meter Response Time: Less than 5 seconds for full scale deflection.

Internal Calibrator: 100 mw dc ± 1% into 45 to 55 ohms.

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:

DC	Upper Ranges ½%
	Two Lowest Ranges 2%
0 to 1 GC	Upper Ranges 1%
	Two Lowest Ranges 3%
1 to 4 GC	Upper Ranges 2%
	Two Lowest Ranges 4%
4 to 10 GC	Upper Ranges 3%
	Two Lowest Ranges 5%
10 to 12.4 GC	Upper Ranges 4%
	Two Lowest Ranges 5%

Power Supply: 115/230 volts ± 10%, 50/60 cycles, approximately 155 watts with no input, 175 watts with 10 watts input.

Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14" deep. Rack Mount: 19" wide, 10½" high, 13½" deep behind panel.

Weight: Net 49 lbs. Shipping 60 lbs. (cabinet mount). Net 44 lbs. Shipping 59 lbs. (rack mount).

Price: ⓗⓟ 434A, $1,600.00 (cabinet); ⓗⓟ 434AR, $1,585.00 (rack mount).

Data subject to change without notice.

431A POWER METER

New Accuracy and Temperature Stability; Power Measurements 1 μw to 10 mw

Advantages:

Drift less than 2 μw per degree Centigrade for a wide temperature range

± 3% accuracy on all ranges. Even greater accuracy using simple external calibration procedures

One zero setting for all ranges

Extremely easy to operate

Grounded recorder output

Portable operation (with optional battery pack)

Uses:

Instantaneous microwave power measurements with higher accuracy

Microwave standards measurements with appropriate techniques

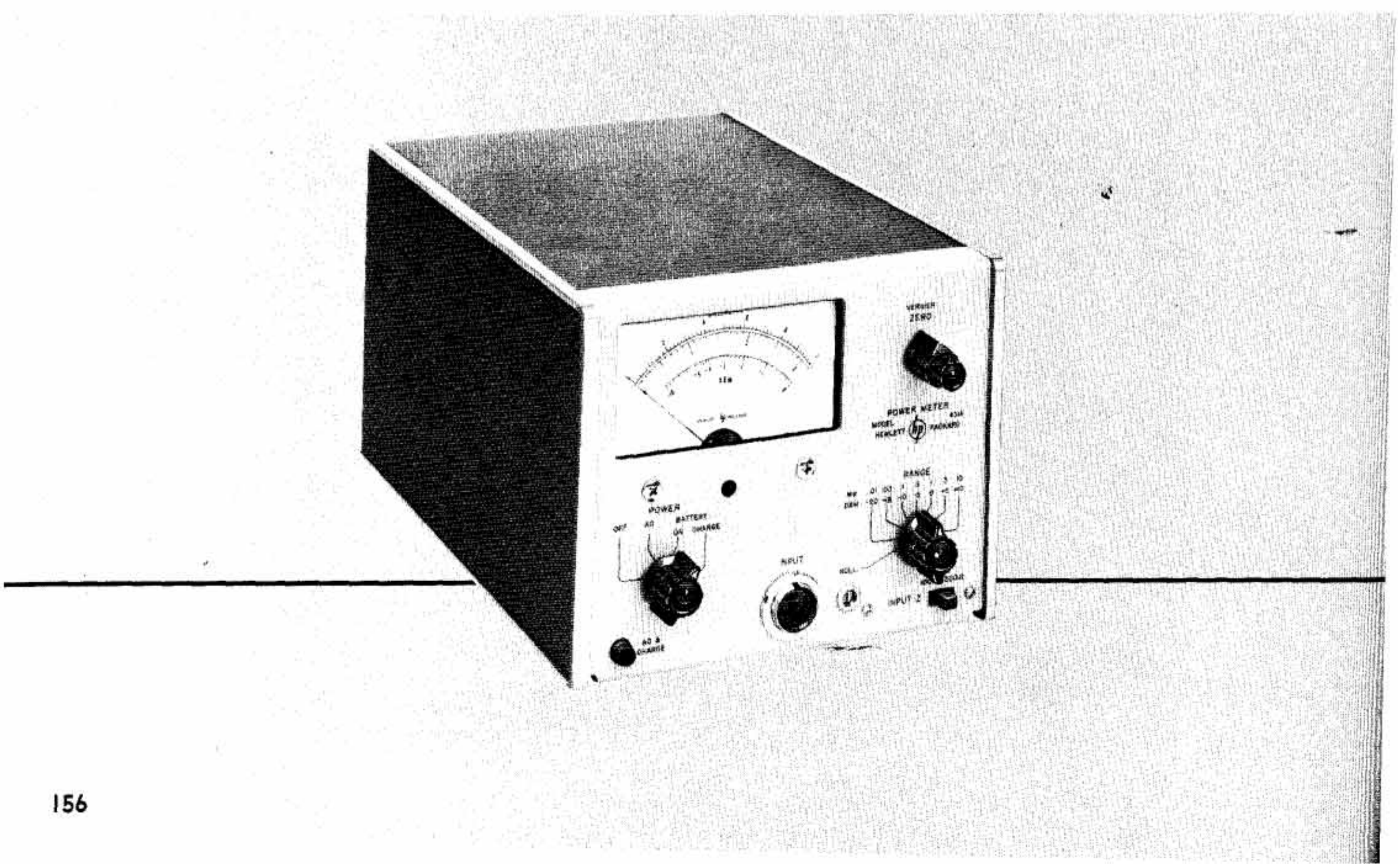
Continual zero-setting is a thing of the past . . . even on the 10 μw range, with the new hp 431A Power Meter. A drift stability of less than 2 microwatts per °C means that in typical laboratory environments one zero setting will hold for hours. In addition, only one zero adjustment is needed to calibrate the 431A 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 sensitivity of 10 db over previously available equipment. Full scale readings of 10 μw to 10 mw are covered in 7 ranges. The meter face is also calibrated in dbm with 5 db between ranges. Direct-reading accuracy is ± 3% of full scale.

Newly-designed temperature-compensated thermistor mounts are required for operation with the hp 431A. The new hp 478A Coaxial Mount covers 10 MC to 10 GC (KMC) and the new 486A Waveguide Mount is being made available for the various waveguide bands.

Microwave standards measurements can be made to high accuracy and resolution with the Model 431A by using the automatic bridge as a transfer device. A dc calibration input jack permits precise dc calibration of the thermistor mount. The grounded output jack will then drive an appropriate digital voltmeter for increased resolution.

The hp 431A 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 ⓗⓟ 431A. One arm of each is a temperature-sensitive element. The thermistor units are in close thermal proximity in the dual mount. One bridge is made sensitive to a combination of rf power, audio power, and power supplied by ambient temperature change. The other bridge element is made sensitive to audio, temperature, and dc power. By suitable design of the thermistor mounts, the thermal characteristics are made virtually identical. In this way, dc power in one bridge is made equal to rf power in the other. The dc power is metered. 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 new ⓗⓟ 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

ⓗⓟ 431A

Power Range: 7 ranges. Full scale readings from 10 μw to 10 mw. Also calibrated in dbm from -30 dbm to $+10$ dbm.

Accuracy: $\pm 3\%$ of full scale on all ranges.

Overall Thermal Drift: Less than 2μw/°C (includes meter and 478A/486A mounts).

Operating Impedance: 100 or 200 ohms, negative, for operation with ⓗⓟ 478A/486A.

Recorder/Voltmeter Output: Phone jack on rear with 1 ma into maximum of 2,000 ohms.

Calibration Input: Binding posts on rear for calibration of bridge with precise dc standards.

Power: 1½ watts, 115/230 v $\pm$ 10%, 50–1,000 cps.

Dimensions: 7½" wide, 6½" high, 12½" deep.

Weight: Net, approximately 10 lbs.

Accessories Furnished: 5-foot interconnection cord for ⓗⓟ temperature-compensated thermistor mounts.

Accessories Available: Rechargeable battery pack.

Price: ⓗⓟ 431A, $345.00.

ⓗⓟ 478A THERMISTOR MOUNT

Newly-designed model 478A Thermistor Mount, a wide-range, temperature compensated device, contains two thermistor pairs for use with the dual bridge ⓗⓟ 431A Power Meter. Frequencies from 10 MC to 10 GC (KMC) are covered with this one broadband unit, and no tuning is required.

Very similar thermal environments are provided for the two thermistor pairs. Excellent tracking is achieved, even when thermal shocks are applied. When used with the ⓗⓟ 431A Power Meter, Model 478A gives high accuracy and virtually drift-free operation.

Specifications

ⓗⓟ 478A with ⓗⓟ 431A

Frequency Range: 10 MC to 10 GC.

SWR: Less than 1.5 (less than 1.3 — 50 MC to 7 GC).

Power Range: 1 μw to 10 mw.

Elements: Four 100 ohm, negative temperature coefficient thermistors permanently installed.

Price ⓗⓟ 478A, $145.00.

ⓗⓟ 486A WAVEGUIDE THERMISTOR MOUNT

X-band power measurements can now be made with high accuracy and new operating convenience. New ⓗⓟ 486A is a temperature-compensated 1 μw sensitivity mount containing two thermistor elements in a mounting scheme providing very similar thermal environments. Extremely close temperature tracking is achieved, even with the application of thermal shocks, making the instrument remarkably free from drift.

Model 486A covers X band, with no tuning required. Temperature-compensated waveguide mounts for other bands are also being made available. Request latest price and delivery information.

Specifications

ⓗⓟ 486A with ⓗⓟ 431A

Frequency Range: 8.2 to 12.4 GC.

Power Range: 1 μw to 10 mw.

SWR: Less than 1.5.

Elements: Two permanently installed 100-ohm negative coefficient thermistors.

Waveguide Size: 1 x ½ inches.

Price: ⓗⓟ 486A, $145.00.

Data subject to change without notice.

hp 430C MICROWAVE POWER METER

Direct, Automatic, Instantaneous Pulsed or CW Power Readings

Advantages:

Reads direct in dbm or mw; no tedious calculations

Wide power range; nominal range extendable with directional couplers and attenuators

Automatic operation; usable with many different bolometers

Uses:

Instantaneous microwave power measurements, pulsed or CW

Use on waveguide or coaxial system

This hp Microwave Power Meter gives you instantaneous rf power readings direct 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 either a negative or positive temperature coefficient bolometer at 100 or 200 ohm levels. Power is read direct in milliwatts, 0.01 to 10 mw, or in dbm from −20 to +10. Higher powers may be measured by adding attenuators such as hp 370, 380 or 382A series to the system. Directional couplers such as hp 750 or hp 752 may also be used to sample energy.

When used in an appropriate bolometer mount, instrument fuses are generally satisfactory for measuring CW, pulsed, square- or sine-wave modulated power at frequencies up to 4 GC (KMC). Barretters and thermistors can be used for these measurements at much higher frequencies; up to 12.4 GC for barretters (in hp mounts) and up to 40.0 GC for certain thermistors.

Hewlett-Packard waveguide bolometer mounts for the 430C are available covering, collectively, the frequency spectrum from 2.6 to 40.0 GC. Each bolometer mount covers a

complete waveguide band. In addition, three coaxial bolometer mounts cover the frequency spectrum from 10 MC to 10 GC. Model 430C Microwave Power Meter will furnish dc bias current for all bolometer mounts which require up to 16 ma bias current. Fine as well as coarse control of the bias current permits exact balancing of the bolometer element in the bridge over wide range ambient temperature variations.

Circuit Description

430C consists of an audio bridge, one arm of which is a power-sensitive element. The bridge is initially balanced with no rf power in the element. As rf power is applied, the equivalent in audio power is automatically removed, so the bridge remains in balance. The change in audio power level indicates directly on a VTVM calibrated to show rf power in the sensitive bridge arm.

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. (0 dbm = 0.001 watt). Power range may be extended with attenuators or directional couplers.

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 positive or negative temperature coefficient bolometers. DC bias current is continuously adjustable and independent of bolometer resistance and power level range.

Suitable bolometers are:

Instrument fuses: G-28A 1/100 amp fuse.

Barretters: Sperry 821, Narda N821B or N610B, PRD 610A, 614, 617 or 631C.

Thermistors: W. E. D166382 and 32A3, V. E. Co. 32A3, 32A5, Narda 333, 334.

Accuracy: ± 5% of full scale reading.

Power: 115/230 v ± 10%, 50/1,000 cps, 90 watts.

Dimensions: Cabinet Mount: 7½" wide, 11½" high, 14¼" deep. Rack Mount: 19" wide, 7" high, 13⅛" deep behind panel.

Weight: Net 14 lbs. Shipping 19 lbs. (cabinet mount). Net 18 lbs. Shipping 30 lbs. (rack mount).

Accessories Available: AC-16K Video Cable Assembly, $6.50; AC-16D Cable Assembly, $3.50.

Price: 430C, $250.00 (cabinet); 430CR, $255.00. (rack mount).

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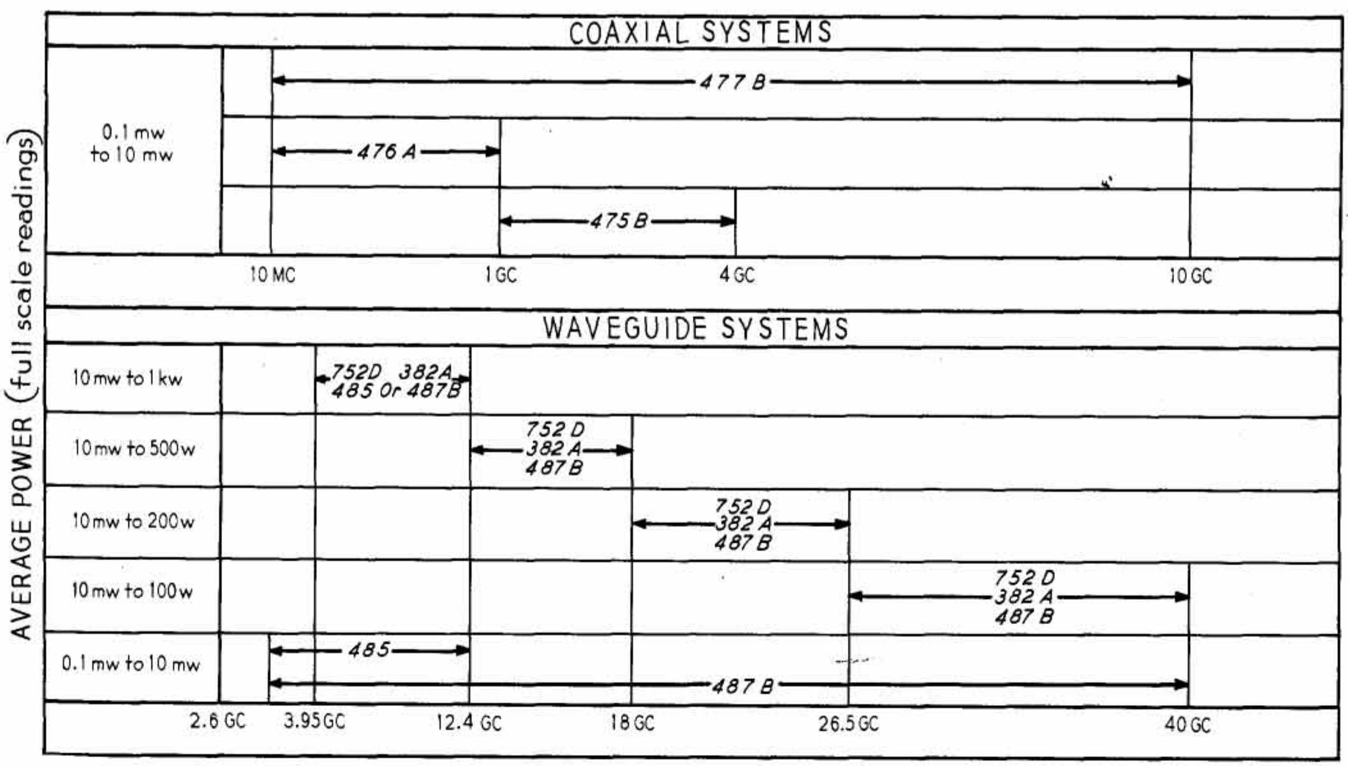

hp 477B Thermistor Mount

This thermistor mount provides full frequency coverage 10 MC to 10 GC with SWR of less than 1.5. It requires no tuning, and employs long time-constant elements assuring measurement accuracy even for low duty cycle pulses. The instrument is not susceptible to burnout even at power levels as high as 1 watt.

hp 477B is designed for use with the hp 430C Microwave Power Meter and can also be used with other bolometer bridges providing negative temperature coefficient operation at the 200 ohm level. Approximately 13 ma of bias is required.

Specifications

Frequency Range: 10 MC to 10 GC (KMC).

SWR: Less than 1.5 (less than 1.3—50 MC to 7 GC).

Power Range: 0.01 to 10 mw (with hp 430C Microwave Power Meter).

Element: 200 ohm, negative temperature coefficient thermistor included.

Accessories Available: AC-16K Video Cable Assembly, $6.50.

Price: hp 477B, $75.00.

hp 476A Universal Bolometer Mount

Used with hp 430C Microwave Power Meter, this universal bolometer mount measures power from 10 to 1,000 MC and gives instantaneous, automatic power readings from 0.02 to 10 milliwatts. No tuning or adjustment is necessary. Higher powers may be measured by use of attenuators and directional couplers in conjunction with Model 476A. SWR is low, and reflected power is less than 0.1 db under most conditions.

Specifications

Nominal Impedance: 50 ohms.

Maximum SWR: Less than 1.15, 20 to 500 MC.
Less than 1.25, 10 to 1,000 MC.

Maximum Power: 10 milliwatts.

Bolometer Element: Four 8.25 ma instrument fuses, specially selected and treated. (hp G-28B.)

Accessories Available: AC-16F RF Cable Assembly, $15.00; AC-16K Video Cable Assembly, $6.50.

Price: hp 476A, $85.00.

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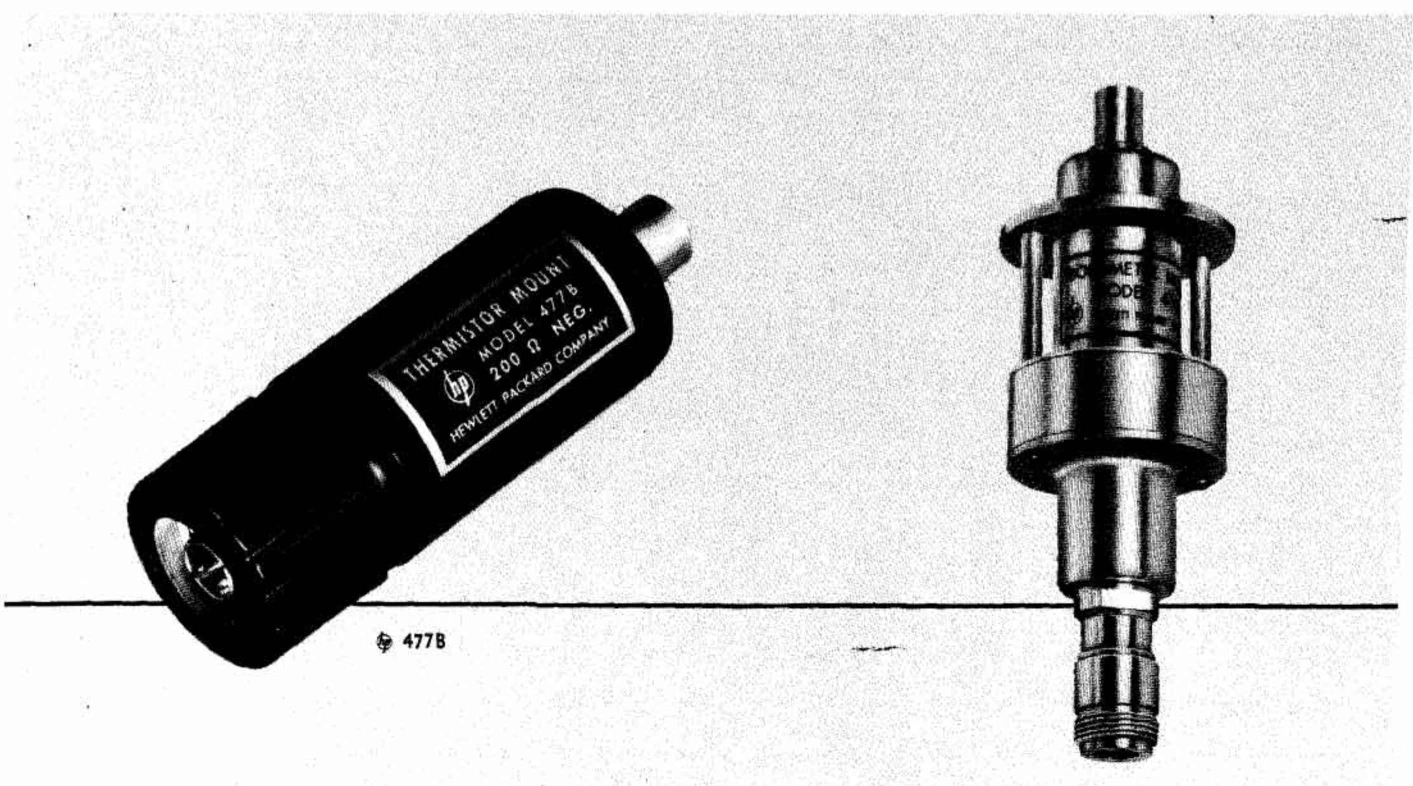


hp 477B

hp 476A

Simple Devices for Measuring or Detecting RF Power

Hewlett-Packard offers three basic 485 series Mounts, each ideally designed for its function and frequency range.

ⓗ **S485A**, 2.6 to 3.95 GC (KMC), is offered in the S band range only. This instrument uses a Sperry 821 or Narda N821 barretter and requires no tuning. SWR is less than 1.35 over the entire waveguide band.

ⓗ **485B series**, for higher waveguide frequencies (3.95-12.4 GC), is tuned by a variable short adjustable to SWR of less than 1.25 full range. For power measurements this results in a reflection loss of less than 0.1 db. ⓗ 485B Mounts employ either a Sperry 821 or Narda N821 barretter. Or, for maximum sensitivity a 1N21 or a 1N23 silicon crystal may be used. Detector elements can be quickly interchanged.

ⓗ **485D Waveguide Barretter Mounts** are available in S, G, and J bands covering 2.6 to 8.2 GC. These instruments are supplied with factory-installed 821-type barretters tested for SWR, frequency response and square-law characteristics. Sensitivity is 0.2 v/mw, SWR ranges from 1.35 to 1.5, response is ± 1 db and variation from square-law characteristic is less than ± 0.5 db. No tuning required. ⓗ AC-60K Barretter Matching Transformer is required to interconnect the 485D with ⓗ 416A Ratio Meter (pages 172, 173).

All models have BNC output connectors mating with UG88/U plugs.

Specifications

Model	Maximum SWR	Frequency Range GC (KMC)	Fits Waveguide Size (in.)	Length (in.)	Price
S485A[1]	1.35	2.60 - 3.95	3 x 1½	4-11/16	$165
G485B[1]	1.25	3.95 - 5.85	2 x 1	9-5/16	95
J485B[1, 2]	1.25	5.85 - 8.20	1½ x ¾	7⅜	90
"	1.35	5.50 - 5.85			
"	1.50	5.20 - 5.50			
H485B[1]	1.25	7.05 - 10.0	1¼ x ⅝	6⅜	85
X485B[1]	1.25	8.20 - 12.4	1 x ½	6	75
S485D	1.5	2.60 - 3.95	3 x 1½	4½	185
G485D	1.5	3.95 - 5.85	2 x 1	3⅛	170
J485D	1.5*	5.20 - 8.20	1½ x ¾	4¼	170

[1]Detector not supplied. [2]SWR increases to 1.5 at 5.2 GC.
All mounts accept either barretter or crystal except -*hp*- S485A, which employs barretter only.
*From 5.2 to 7.5 GC. Increases to approximately 2.0 at 8.2 GC.

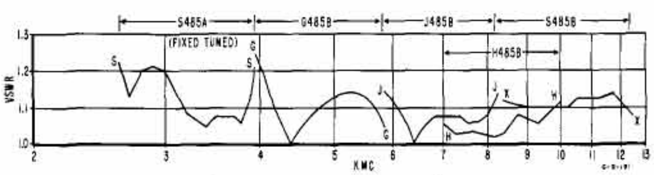
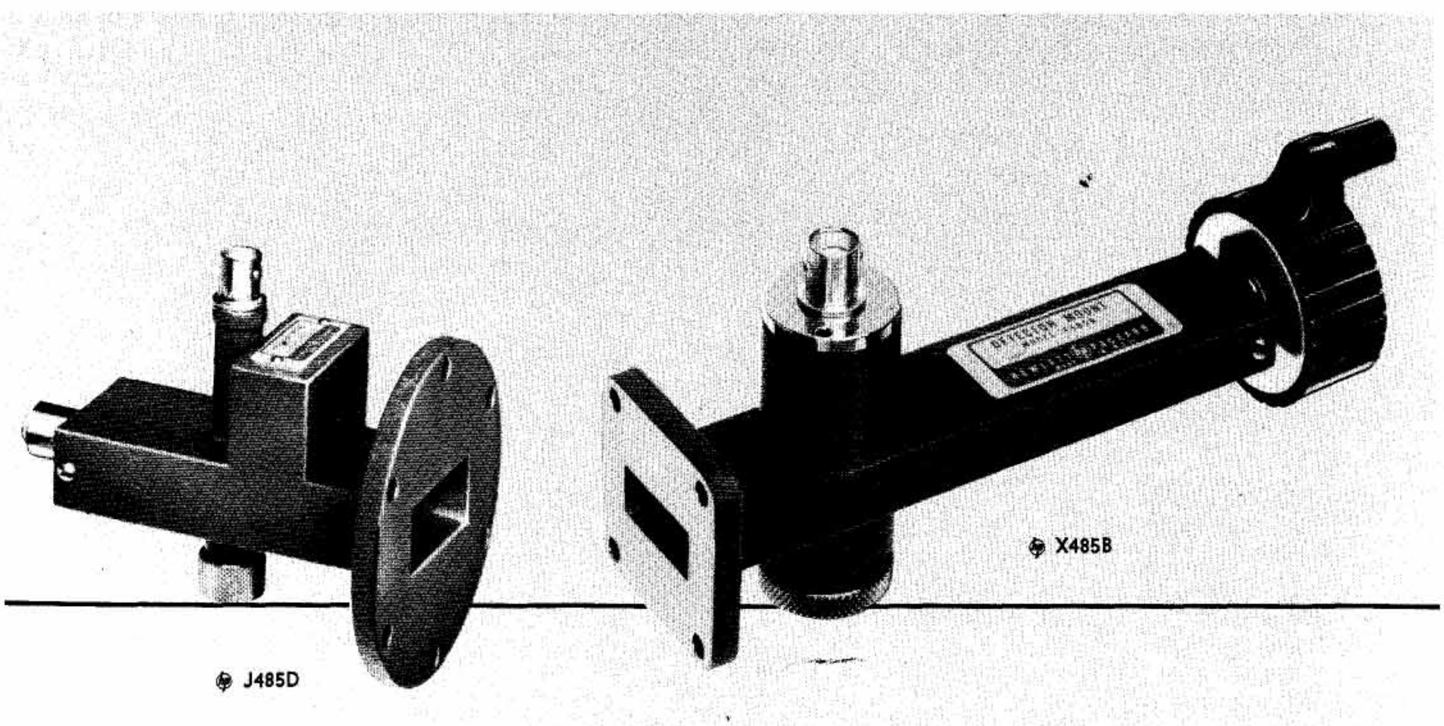


Figure 1. Typical SWR vs. Frequency, ⓗ 485, when used with barretter.

Data subject to change without notice.



ⓗⓟ 487 WAVEGUIDE THERMISTOR MOUNTS

Low SWR, No Tuning. Covers Full Waveguide Frequency Range

Hewlett-Packard 487 series Waveguide Thermistor Mounts are dependable, accurate and convenient instruments that materially simplify setups and save operator time in microwave power measurement.

Series 487 instruments collectively cover all frequencies from 2.6 to 40.0 GC (KMC).

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. Since thermistors have inherent overload protection, and since the majority of power is reflected during overload conditions, burnouts are virtually impossible.

Model 487 mounts are equipped with cover flanges and BNC output connectors. They are designed for use with microwave power meters such as ⓗⓟ 430C or other instruments responsive to negative temperature coefficient bolometers operating at the 100 or 200 ohm level.

Specifications

Model	Maximum Power	Maximum SWR	Frequency Range GC (KMC)	Fits Waveguide Size (in.)	Length (in.)	Price
S487B	10 mw	1.35	2.60 - 3.95	3 x 1½	2⅜	$105.00
G487B	10 mw	1.5	3.95 - 5.85	2 x 1	2⅛	95.00
J487B	10 mw	1.5	5.3 - 8.2	1½ x ¾	1¾	90.00
H487B	10 mw	1.5	7.05 - 10.0	1¼ x ⅝	1 5/16	80.00
X487B	10 mw	1.5	8.2 - 12.4	1 x ½	1 3/16	75.00
M487B	10 mw	1.5	10.0 - 15.0	0.850 x 0.475	15/16	110.00
P487B	10 mw	1.5	12.4 - 18.0	0.702 x 0.391	13/16	110.00
K487C[1]	10 mw	2.0	18.0 - 26.5	½ x ¼	1⅝	225.00
R487B[1]	10 mw	2.0	26.5 - 40.0	0.360 x 0.220	1⅜	225.00

Thermistor: Permanently installed 100-ohm negative coefficient thermistor. (K487C and R487B use 200-ohm thermistors.)

Thermistor Time Constant: Approximately 1 second when cooling on an open circuit.

Accessories Available: AC-16K Cable Assembly, $6.50.

[1]K and R-band units with UG425/U and UG381/U flanges are available; specify K487BC or R487BC.

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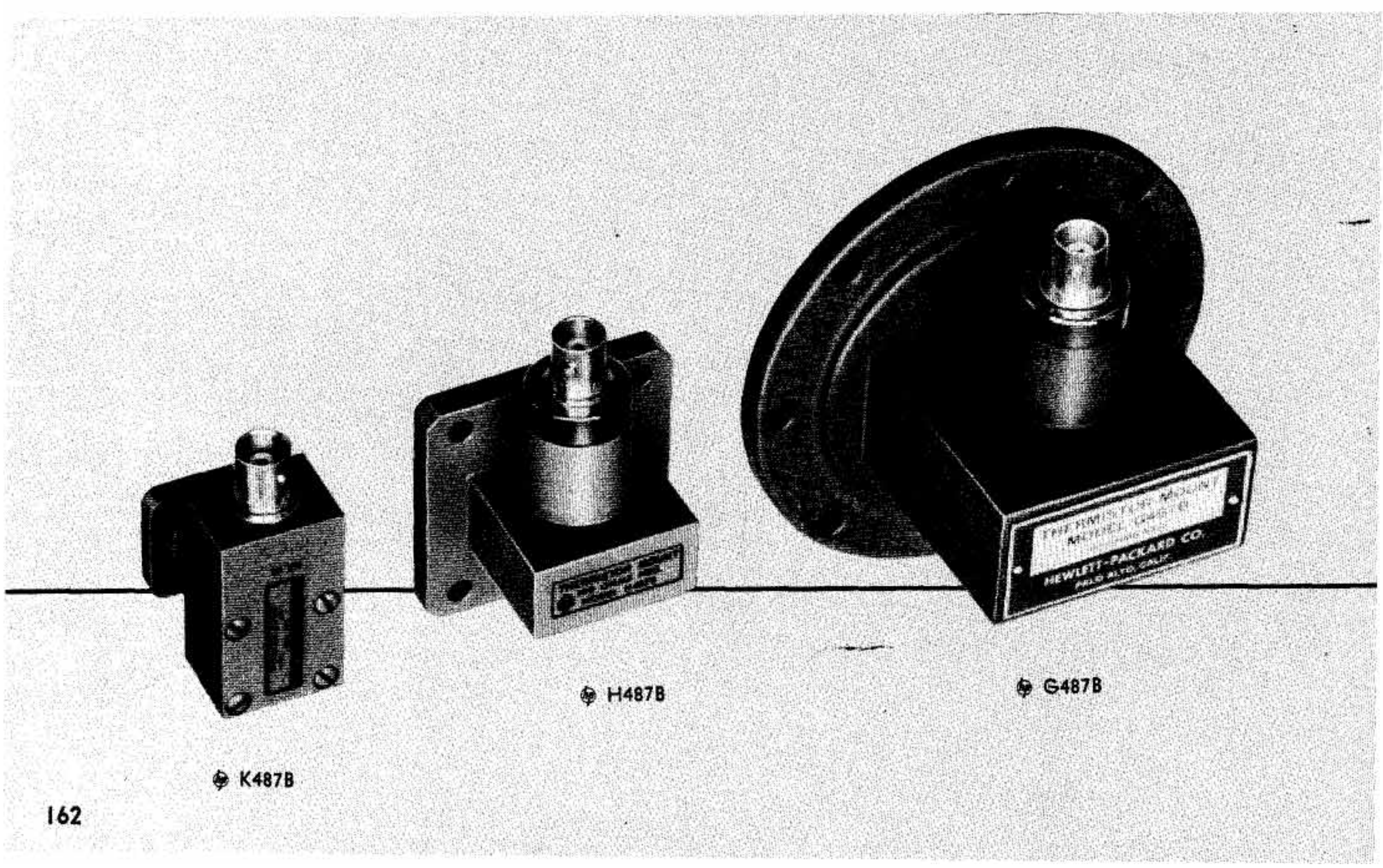

ⓗⓟ K487B ⓗⓟ H487B ⓗⓟ G487B

Of all the possible measurements to be made in design and production, probably the most important is impedance. With distributed parameters impedance varies with the position of measurement. Hence all impedance measurements must be referred to some reference plane. Since impedance determines reflected energy caused by the load, information concerning a load can often best be obtained by determining the magnitude of the reflection coefficient.

The value of the reflection coefficient can be determined by using a slotted section of a transmission line and measuring the standing wave ratio, (ratio of maximum to minimum voltage in the system feeding the load). It also can be measured directly with a reflectometer by sampling the incident and reflected waves and obtaining their ratio which is equal to the reflection coefficient. The reflectometer method will be explained following the discussion of the slotted line.

Slotted Line Measurements

A typical setup for making slotted line measurements is shown in Figure 1. The transmission system contains the incident wave and a reflected wave which is proportional to the mismatch of the load. These two waves will alternately cancel and add, setting up a standing wave pattern along the line. By inserting a probe into the slotted section and sliding it along the line the resultant voltage pattern may be measured. The usual practice is to amplitude modulate the signal source and to use a crystal or bolometer to detect the rf at the probe. The detected output of the probe is connected to a high sensitivity, tuned voltmeter, such as -hp- 415B Standing Wave Indicator. Using this procedure, the SWR and the position of maxima and minima of the load can be determined. The load is then replaced by a short circuit and the shift of the minimum is recorded. By entering this information on a Smith Chart, the measured impedance can be transformed back to the point of interest. In this way, one can determine the value of the reflection coefficient and the impedance in magnitude and phase.

Slotted Line Techniques

In measuring with this setup there are several places where errors may occur. A proper operating technique will eliminate or minimize these errors. Errors may arise from the following causes: probe loading, generator mismatch, detector characteristics, harmonics, FM, and other spurious signals.

Harmonics and spurious signals should be minimized by use of low pass filters such as Hewlett-Packard 360 and 362A series *(page 186)*. Proper modulation techniques are explained in the signal generator section of this catalog *(pages 127–147)*. Of special importance is the fact that modulation should not be attempted by very short pulses or poor quality square waves. When modulating klystrons in such a manner the resulting FM tends to obscure the nulls of the standing waves. To avoid FM, modulation of klystron signal sources should be by square wave.

Since the ratios of different voltage levels are being measured with slotted lines, it is essential that the detection follow the same law for all levels. If barretters are operated at levels less than 200 microwatts and crystals at power levels of less than 20 microwatts, the characteristics are closely square law. It is for this condition that the -hp- 415B meter scale is calibrated. This condition will be adequately met in the setup shown in Figure 1 (for standing wave ratios of 10 to 1 or less), if the probe coupling is reduced to a point where the standing wave minimum is 5 to 10 db above the system noise level.

The sampling probe will extract some power from the line to supply the indicating devices and in addition will set up reflections in the line from the probe itself. Both errors become greater as the probe insertion is increased. It is therefore important in slotted line measurement to keep the probe penetration at a minimum.

The power extraction by the probe can be explained by considering the probe as admittance shunting the line. This admittance is kept small by coupling as loosely as possible (small penetrations) and by using a high sensitivity detector in conjunction with a source output of one milliwatt or more. If the coupling between the probe and the line is not small, shunt admittance introduced by the probe will cause the measured SWR to be lower than the true SWR *(as shown in Figure 2)* and will shift both the maximum and the minimum from their natural position.

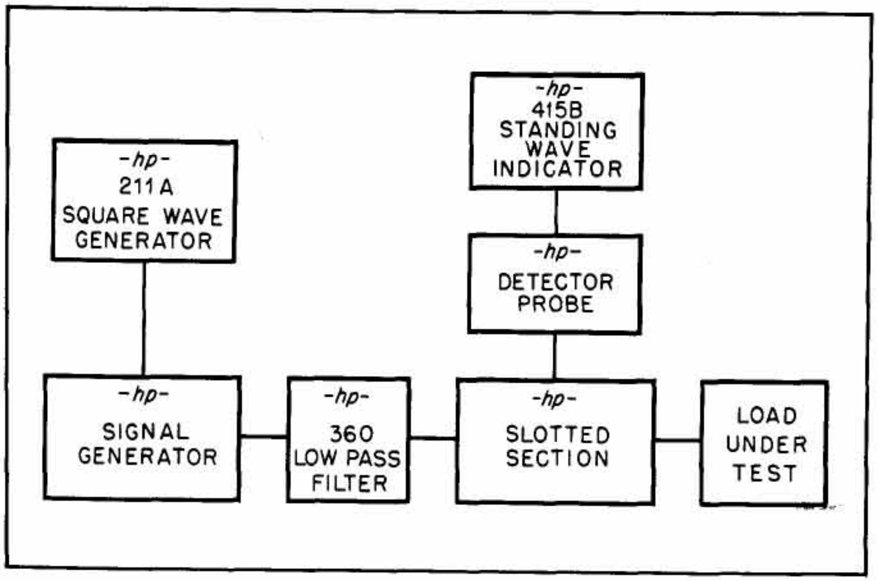

Figure 1. Typical setup for impedance measurements.

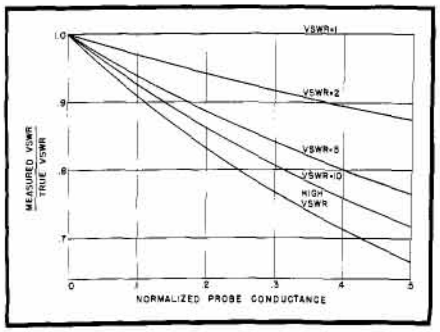

Figure 2. Effect of probe penetration on measured SWR.

An exception to this minimum penetration rule occurs when it is desired to examine in detail the minimum point on the standing wave ratio pattern. For this work a greater probe penetration can be tolerated because the voltage minimum corresponds to the lowest impedance point on the line.

In addition to extracting power from the line, the penetration of the sampling probe into the slotted section gives rise to reflections from the probe itself. These reflections travel back towards the generator. If the generator is mismatched, these reflections are re-reflected. When the probe is moved under these conditions, the phase of its reflection is changed and errors result. However, reflections from the generator are a second-order effect, important only when measuring low standing wave ratios (2 or less). In this case, a moderately good match between the generator and load is desirable. In general, the match of an ⓗⓟ signal generator is sufficient for this purpose, providing the cables and connectors do not introduce additional reflection. However, when klystrons drive a waveguide network directly, the match is poor. Therefore, the klystron should always be followed by a pad or an isolator.

Impedance Measurements With VHF Bridge

Below 500 MC, slotted sections become exceedingly long; and other techniques for impedance measurements are more desirable. For these frequencies, ⓗⓟ Model 803A VHF Bridge is ideal. *(See Figure 3.)*

The VHF bridge provides a convenient means of measuring impedances, reading directly both magnitude and phase angle. The bridge is operated simply by tuning two controls until a sharp null is obtained. At the null, one dial reads unknown impedance in ohms and the other dial shows phase angle.

Because of the null nature of the measurement, the voltages measured are very small. Therefore, to avoid any effects from extraneous voltages, lines connected to the bridge should be adequately shielded. The signal source supplying this bridge should be capable of delivering several milliwatts of power for a well defined sharp null to be observed. The detecting equipment should have high sensitivity, as does the ⓗⓟ 417A VHF Detector which is designed primarily to be used with Model 803A Bridge.

The bridge is basically an unbalanced device; and in many cases it is desirable to measure balanced systems. This can be accomplished by the use of a balun. A half wavelength balun is equivalent to a 4 to 1 impedance transformer. Hence, impedances measured at the input of the balun should be multiplied by 4 to obtain the actual impedance.

Reflectometer Measurements

The reflectometer is the most useful impedance measuring technique for fast, comprehensive production measurements. The reflectometer will indicate magnitude of impedance but will not provide phase information as will a slotted line measurement. However, in the typical production situation an SWR measurement alone is quite adequate, and phase information is not needed.

With the availability of the 938/940 Frequency Doubler Sets *(see pages 146, 147)* which are capable of providing swept frequency rf power in K and R bands, reflectometer capabilities are extended to 40 GC (KMC). A typical reflectometer setup is shown in Figure 4. This arrangement determines the magnitude of the reflection coefficient by using two directional couplers to sample the incident power to a load and the reflected power. The couplers drive detectors which are connected to a 1,000 cycle ratio meter *(ⓗⓟ 416A, pages 172, 173)* where a ratio measurement is made. Since the ⓗⓟ 416A is calibrated for square law detectors the resultant ratio of the two sampled powers is indicated directly as reflection coefficient on a front panel meter. Model 416A also provides a dc output to an X-Y recorder for making permanent records.

The reflectometer method is most practical for measuring reflection coefficients up to approximately 0.5 (SWR 3.0). When used with swept frequency techniques and calibrated with a fixed short circuit at 100% reflection, accuracies of approximately ± .02 may be obtained for reflection coefficients of 0.1 (SWR of 1.22). For reflection coefficients of 0.4 (SWR of 2.3) accuracies of approximately ± .04 may be obtained. The potential accuracy of the reflectometer, however, is greatest at low SWR's when used at a fixed frequency. A rather simple calibration procedure, using a slide screw tuner, a moving load, and a sliding short circuit, cancels out ambiguity caused by the reverse

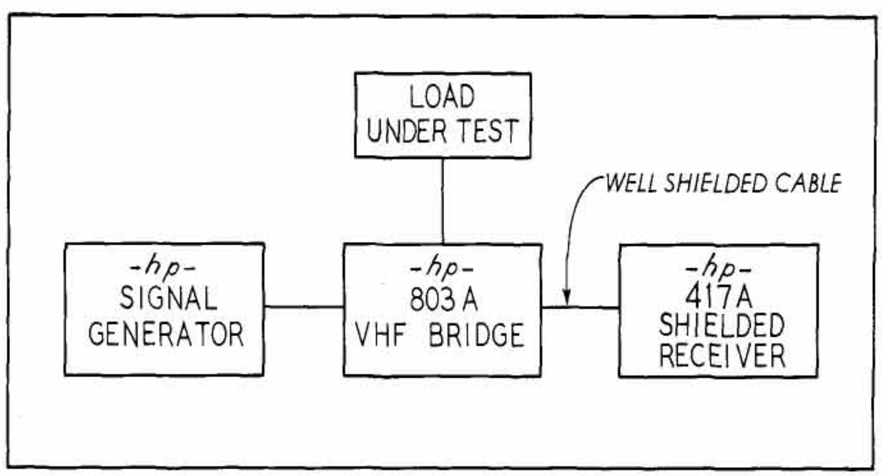

Figure 3. Impedance measurements for frequencies below 500 MC.

coupler directivity. Under ideal conditions errors of less than ± .005 in reflection coefficient are attainable; this is equivalent to a slotted line measurement in a line with a residual SWR of 1.01.

hp reflectometers are available to measure reflection coefficients rapidly and with good accuracy in all hp waveguide frequencies, as well as for a wide frequency range in coaxial cable systems.

The table below lists the required components needed to set up a reflectometer in any given frequency range, both coaxial and waveguide. In the K and R band frequency regions some overlap of driving generators is required.

Although electronically swept rf sources provide faster measurements, they are not an absolute necessity. Very satisfactory measurements may be made with any manually-tuned signal source and an X–Y recorder at the output of the ratiometer. It is only necessary to sweep manually through the entire range to get a plot of reflection coefficient. In the frequency range from 36 to 40 GC for instance, the 628A Signal Generator may be used in a manual sweep mode.

A series of hp application notes is available on request to provide detailed information on certain microwave measurements, techniques; for instance *#21 Microwave Standards Prospectus*, *#27 Basic Microwave Measurements*, *#38 Microwave Measurements for Calibration Labs*, and *#39 Standards Calibration Procedures*.

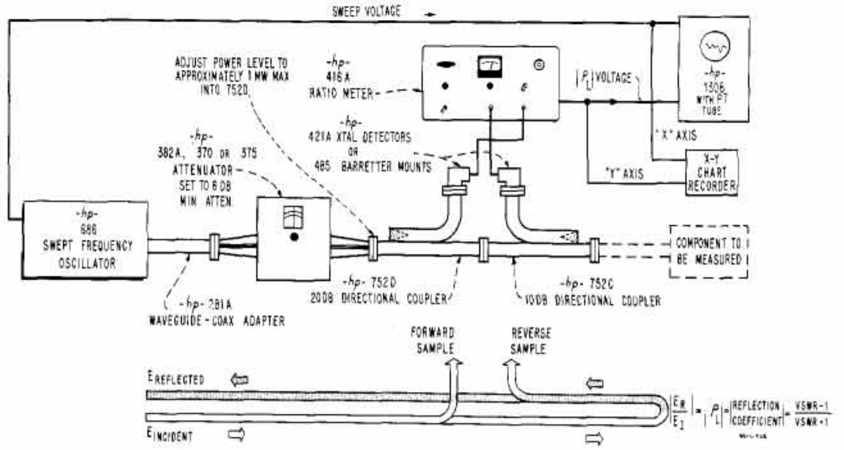

Figure 4. Typical reflectometer setup. *Write for hp Application Note Number 42, APPLICATIONS OF THE 416A RATIOMETER, for a full description of the reflectometer technique, including error analysis. Also request Hewlett-Packard Journal, Vol. 12, No. 4, Improved Sweep Frequency Techniques for Broadband Microwave Testing.*

Table I. Equipment for reflectometer systems, coaxial and waveguide, using hp 416A Ratio Meter

	Detectors Two Required	Forward Directional Coupler	Reverse Directional Coupler	Attenuator	Waveguide to Coax. Adapter	Signal Source	Adjustable Short	Slide Screw Tuner	Moving Load
COAXIAL									
216 - 450 MC	476A[1]	764D[2]		Weinschel 50 - 10	——	608C 10 - 480 MC	——	——	——
450 - 945	476A[1]	765D[2]		Weinschel 50 - 10	——	612A 450 - 1220 MC	——	872A	——
940 - 1975	420B (matched)	766D[2]		Weinschel 210 - 10	——	682C 1 - 2 GC	——	872A	906A
1900 - 4000	420B (matched)	767D[2]		Weinschel 210 - 10	——	683C 2 - 4 GC	——	872A	906A
WAVEGUIDE Band									
S - 2.6 - 3.95 GC	S485D[1]	S752D (20 db)	S752C (10 db)	S375A	S281A	683C 2 - 4 GC	S920A	S870A	S914A
G - 3.95 - 5.85	G485D[1]	G752D (20 db)	G752C (10 db)	G382A	G281A	684C 4 - 8.1 GC	G920A	G870A	G914A
J - 5.3 - 8.2	J485D[1]	J752D (20 db)	J752C (10 db)	J382A	J281A	684C 4 - 8.1 GC	J920A	J870A	J914A
H - 7.05 - 10.0	H421A (matched)	H752D (20 db)	H752C (10 db)	H382A	H281A	H01 686C 7-11 GC	H920A	H870A	H914A
X - 8.2 - 12.4	X421A (matched)	X752D (20 db)	X752C (10 db)	X382A	——	686C 8.2 - 12.4 GC	X920A	X870A	X914B
M - 10.0 - 15.0	M421A (matched)	M752D (20 db)	M752C (10 db)	M382A	——	686C 8.2 - 12.4 GC 687C 12.4 - 18 GC	M920A	M870A	M914A
P - 12.4 - 18.0	P421A (matched)	P752D (20 db)	P752C (10 db)	P382A	——	687C 12.4 - 18 GC	P920A	P870A	P914A
K - 18.0 - 26.5	K422A (matched)	K752D (20 db)	K752C (10 db)	K382A	——	938A 18 - 26.5 GC (See pages 142, 143 for driver)	K920A	K870A	K914B
R - 26.5 - 40.0	R422A (matched)	R752D (20 db)	R752C (10 db)	R382A	——	940A 26.5 - 40 GC (See pages 142, 143 for driver)	R920A	R870A	R914B

[1]Requires AC-60K Barretter Matching Transformer.

[2]764D - 767D are dual directional couplers, only one required.

Supplementary equipment for greater convenience: Oscilloscope, long persistence CRT, hp Models 120A, 122A or 130B with P-7 phosphor.
X-Y Recorder, F. L. Moseley Model 2D.

ⓗⓟ 415B STANDING WAVE INDICATOR

Reads Direct in SWR and db

Specifications

Frequency: 1,000 cps ± 2% (315 to 2020 cps on special order).
Sensitivity: 0.1 μv at a 200 ohm level for full scale deflection.
Noise Level: Less than 0.03 μv ref. to input operated from a 200 ohm resistor.
Amplifier Q: 25 ± 5.
Calibration: Square law. Meter reads SWR, db.
Range: 70 db. Input attenuator provides 60 db in 10 db steps. Accuracy ± 0.1 db per 10 db step. Cumulative error ± 0.2 db. max.
Scale Selector: "Normal," "Expand," and "−5 db."
Meter Scales: SWR: 1–4; SWR: 3–10; Expanded SWR: 1–1.3; db: 0–10; Expanded db: 0–2.
Gain Control: Adjusts to convenient reference level. Range at least 10 db.
Input: "Bolo" (200 ohms). Bias provided for 8.7 ma bolometer or 1/100 amp. fuse; or 4.3 ma low current bolometer.
"Crystal." 200 ohms for crystal rectifier.
"200,000 ohms." High impedance for crystal rectifier as null detector.
Output: Jack for recording milliammeter having 1 ma full scale deflection, internal resistance of approx. 1,500 ohms.
Power: 115/230 v ± 10%, 60 cps (other frequencies available on request), 55 watts.
Dimensions: Cabinet Mount: 7½" wide, 11¾" high, 12½" deep. Rack Mount: 19" wide, 7" high, 11" deep behind panel.
Weight: Net 13 lbs. Shipping 19 lbs. (cabinet mount). Net 17 lbs. Shipping 29 lbs. (rack mount).
Accessories Furnished: 1 41A-16E Cable Assembly.
Accessories Available: Plug-in Filters (specify frequency); 415B 42B (315-700 cps), $60.00. 415B-42C (700-2020 cps), $50.00. AC-16K Video Cable Assembly, $6.50. AC-16D Cable Assembly, $3.50.
Price: ⓗⓟ 415B, $200.00 (cabinet); ⓗⓟ 415BR, $205.00 (rack mount).

Data subject to change without notice.

The ⓗⓟ 415B is designed for use with ⓗⓟ slotted lines and detector mounts for the measurement of standing wave ratio or as a null detector for bridge measurements. Consisting of a high gain amplifier with very low noise level, the instrument operates at a fixed audio frequency and presents amplifier output on a square law calibrated meter reading direct in SWR or db. Features include a 5 db attenuator to allow all measurements to be made in the more readable upper portion of the meter scale, an expanded SWR scale for accurate measurements of very flat systems, and a recorder output terminal for making permanent SWR records. A simple gain control adjusts the instrument to a convenient level.

Input Arrangements

Three input arrangements are provided. A switch selects (1) a 200 ohm termination with bias of 4.3 or 8.7 ma for bolometers, (2) an unbiased 200 ohm termination for crystals, (3) a 200,000 ohm load for null measurements. A jack and monitor cable are provided for connecting an external milliammeter to measure bolometer current.

The instrument is normally supplied for operation at 1,000 cps. However, on special order it is available equipped for operation at any filter frequency from 315 to 2,020 cps (should not be harmonically related to power line frequency). Units for converting the 415B to operation at any frequency in the above range can be obtained at nominal charge and installed in the field.

805C/D SLOTTED LINES

"Parallel-Plane" Design Gives Utmost Electrical Stability

The 805 Slotted Line incorporates a different structural design with precision manufacture, resulting in an instrument of unvarying accuracy for the measurement of microwave circuits.

This instrument employs two parallel planes and a rigid central conductor, offering important advantages over the standard slotted section.

For example, the parallel planes are rigid; insuring greater accuracy and a rigid probe carriage. The central conductor is proportionately larger and more rigid, with less tendency to bow. Depth of probe penetration is inherently less critical, and carriage inaccuracies are minimized. Leakage is also low because the effective slot opening is small. SWR of the basic section is less than 1.02.

The probe circuit is tunable 500 to 4,000 megacycles. Depth of probe penetration can be quickly and easily adjusted.

Two versions of the 805 are offered; the 805C, provided with Type N connectors, and the 805D with connectors suitable for mating to RG44/U stub supported coaxial cable.

Basic slab sections of 805C/D and 872A Coaxial Slide Screw Tuners *(see page 187)* are identical. Two connectors can be eliminated when flattening a coaxial system by mounting both an 805C or D and 872A on one slab section. In this arrangement, the lower frequency limit becomes approximately 1,000 MC.

Specifications

805C

Frequency Range: 500 MC to 4,000 MC (minimum frequency determined by usable length of 14½ inches).
Characteristic Impedance: 50 ohms. (For use with any 50 ohm cable using Type N connector.)
Connectors: Type N. (One male; one female.) Special fittings designed to mate with Type N connectors, provide a minimum SWR. Connectors compensated so that either end may be connected to the load.
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), Sperry 821 barretter, Narda N821 barretter, or selected 1/100 amp. instrument fuse.
Weight: Net 18 lbs. Shipping 30 lbs.
Accessories Furnished: 1 803A-76G shorting plug; 1 8A-76H shorting jack.
Accessories Available: AC-16F rf Cable Assembly, $15.00; 475B-34V Barretter Adapter, $2.00; AC-16K Cable Assembly, $6.50. 8A-45 Carrying case 29" long, 9½" high, 9½" wide, $65.00.
Price: 805C, $525.00.

805D

Characteristic Impedance: 46.3 ohms. For use with RG 44/U stub supported coaxial cable. ⅞" outside diameter.
Connections: (One male, one female UG 45/U and UG 46/U.)
Residual SWR: 1.02.
Accessories Furnished: 1 8B-76G shorting plug.
Accessories Available: 8B-76H shorting jack, $6.00; AC-16K; 475B-34V; 8A-45, as described above.
Price: 805D, $600.00.

(Other specifications same as 805C)

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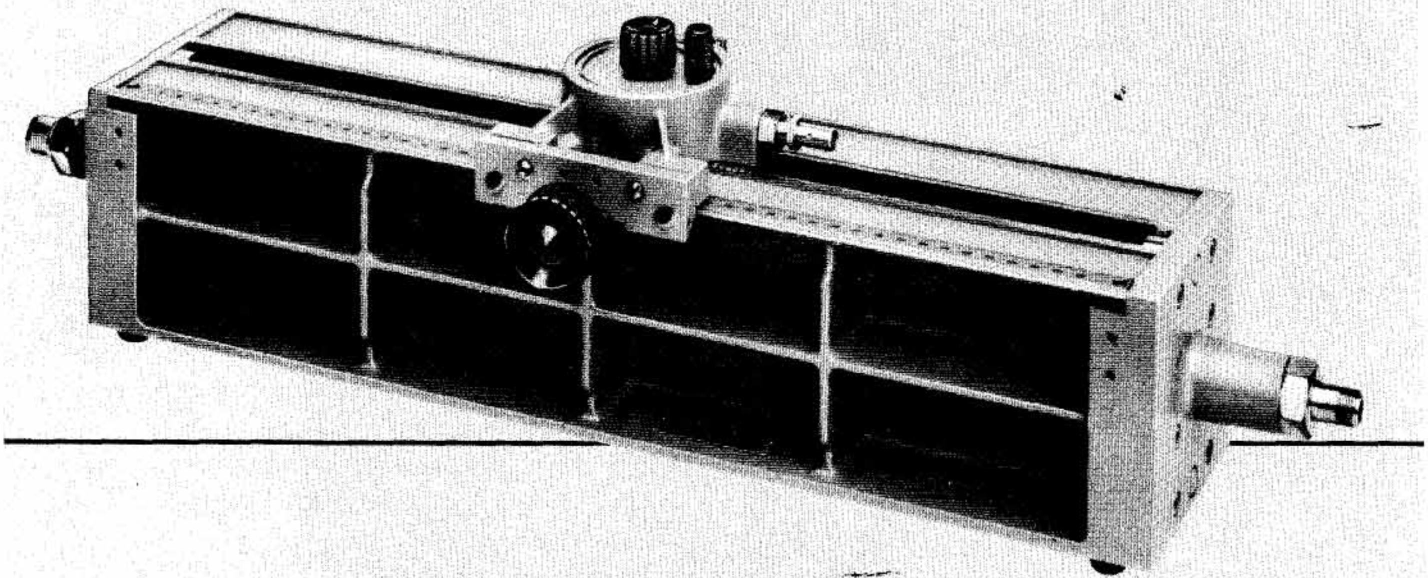


805C

hp 809B/814B UNIVERSAL PROBE CARRIAGES

Low Cost, Precision Tools for Microwave Readings to 40 GC (KMC)

Advantages:

Universal mounting for different slotted sections

Slotted sections interchange in 30 seconds

Broad usefulness, 3 to 40 GC (KMC)

809B carriage operates with waveguide or coaxial sections

Precision accuracy, highest stability

Simple operation, compact, low cost

Use To Measure:

Characteristics of rf waveguide systems or coaxial transmission lines

Standing wave magnitude and phase

Impedance

System flatness, connector reflection

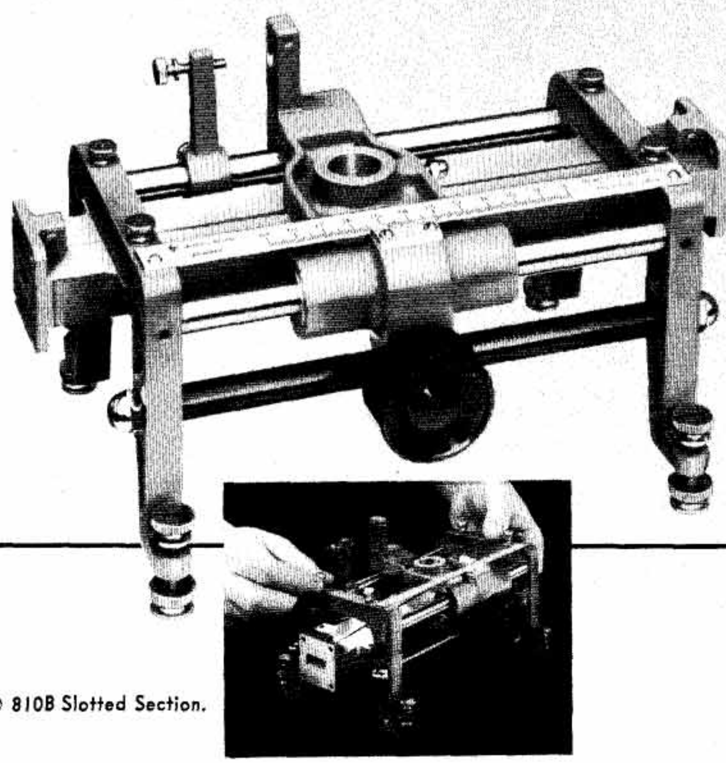
Degree of antenna match

Percent of transmitted or reflected power

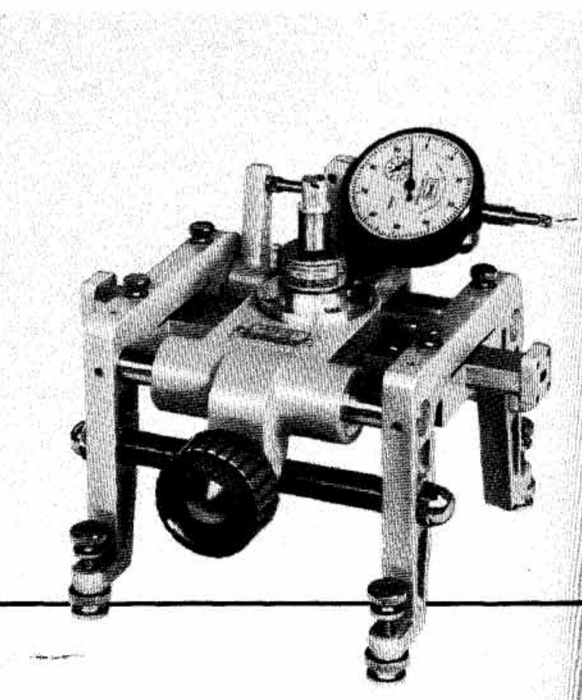
Models 809B and 814B Universal Probe Carriages are precision-built mechanical assemblies designed to operate, respectively, with hp 810B series and 815B series slotted sections. The combination of 809B Carriage and 810B series sections covers 3.95 to 18.0 GC. Model 814B Carriage and 815B series sections cover 18.0 to 40.0 GC.

These Universal Probe Carriages greatly simplify measurements involving a number of waveguide bands, and eliminate the cost of a special probe for each band. There is an appreciable saving on engineering time since waveguide sections can be interchanged in seconds. Manufacture of both carriages is of highest quality throughout to assure maintenance-free service, positive mechanical positioning of interchangeable waveguides, and precise installation of the mating hp probes *(see pages 170, 171)*. hp 809B has a vernier scale permitting readings to 0.1 mm and provision for mounting a dial gauge for greater accuracy. hp 814B has a dial indicator which may be read directly to 0.01 mm.

hp 810B Waveguide Slotted Sections. (for 809B) are accurately machined sections of waveguide in which a small longitudinal slot is cut. They fit the 809B Carriage in a precisely indexed position. A traveling probe mounted on the 809B samples the waveguide's electric field along the



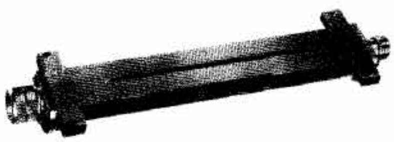
hp 809B with hp 810B Slotted Section.



hp 814B with hp 446B Probe and hp 815 Slotted Section

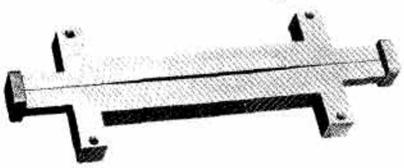
slot, and permits precise plotting of variations throughout the length of probe travel. Slotted sections are accurately machined from normalized aluminum castings to insure a uniform cross-section. Ends of the slots are tapered to reduce slot reflection to less than 1.01 SWR.

hp 806B Coaxial Slotted Section (for 809B). This instrument provides continuous coverage from 3 to 12 GC. Impedance is 50 ohms to match flexible coaxial cables. The broadband section has special fittings mating with Type N connectors to assure minimum SWR.



hp S810A Waveguide Slotted Section. This instrument is a conventional slotted waveguide complete with a probe carriage mounted directly on the section. Model S810A is available in the 3″ x 1½″ (2.6 to 3.95 GC) S band frequency range only. It uses hp Broadband Probes and Detector Mounts shown on pages 170, 171.

hp 815B Waveguide Slotted Sections (for 814B). Available in K and R bands (18.0 to 40.0 GC), these waveguide slotted sections are carefully machined for time-saving accuracy in measurement.



Specifications

hp 809B Universal Probe Carriage

Carriage: Mounts all hp 810B Waveguide Slotted Sections and hp 806B Coaxial Slotted Section.

Probe Required: hp 442B Broadband Probe in combination with hp 440A Detector or hp 444A Untuned Probe *(see pages 170, 171)*.

Probe Travel: 10 centimeters.

Calibration: Metric. Vernier permits readings to 0.1 mm. Provision for dial gauge installation.

Accuracy: When used with waveguide sections, SWR of 1.02 can be easily read. Slope error of slotted sections may be eliminated by adjustment.

Dimensions: 8″ long, 6¼″ wide, 5″ high.

Price: hp 809B, $175.00.

hp S810A Waveguide Slotted Section

Conventional waveguide slotted section with probe carriage mounted directly on waveguide. Will accept hp 442B or 444A Probes.

Frequency Range: 2.6 to 3.95 GC.

Slope and Irregularities: 1.01 SWR.

Residual SWR: Less than 1.01.

Waveguide Size: 3″ x 1½″.

Length: 12¾″.

Price: hp S810A, $450.00.

hp 806B Coaxial Slotted Section

Carriage: Fits hp 809B Universal Probe Carriage.

Frequency Range: 3 to 12 GC.

Connections: 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.

Residual SWR: Less than 1.04, 3 to 8 GC.
Approximately 1.06, 8 to 10 GC.
Approximately 1.1, 10 to 12 GC.

Pickup Error: Probe pickup variation along line is less than 0.1 db except at extreme ends where variation is less than 0.4 db.

Length: 10″.

Price: hp 806B, $200.00.

hp 814B Universal Probe Carriage

Carriage: Mounts all hp 815B Waveguide Slotted Sections.

Probe Required: hp 446B Untuned Probe *(see pages 170, 171)*.

Probe Travel: 4 centimeters.

Calibration: Metric. Dial indicator reads direct to 0.01 mm.

Accuracy: SWR of 1.02 can be read.

Dimensions: 6¼″ long, 6¼″ wide, 6¼″ high.

Price: hp 814B, $225.00.

hp 810B/815B Slotted Sections

Model	Frequency Range GC	Fits Waveguide Size (in.)	Overall Length (in.)	Price
G810B	3.95 - 5.85	2 x 1	10¼	$125.00
J810B	5.20 - 8,20	1½ x ¾	10¼	110.00
H810B	7.05 - 10.0	1¼ x ⅝	10¼	110.00
X810B	8.20 - 12.4	1 x ½	10¼	90.00
M810B	10.0 - 15.0	.850 x .475	10¼	110.00
P810B	12.4 - 18.0	.702 x .391	10¼	110.00
K815B	18.0 - 26.5	.500 x .250	7-9/16	265.00
R815B	26.5 - 40.0	.360 x .220	7-9/16	265.00

Discontinuity due to slot results in SWR of less than 1.01. Slope and irregularities: 1.01 SWR.

Data subject to change without notice.

hp 420A Crystal Detector

hp 420A couples a Type N coaxial line to a modified 1N26 silicon diode for the detection of rf signals from 10 MC to 12.5 GC (KMC). Careful engineering and construction keep SWR low and give a flat frequency response over the three-decade frequency range. The polarity of the output signal is negative.

Specifications

Frequency Range: 10 MC to 12.5 GC.
Sensitivity: Approximately 0.1 v/mw.
Frequency Response: ± 3 db.
Maximum SWR: 3.
Input Connector: Type N Male.
Output Connector: BNC Female.
Detector Unit: Modified 1N26 crystal, installed.
Size: ¾" diameter, 3" long; shipping weight 1 lb.
Price: hp 420A, $50.00.

hp 420B Coaxial Reflectometer Crystal Mount

Model 420B is similar in construction to the 420A but is designed specifically for applications where good square-law characteristics are desired. The 420B contains a video load resistor selected to give optimum square-law response. For use in reflectometer systems the 420B is available in matched pairs. A matched pair of 420B's have identical individual specifications but the differences in frequency response and deviations from square-law combined are held within ± 2 db for the pair over the 1 to 4 GC range.

Specifications

Same as Model 420A except:
Frequency Response: Single unit same as 420A. Pairs matched within ± 1 db from 1 to 4 GC.
Square-law Characteristic: ± 1 db maximum variation from square-law over 1 to 4 GC and 0 to −40 dbm.
Matched Pairs: Difference in frequency response and square-law characteristics combined (but excluding basic sensitivity) does not exceed ± 2 db for the pair.
Detector Unit: Selected crystal with matched video load, factory installed.
Price: hp 420B, $75.00. Matched pair, $150.00.

hp 421A Crystal Detectors

These crystal detectors are accurate square-law devices for waveguide systems from H through P band, 7 to 18 GC. Each detector employs a crystal and video load resistor selected for optimum square-law characteristics. Models 421A are broadband instruments which have a flat frequency response and low SWR over the full waveguide band. Since tuning is unnecessary, measurements may be made at different frequencies rapidly. For reflectometer applications Model 421A Crystal Detectors are available in matched pairs.

Specifications

Sensitivity: Approximately 0.05 v/mw.
SWR: 1.5 maximum.
Frequency Response: ± 2 db.
Square-law Characteristic: ± 1 db from 0 to − 40 dbm.
Detector Unit: Modified 1N26 crystal and video resistor, installed.
Matched Pairs: Differences in frequency response and square-law characteristics combined (excluding basic sensitivity) do not exceed ± 2 db for the pair.

Price:	H421A	X421A	M421A	P421A
	7 to 10 GC	8.2 to 12.4 GC	10 to 15 GC	12.4 to 18 GC
Single Unit:	$ 95.00	$ 75.00	$125.00	$130.00
Matched Pairs:	210.00	170.00	270.00	280.00

hp 422A Crystal Detectors

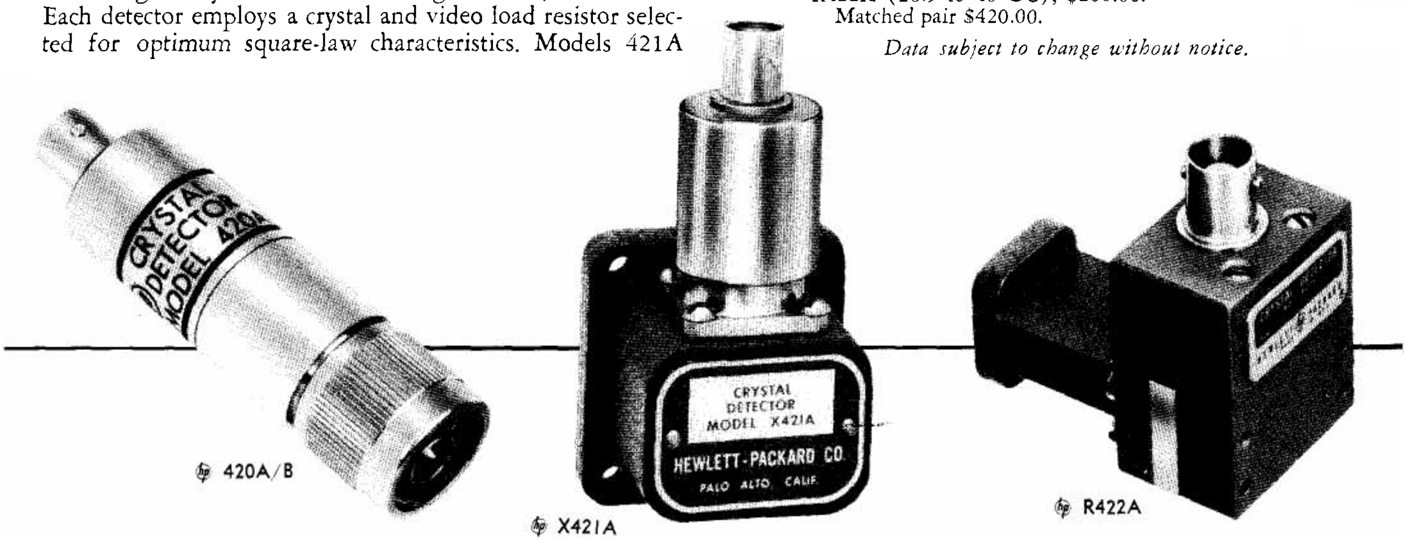
These new crystal detectors for K and R band waveguide systems (18 to 40 GC) combine high sensitivity and flat frequency response with accurate square-law characteristics. High sensitivity is obtained by mounting an hp-developed silicon diode within the waveguide, and flat response is achieved by making the resonant frequency high. The crystal is mounted at the end of a tapered section of waveguide which matches the crystal to the waveguide impedance to keep SWR low over the entire waveguide band. Models 422A are furnished with an hp AC-67D Feed-Thru Termination consisting of a shunt resistor selected for optimum square-law characteristics. This termination may be removed for greater sensitivity.

Model 422A Detectors are available in matched pairs for reflectometer systems. Differences in frequency response plus square-law characteristics (excluding basic sensitivity) do not exceed ± 2 db in a matched pair.

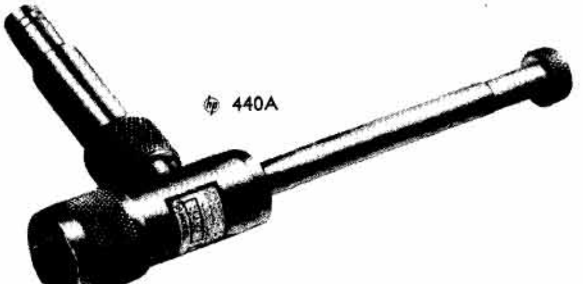
Specifications

Sensitivity: 0.05 v/mw.
SWR: 2.5 maximum.
Frequency Response: ± 2 db.
Square-law Characteristic: ± 1 db from −3 to −40 dbm.
Maximum Power: 100 mw.
Prices: K422A (18 to 26.5 GC), $200.00.
Matched pair $420.00.
R422A (26.5 to 40 GC), $200.00.
Matched pair $420.00.

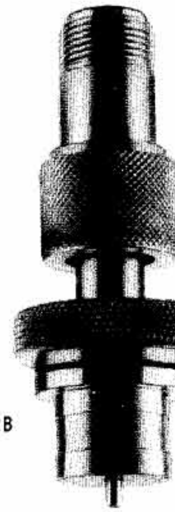
Data subject to change without notice.



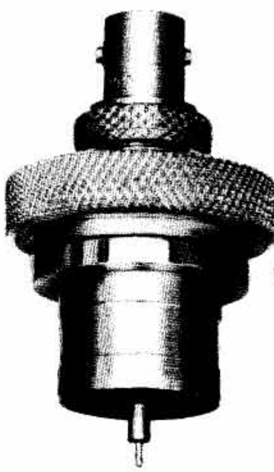
hp 420A/B
hp X421A
hp R422A



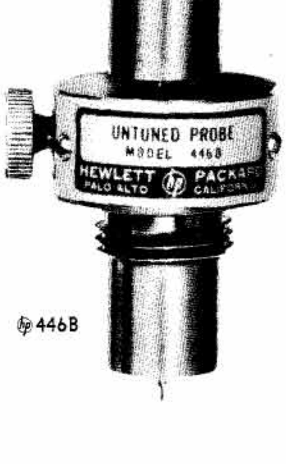
hp 440A



hp 442B



hp 444A



hp 446B

hp 440A Detector Mount

A simple, easily used instrument for detecting rf energy in coaxial or waveguide systems. In coaxial use it covers all frequencies 2.4 to 12.4 GC(KMC). Uses either 1N21 or 1N23 silicon crystal, 1/100 ampere instrument fuse or Sperry 821 barretter. Simple single stub tuning. Type N rf input connector. BNC output jack. With hp 442B (below) becomes sensitive, easily tuned detector for slotted waveguide sections. (Detector element not furnished as part of instrument.) hp 440A, $85.00.

hp 442B Broadband Probe

hp 442B is designed to be used with the 810 series of slotted waveguide sections, the 806B Coaxial Slotted Line and the 809A Universal Probe Carriage. The probe consists of a small antenna and housing which samples the rf field in the slotted section. Sampled rf appears at a female Type N connector, permitting connection to a receiver, spectrum analyzer or other equipment. Probe penetration is variable and the probe can be locked in place with a friction-type locking ring. Spurious resonances are prevented by poly-iron inserts and the antenna probe is shielded.

A sensitive detector for slotted line measurements is formed when the 442B is used with the 440A Detector Mount. hp 442B, $40.00.

hp 444A Untuned Probe

Model 444A Untuned Probe consists of an antenna and crystal detector in a convenient housing which mounts in an 809B Universal Probe Carriage. Probe penetration into a slotted section can be varied quickly and easily, and a locking ring fixes penetration. The detector is located near the rf pickup, minimizing residual reactances. Hence the instrument has high sensitivity and flat response over a wide range of frequencies from the middle of S-band through P-band. Poly-iron inserts damp spurious resonances.

Specifications

Frequency Range: 3 to 18 GC.
Output Connector: BNC.
Detector: Modified 1N26 Silicon Diode installed.
Replacement Detector: hp 444A-25E crystal.
Price: hp 444A, $40.00.

hp 446B Untuned Probe

Model 446B is a broad band detector and probe which covers K and R-band waveguide frequencies without tuning. It is designed for use with hp 814B Universal Probe Carriage and K and R-band 815B Waveguide Slotted Sections. The detector is a modified 1N53 silicon diode mounted in a housing carefully designed to eliminate spurious resonances. Penetration of the probe into the waveguide is quickly and easily adjusted.

Specifications

Frequency Range: 18 to 40 GC.
Detector: Modified 1N53 silicon diode, installed.
Mounts in: 814B Universal Probe Carriage.
Price: hp 446B, $145.00.

Data subject to change without notice.

hp 416A RATIO METER

Ease and Accuracy for Reflection Coefficient Measurements

Advantages:

Makes waveguide reflection coefficient measurements practical

Allows continuous swept-frequency oscilloscope presentation

Eliminates amplitude-variation error

Operates accurately over 20/1 incident power level range

Simplifies reflectometer setups for faster production checks, wide band system alignment and laboratory investigation

Use For:

Fast reflection coefficient measurements over broad frequency range

SWR measurement independent of rf power level

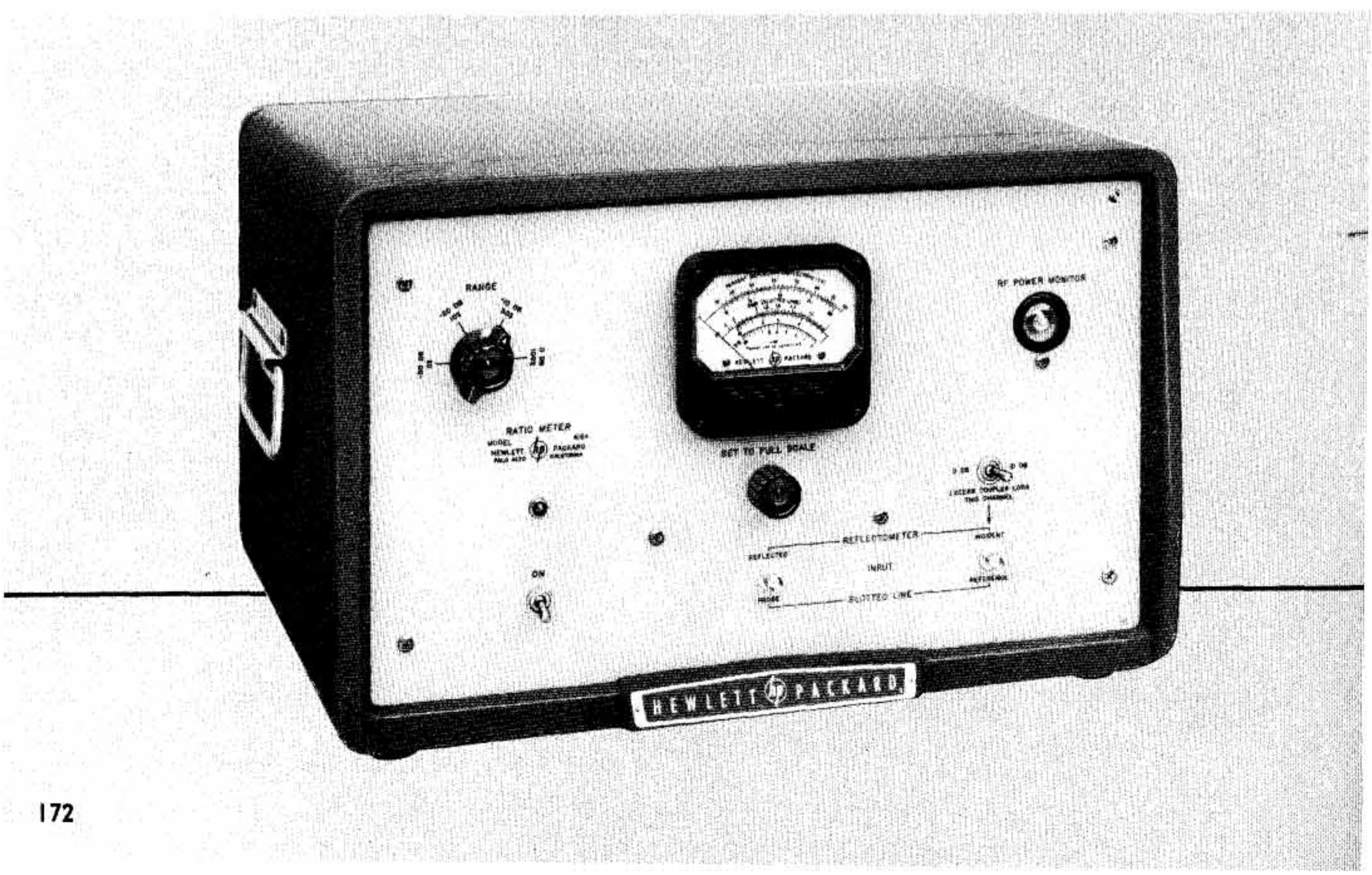
Reflection coefficient measurements with a reflectometer setup are recognized as an ideal method of evaluating waveguide system performance. The reflectometer setup can save engineering time by eliminating tedious SWR measurements with slotted lines, and when driven by a swept oscillator (such as hp 682C-687C Electronic Sweep Oscillators, pages 144, 145), such setups make possible direct and continuous oscilloscope presentation of reflection coefficient over a wide frequency range.[1]

The hp 416A Ratio Meter eliminates the two major drawbacks heretofore present in the reflectometer setup by eliminating adjustments to correct for source amplitude variations and eliminating necessity for measuring separately the forward and reverse power.

hp 416A automatically combines forward and reverse signals and displays their ratio directly, irrespective of amplitude variations.

The instrument also is an excellent standing wave indicator for conventional slotted line measurements, and in this application again eliminates the inconvenience of adjustments due to power source amplitude variations.

[1] See hp Application Note 42, "Applications of the 416A Ratio Meter."



Reflectometer Setup

Arrangement of a typical reflectometer setup with ⓗ 416A Ratio Meter is shown in Figure 1. *(See pages 163-165 for further details in table "Equipment Required for Waveguide for Reflectometer Systems, Coaxial and Waveguide.")* This setup provides continuous and direct oscilloscope presentation of the reflection coefficient of an unknown load at varying frequencies. A swept oscillator supplies power through directional couplers mounted back-to-back. One coupler samples forward power, the other reverse or reflected power. Both couplers are terminated in waveguide detector mounts such as ⓗ 421A which demodulate system power and provide 1,000 cps signals to the ratio meter. The oscilloscope presents frequency on its horizontal axis vs. reflection coefficient on the vertical axis. Thus a continuous visual study can be made of reflection coefficient at any frequency within the system's range.

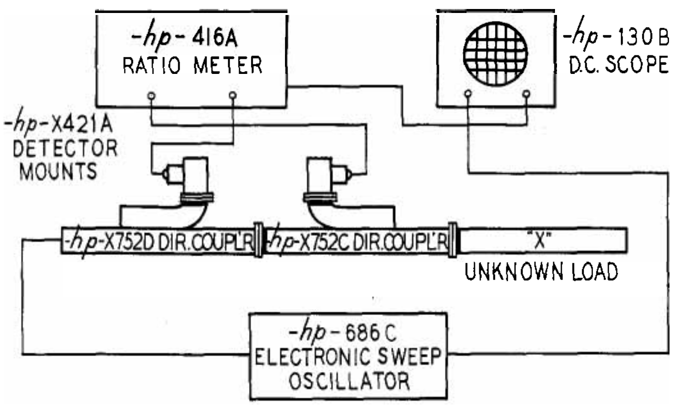


Figure 1. Typical Reflectometer Setup. Note use of two directional couplers back-to-back, with individual detectors, for simultaneous evaluation of incident and reflected powers.

Simple Operation

The ⓗ 416A operates in an exceptionally straightforward manner. An rf power monitor on the panel indicates the proper power level and modulating frequency. The system is calibrated by employing a short in place of the load to establish the point of 100% reflection. Also, standard reflections such as ⓗ 916 *(see page 190)* may be employed to established calibration.

When the ratio meter is used as an SWR indicator, a similarly simple adjustment is all that is required to establish unity SWR at a voltage maximum point on the slotted line.

Extreme Accuracy

Model 416A is capable of the highest accuracy—exceeding that of the best-slotted line sections—when measurements are made at a single frequency. Using a slide-screw tuner such as ⓗ 870A *(see page 187)* to compensate for the small directivity deficiency of ⓗ 752 Directional Couplers, accuracy of better than ± 0.005 can be expected. This is equivalent to a residual SWR of approximately 1.01. For swept frequency operation, accuracies of ± 0.015 can be expected with loads having small SWR. Even with loads having high SWR, accuracies of 0.05 can be expected.

Specifications

Accuracy: ± 3% full-scale for 20 to 1 range of incident or reference rf power.

Calibration: Square-law.

Frequency: 1,000 cps ± 40 cps.

Input Voltage: Incident or Reference Channel: 3 mv to 100 mv rms. Reflected or Probe Channel: 3.0 μv to 100 mv rms for full scale deflection. (Square or sine-wave.)

Input Impedance: Approximately 75 K ohms, both channels.

"Excess Coupler Loss": Includes provision for increasing sensitivity of Incident Channel by 10 db for reflectometer setups employing couplers with different coefficients.

Output: Connectors for oscilloscope and high impedance recorder.

Adjustments: "Set to Full Scale" control for initial calibration with 100% reflection, or at SWR peak.

Internal Check: "Eye" tube continuously monitors input amplitude (and frequency indirectly) to assure proper operating range for instrument and crystal detectors.

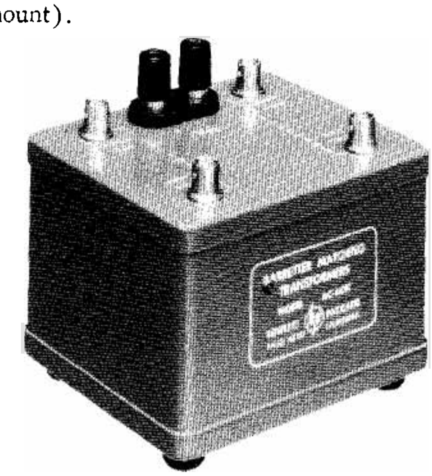
Power: 115/230 v ± 10%, 50/60 cps, 115 watts.

Dimensions: Cabinet Mount: 20¾″ wide, 12¾″ high, 14½″ deep. Rack Mount: 19″ wide, 10½″ high, 14″ deep behind panel.

Weight: Net 36 lbs. Shipping 47 lbs. (cabinet mount). Net 28 lbs. Shipping 41 lbs. (rack mount).

Accessories Available: AC-16K Video Cable Assembly, $6.50. AC-60K Barretter Matching Transformer, $80.00.

Price: ⓗ 416A, $550.00 (cabinet); ⓗ 416AR, $535.00 (rack mount).



ⓗ AC-60K Matching Transformer

This instrument consists of two step-up transformers and appropriate bias circuitry for impedance matching between ⓗ 485 series Barretter Mounts and the ⓗ 416A Ratio Meter. Designed specifically for reflectometer application, ⓗ AC-60K matches 200 ohm barretters such as Sperry 821 or Narda N821B. An 8.75 ma bias is supplied from the 416A Ratio Meter. The AC-60K measures 4¾″ x 4″, and is 3½″ high. Weight is 2 lbs. The instrument is supplied with three cable assemblies for connection to ⓗ 416A. $80.00.

Data subject to change without notice.

hp 803A VHF BRIDGE

Reads Any Impedance Directly Between 52 and 500 MC

Advantages:

Direct reading,
  2 to 2,000 ohm impedances
  $-90°$ to $+90°$ phase angle

Wide range, 52 to 500 megacycles

Simple, easy operation

Faster than slotted lines

Compact size

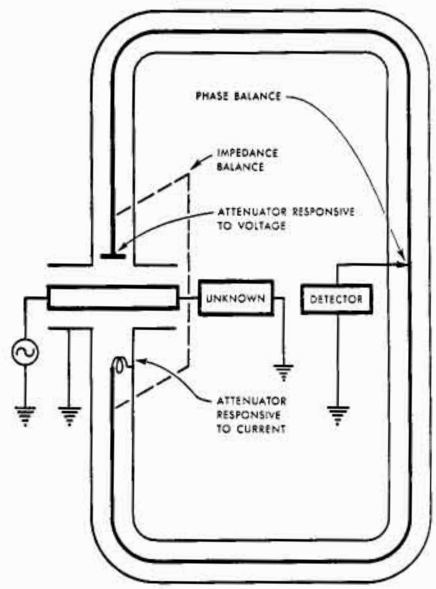
Standard Type N connector

Uses:

Determines characteristics of:
- Antennas
- Transmission lines
- RF chokes
- Resistors
- Condensers

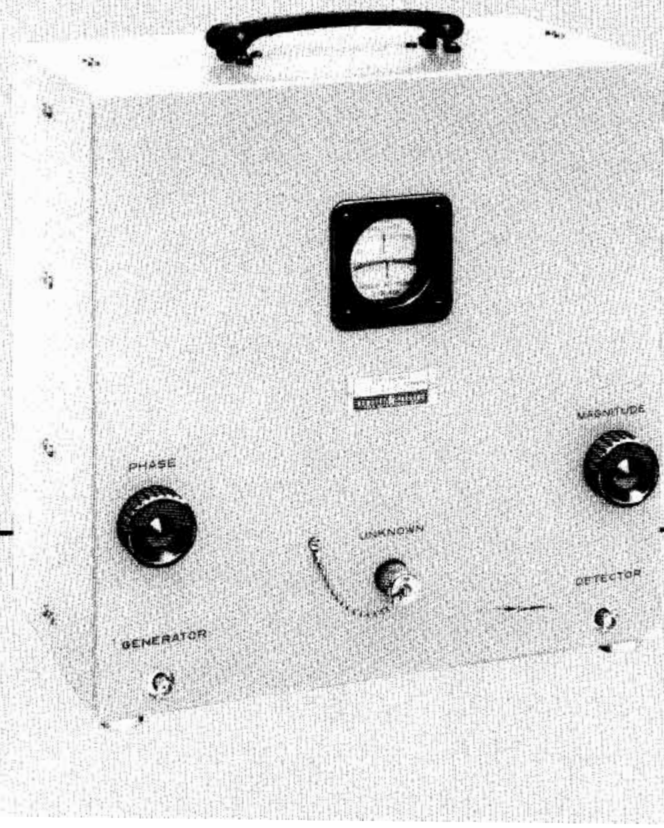
Measures:
- Connector impedances
- Standing wave ratios
- % reflected power
- VHF system flatness

Model 803A vhf Bridge provides direct impedance measurements in the vhf range. It measures impedance by sampling the electric and magnetic fields in a transmission line. Two attenuator systems are controlled simultaneously. One responds to the electric field in the transmission line, and the other responds only to the magnetic field in the transmission line. The combination is adjusted for equal output from each attenuator. These two signals are applied to opposite ends of a transmission line. Phase is determined by finding their point of cancellation. (See diagram.) This method effectively overcomes the narrow frequency limitations of conventional bridges, and permits hp Model 803A to make readings at frequencies up to 1,000 MC and down to 5 MC.



Simple to Operate, Direct Reading

In operation, the instrument is similar to a standard bridge, much simpler to use and more compact than a slotted line. Two controls are simultaneously tuned until a sharp null is obtained. At the null, one dial reads unknown impedance direct in ohms, and the other dial shows phase angle.



Impedances between 2 and 2,000 ohms are read directly, and higher or lower values may be readily determined by using a transmission line of known length as an impedance transformer. Phase angles up to $\pm$ 90° can be measured at frequencies as low as 52 MC. Calibration of phase angle is direct in degrees at 100 MC, and angles at other frequencies can be readily determined by multiplying angle read by frequency in MC and dividing by 100.

Broad Usefulness

Virtually all measurements which can be made with a slotted line can be made more easily and swiftly with the compact Model 803A vhf Bridge. The instrument is extremely useful for determining rf resistance—even at frequencies as low as 5 MC or high as 1,000 MC. It also offers fast, accurate determination of antenna and transmission line characteristics and impedances, capacity, inductance, etc. Its broad usefulness makes this equipment a real time saver to engineers working in the vhf band.

Specifications

hp 803A

Measurement Range: Impedance magnitude, 2 to 2,000 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 52 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) x Frequency (MC)/100.

Accuracy: (Over range 52 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.

Charts are provided with each instrument so that impedance readings may be corrected to better than $\pm$ 2% and phase angle to better than $\pm$ 1.2° over the entire frequency range.

Frequency Range: Maximum accuracy 52 to 500 MC. Useful down to 5 MC and up to 1,000 MC. Maximum measurable phase angle at 5 MC is —8.8° to +8.8°.

External rf Generator: Requires an AM signal source of at least 1 mw. High signal level is desirable. (hp Model 608C vhf Signal Generator, pages 134, 135, is ideal for this purpose.)

RF Detector: Requires a well-shielded vhf receiver of good sensitivity. (hp Model 417A vhf Detector is designed for this use.)

Dimensions: Cabinet Mount: 14¼″ wide, 15¼″ high, 9″ deep.

Weight: Net 28 lbs. Shipping 39 lbs.

Accessories Furnished: 1 803A-16D Cable Assembly; 1 803A-16E Cable Assembly; 1 803A-76G Shorting Plug.

Price: hp 803A, $900.00.

hp 417A VHF DETECTOR

This hp instrument is a super-regenerative (AM) receiver covering all frequencies between 10 and 500 MC in 5 bands. Designed for use with the hp 803A Bridge, Model 417A provides a high sensitivity of approximately 5 microvolts over the entire frequency band. It is designed for fast, simple operation, and has a single, convenient frequency control directly calibrated in megacycles.

The instrument is thoroughly shielded and is suitable for general laboratory use, including the determination of approximate frequency, noise, interference, etc. It is lightweight for portability, sturdily built, and compact to occupy a minimum of bench space.

Specifications

hp 417A

Frequency Range: 10 to 500 MC, continuous coverage, 5 bands. Directly calibrated in MC.

Sensitivity: Approximately 5 microvolts over entire frequency range.

Power: 115/230 v $\pm$ 10%, 50/60 cps, 35 watts.

Dimensions: Cabinet Mount: 9¼″ wide, 12½″ high, 9″ deep.

Weight: Net 18 lbs. Shipping 31 lbs.

Accessories Available: AC-16B Cable Assembly, $5.50; AC-16K Cable Assembly, $6.50; 803A-16E Input Cable Assembly, $9.00.

Price: hp 417A, $400.00.

Data subject to change without notice.

NOISE FIGURE

In microwave communications, 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 received signal level by raising the power of the transmitter. For example, a 5 db improvement in receiver noise figure is equivalent to increasing the transmitter power by 3:1.

The noise appearing at the output of a receiver or an amplifier is the sum of the noise arising from the input termination (source) and the noise contributed by the receiver or amplifier itself. The noise factor is the ratio 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. Noise figure is noise factor expressed in db.

The noise figure of a receiver may be measured by using a signal generator input and an output power (square law) detector. However this method is time consuming and has the added disadvantage that the effective power gain-bandwidth characteristics of the device must be determined. Moreover the available signal power may be difficult to determine accurately at the low levels involved.

Automatic noise figure measurements utilizing standard broadband noise sources which supply a noise spectrum of known power, flat with frequency, overcome the drawbacks of the signal generator method. At intermediate and low radio frequencies temperature limited diodes are suitable as excess noise sources, while at microwave frequencies gas discharge tubes in suitable waveguide sections are both accurate and reliable. Hewlett-Packard Noise Figure Meters utilize the noise source technique.

Automatic noise figure measurements with Hewlett-Packard Noise Figure Meters depend upon the periodic insertion of a known excess noise power at the input of the device under test. Subsequent detection of the noise power in later IF stages of the device results in a pulse train of two power levels. The power ratio of these two levels contains the desired noise figure information. For instance, in the simplified diagram of Figure 1, the various contributions of noise power to the output pulse ratio are shown.

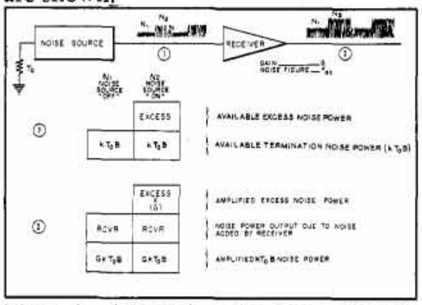


Figure 1. *Automatic noise figure measurement of microwave device (Composition of Noise Power).*

kT_0B is the available noise power from the reference load where:

k = Boltzmann's constant

T_0 = Temperature of reference load in degrees Kelvin.

B = Bandwidth of measuring system

Excess noise power added by the noise source is based on the effective fired temperature of the source. An argon gas discharge, for instance, is 15.2 db above the reference temperature power. Then the total noise power output of the receiver with noise source "OFF" is:

$$N_1 = GkT_0B + RCVR \qquad (1)$$

where G is receiver power gain

and total noise power output of the receiver with noise source "ON" is:

$$N_2 = GkT_0B + RCVR + EXCESS \times (G) \qquad (2)$$

Noise factor is defined above as:

$$F = \frac{GkT_0B + RCVR}{GkT_0B}, \text{ or} \qquad (3)$$

$$\frac{\text{(Total noise output from device)}}{\text{(Output power if noiselessly amplified)}}$$

So:

$$RCVR = (F - 1)\ GkT_0B \qquad (4)$$

which is noise output power contributed by the RCVR.

Also the excess noise power from the gas discharge at the input is:

$$EXCESS = \left(\frac{T_2 - T_0}{T_0}\right) kT_0B \qquad (5)$$

where T_2 is the effective fired temperature of the noise source.

Then the ratio at the output: $\frac{N_2}{N_1}$ =

$$\frac{GkT_0B + (F-1)GkT_0B + \left(\frac{T_2 - T_0}{T_0}\right)GkT_0B}{GkT_0B + (F-1)\ GkT_0B} \qquad (6)$$

by substitution from (1), (2), (4), & (5)

And

$$F = \frac{\left(\frac{T_2 - T_0}{T_0}\right)}{\left(\frac{N_2 - N_1}{N_1}\right)} \qquad (7)$$

Note that the gain-bandwidth factor (GB) has disappeared.

Finally (8)

$$F_{db} = 10 \log\left(\frac{T_2}{T_0} - 1\right) - 10 \log\left(\frac{N_2}{N_1} - 1\right)$$

The first term is a known quantity and expressed in db of excess noise ratio. For an argon discharge excess noise ratio is 15.2 db:

Then:

$$F_{db} = 15.2 - 10 \log\left(\frac{N_2}{N_1} - 1\right) \qquad (9)$$

Thus the ratio $\frac{N_2}{N_1}$ contains the desired noise figure information. Hewlett-Packard Models 340B, 342A, and 344A Noise Figure Meters measure noise figure as a function of this ratio.

Model 340B requires a 30 or 60 megacycle input from the device under test. Input circuitry of the 342A features a vhf converter which provides for 5 input frequencies: 30, 60, 70, 105 and 200 megacycles.

The new ⓗⓟ 344A transistorized Noise Figure Meter has been specifically designed for radar system applications where time-shared noise figure measurements are extremely important to assure that radar sets are operating at peak performance. Sensitivity has been made very high to permit noise sources to be decoupled by as much as 20 db from the main transmitter line. Alarm circuitry for remote indication of excessive noise figure, as well as remote metering of noise figure, is available in the 344A.

Hewlett-Packard noise sources are available for all frequencies between 10 megacycles and 18,000 megacycles to allow measurements on all rf devices in this range. Sources have been specifically designed for very low fired and unfired SWR to lower coupling ambiguities of the excess noise ratio into the device under test. Waveguide sources have been loaded with resonance suppressing polyiron loads to eliminate high SWR at points in the band caused by the insertion of the noise tube in waveguide.

For further information on automatic noise measurements, write for ⓗⓟ Journal Vol. 9, No. 5 and Vol. 10 No. 6-7. Application Note #43 describes radar system noise measurements.

ⓗⓟ 344A NOISE FIGURE METER

Measure, optimize on operating radar receivers

Continuous noise figure measurement on operating radars is simple and reliable with the ⓗⓟ 344A Noise Figure Meter. Usable with radar receivers in any rf range for which noise sources are available, the 344A permits optimizing the noise figure during operation because of its fast meter response. High sensitivity permits decoupling the noise source up to 20 db from the main transmitter line to minimize degradation of the system.

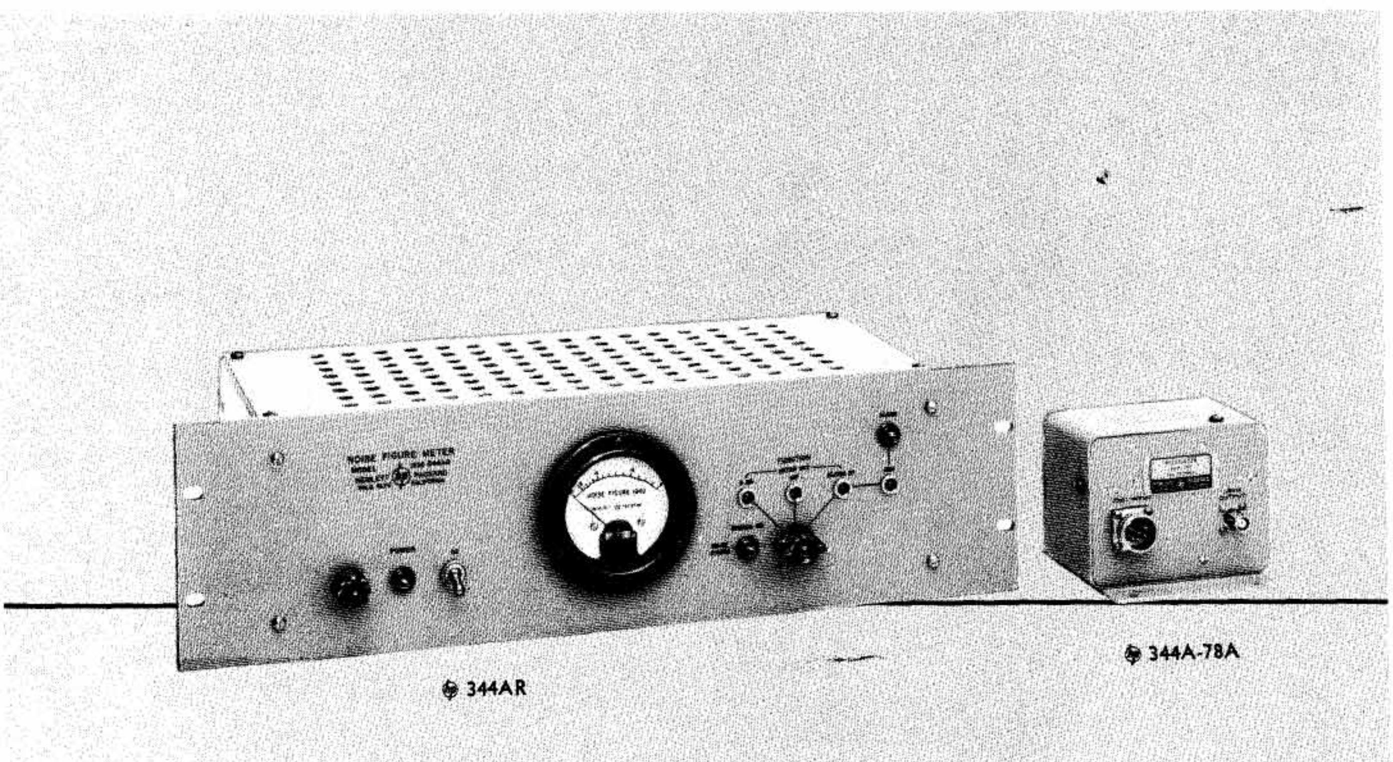
Model 344A is used with a remote modulator (such as ⓗⓟ 344A-78A Modulator pictured) and noise source so that high voltage slip-rings are unnecessary. During radar scan the 344A termination is passive, to eliminate spurious reflections appearing as targets. Designed for pulse rep rates of 90 to 500 pps, the 344A may also be used with high resolution, high prf radar sets at rates up to 3,000 pps by employing sampling techniques.

This automatic instrument is transistorized, compact, rugged and militarized for reliability. Optional alarms indicate noise figure above pre-set level or failure in noise source current.

Data subject to change without notice.

Specifications

Input Frequency: 25 or 30 MC as specified.
Bandwidth: 1 MC.
Input Sensitivity: Requires 35 db ± 5 db of gain between the noise source and ⓗⓟ 344A input.
Input Impedance: 75 ohms nominal. Passive termination during radar scan time.
Return Loss: 20 db from 20 to 40 MC. (During radar scan time.)
Accuracy: ± ½ db, 0 to 12 db; ± 1 db, 12 to 20 db. Does not include excess noise accuracy.
Repetition Rate: Any rate from 90 to 500 pps as specified. (Techniques available for operation above 500 pps.)
Acceptable Repetition Rate Variation: Specified rate ± 25%.
Measurement Duty Cycle: 0.075 minimum (measurement time/repetition period).
Total Duty Factor: 0.075 + (100 μsec)(prf).
Input Trigger: 3 volt positive pulse, 3 μsec duration minimum.
Noise Figure Alarm: (Optional) Front panel lamp indicates when noise figure exceeds preset value. Contact closure for remote alarm.
Source Alarm: (Optional) Front panel lamp indicates improper noise source current. Contact closure for remote alarm.
Output: 100 μa into 2,000 to 3,000 ohms at full scale meter reading for remote metering.
Remote Modulator Operation: Maximum separation depends on total resistance between modulator and Noise Figure Meter. The trigger path must be less than 13 ohms, the dc supply and ground path must be less than 0.5 ohm.
Modulator Output: Sufficient to fire any ⓗⓟ gas-discharge noise source through 6 ft. cable.
Temperature Range: 0 to 52° C.
Humidity: 95%.
Dimensions: Rack mount: 19" wide, 5¼" high. 10⅞" deep including cable allowance. Modulator: 4⅝" wide, 3⅝" high, 4½" deep.
Power: 115 volts ± 10%, 50 to 1,000 cps. 20 to 40 watts depending on noise source and duty cycle. Mating connector: MS-3106R-10SL-3S.
Price: ⓗⓟ 344A (cabinet) or 344AR (rack mount) approximately $1,600.00 including one ⓗⓟ 344A-78A Modulator. (Depends on options and modifications.) ⓗⓟ 344A-78A Modulator, $250.00 each.
(Not available in Western Europe.)



ⓗⓟ 344AR

ⓗⓟ 344A-78A

340B/342A NOISE FIGURE METER

Direct-Reading Automatic Instrument Speeds Noise Figure Measurements

Advantages:

- Gives direct noise figure readings while equipment is being operated
- Cuts receiver alignment time to minutes
- Completely automatic measurement
- Easily used by non-technical personnel
- No periodic recalibration needed
- Fast response; ideal for recorder operation

Uses:

- Measure noise figure and optimize performance in microwave or radar receivers, rf and IF amplifiers
- Select components, crystals, T - R cells and local oscillators for minimum noise
- Compare unknown noise sources against known noise levels
- Design IF amplifiers, crystal mixing circuits, wide band traveling wave tubes, etc.

Receiver and component alignment jobs that once took skilled engineers a full hour are now done in 5 minutes by a semi-skilled worker. Receiver noise figure can often 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.

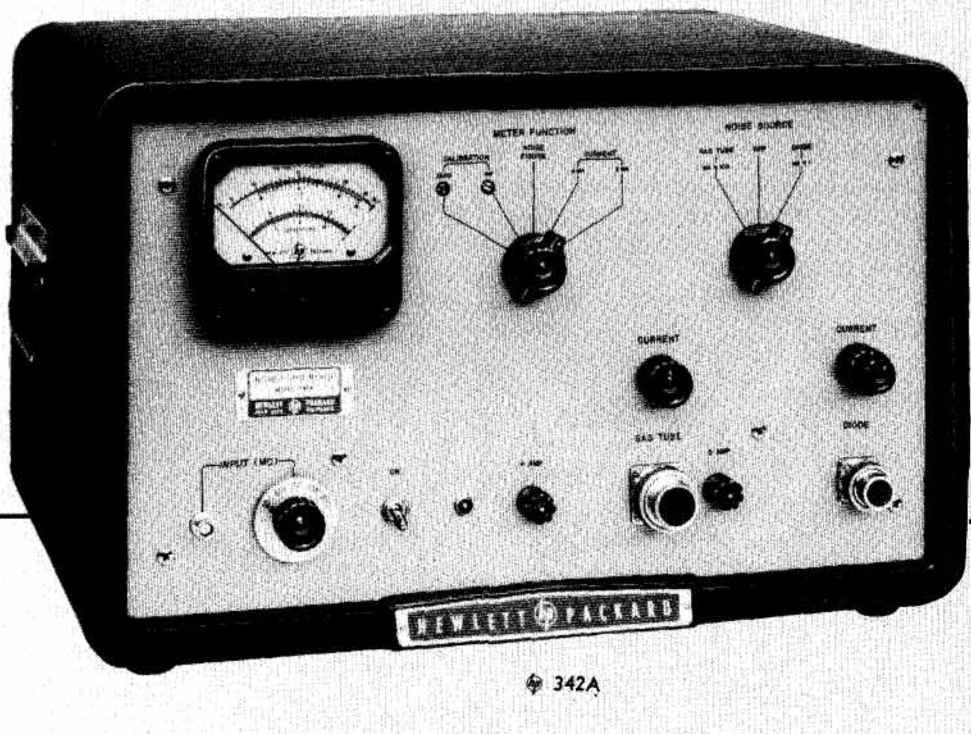
Above are some of the time-saving, cost cutting advantages of Hewlett-Packard noise figure measuring equipment, Models 340B and 342A, plus a variety of coaxial and waveguide noise sources.

Model 340B Noise Figure Meter, when used with an hp noise source automatically measures and continuously displays 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 (KMC).

These Noise Sources are described and specifications given on page 179.

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 60, 70, 105 and 200 MC; the fifth is the basic 342A tuned amplifier frequency of 30 MC.



hp 342A

In operation, a noise source such as a gas discharge tube is connected to the input of a receiver under test. The receiver's IF amplifier output is connected to the 340B or 342A. The Noise Figure Meter pulses the gas discharge tube. When the tube is ignited the noise level is that of the receiver *plus* the discharge tube. When the tube is off, the noise level is that of the receiver 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

ⓗ 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.

ⓗ 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.

ⓗ 347A Waveguide Noise Source. Argon gas discharge tubes mounted in waveguide sections. For all frequencies 2.6 through 18.0 GC, provide uniform noise throughout range; maximum SWR 1.2.

ⓗ 349A UHF Noise Source. Argon discharge tubes providing 15.2 db excess noise for automatic noise figure readings on scatter communications receivers, L-band radars, parametric amplifiers, or other devices 400 to 4,000 MC. Also available with 18.2 db excess noise.

Specifications

ⓗ 340B Noise Figure Meter

Frequency Range: Depends on noise source used.
Noise Figure Range: 3 to 30 db, indication to ∞ with Waveguide Noise Source. 0 to 15 db, indication to ∞ with IF Noise Source.
Zero Offset: Permits low values to be read on sensitive external meter.
Accuracy (excluding source accuracy): $\pm$ 0.5 db, 10 to 25 db; $\pm$ 1 db, 3 to 10 db; 25 to 30 db with Waveguide Noise Source. $\pm$ 0.5 db, 0 to 15 db with IF Noise Source.
Input Requirements: -60 dbm to -10 dbm (noise source on). Corresponds to system gain before 340B of approximately 40 to 90 db with 347A or 349A noise source; approximately 50 to 100 db with 343A or 345B noise source.
Input Frequency: 30 and 60 MC. Other frequencies between 10 and 70 MC on special order.
Bandwidth: 1 MC minimum.
Input Impedance: 50 ohms, nominal.
AGC Output: Nominally 0 to -6 volts from rear binding posts.
Recorder Output: Maximum of 1 ma into maximum of 2,000 ohms to operate a recorder or remote meter.
Power Input: 115/230 v, $\pm$ 10%, 50/60 cps, 185-435 watts depending on line voltage and noise source.
Power Output: Sufficient to operate ⓗ 347A, ⓗ 349A, ⓗ 345B, or ⓗ 343A Noise Sources.
Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 13⅞" deep behind panel.
Weight: Cabinet Mount: Net 40 lbs. Shipping 51 lbs. Rack Mount: Net 34 lbs. Shipping 49 lbs.
Accessories Furnished: ⓗ 340A-16A, 6' cable connects ⓗ 340B to an ⓗ347A or 349A Noise Source.
Price: ⓗ 340B, $715.00 (cabinet); ⓗ 340BR, $700.00 (rack mount). Add $25.00 for special frequencies between 10 and 60 MC. (Not available in Western Europe.)

ⓗ 342A Noise Figure Meter

(Same as 340B except as shown below)

Input Frequency: 30, 60, 70, 105 and 200 MC. 30 MC plus any four frequencies between 38 and 200 MC on special order. Frequency selector switch.

Price: ⓗ 342A, $815.00 (cabinet); ⓗ 342AR, $800.00 (rack mount). (Not available in Western Europe.)

ⓗ 343A VHF Noise Source

Frequency Range: 10 to 600 MC.

Excess Noise: 5.2 $\pm$ 0.1 db, 10 to 200 MC.
5.2 $\pm$ 0.25 db, 200 to 400 MC.
5.2 $\pm$ 0.35 db, 400 to 600 MC.

Source Impedance: 50 ohms, SWR less than 1.1, 10 to 400 MC; less than 1.3, 400 to 600 MC.

Dimensions: 2¾" wide, 2½" high, 5" deep.

Weight: Net ¾ lb. Shipping 2 lbs.

Price: ⓗ 343A, $100.00.

ⓗ 345B IF Noise Source

(Same as 343A except as shown below)

Spectrum Center: 30 or 60 MC, selected by switch. Other frequencies between 10 and 60 MC on special order.

Excess Noise: Nominally 5.2 db into conjugate load.

Source Impedance: 50, 100, 200 and 400 $\pm$ 4% ohms as selected by switch. Less than 1 pf shunt capacitance.

Price: ⓗ 345B, $100.00. Add $25.00 for special frequencies.

ⓗ 347A Waveguide Noise Source

Model	Range, GC (KMC)	Excess Noise, db	Approx. Length	Price
S347A	2.6 - 3.95	15.2 $\pm$ 0.5	22½"	$300.00
G347A	3.95 - 5.85	15.2 $\pm$ 0.5	19"	285.00
J347A	5.3 - 8.2	15.2 $\pm$ 0.5	19"	250.00
H347A	7.05 - 10	15.2 $\pm$ 0.5	16"	225.00
X347A	8.2 - 12.4	15.2 $\pm$ 0.5	14¾"	200.00
P347A	12.4 - 18	15.2 $\pm$ 0.5	14¾"	250.00

SWR all models, fired or unfired, 1.2 max., less than 1.1 average.

ⓗ 349A UHF Noise Source

Frequency Range: 400 to 4,000 MC; wider with correction.

Excess Noise: 15.2 $\pm$ 0.5 db, including insertion loss

SWR: Up to 2,600 MC: less than 1.35 (fired); less than 1.5 (unfired)
2,600 to 3,000 MC: less than 1.5 (fired); less than 1.5 (unfired)
3,000 to 4,000 MC: less than 2.0 (fired); less than 3.0 (unfired)
(Source terminated in coaxial load with less than 1.05 SWR.)

Dimensions: 15" long, 3" wide, 2" high.

Weight: Net approximately 3¼" lbs. Shipping 6 lbs.

Price: ⓗ 349A, $325.00.

Data subject to change without notice.

hp 382A Waveguide Attenuators

Operation of these direct-reading precision attenuators depends on mathematical law instead of the resistivity of attenuating material. Accurate, stable attenuation from 0 to 50 db is assured full range, despite varying temperature and humidity conditions. The instruments feature high power handling capacity and large, easily read dials. Insertion loss at 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,* including both calibration and frequency error.

Specifications

Model	Frequency Range GC (KMC)	Capacity Watts	Length (in.)	Price
G382A	3.95 - 5.85	15	31 5/8	$500.00
C382A	4.7 - 7.05	10	23 1/8	800.00
J382A	5.3 - 8.2	10	25	375.00
H382A	7.0 - 10.0	10	19-15/16	350.00
X382A	8.2 - 12.4	10	15 5/8	275.00
M382A	10.0 - 15.0	10	15	300.00
P382A	12.4 - 18.0	5	12 1/2	275.00
K382A	18.0 - 26.5	2	7 5/8	475.00
R382A	26.5 - 40.0	1	7 1/2	500.00

For all models: Calibrated range, 0 to 50 db. Phase shift, less than 3° variation from 0 to 50 db. Attenuation at zero setting, less than 1 db.

Data subject to change without notice.

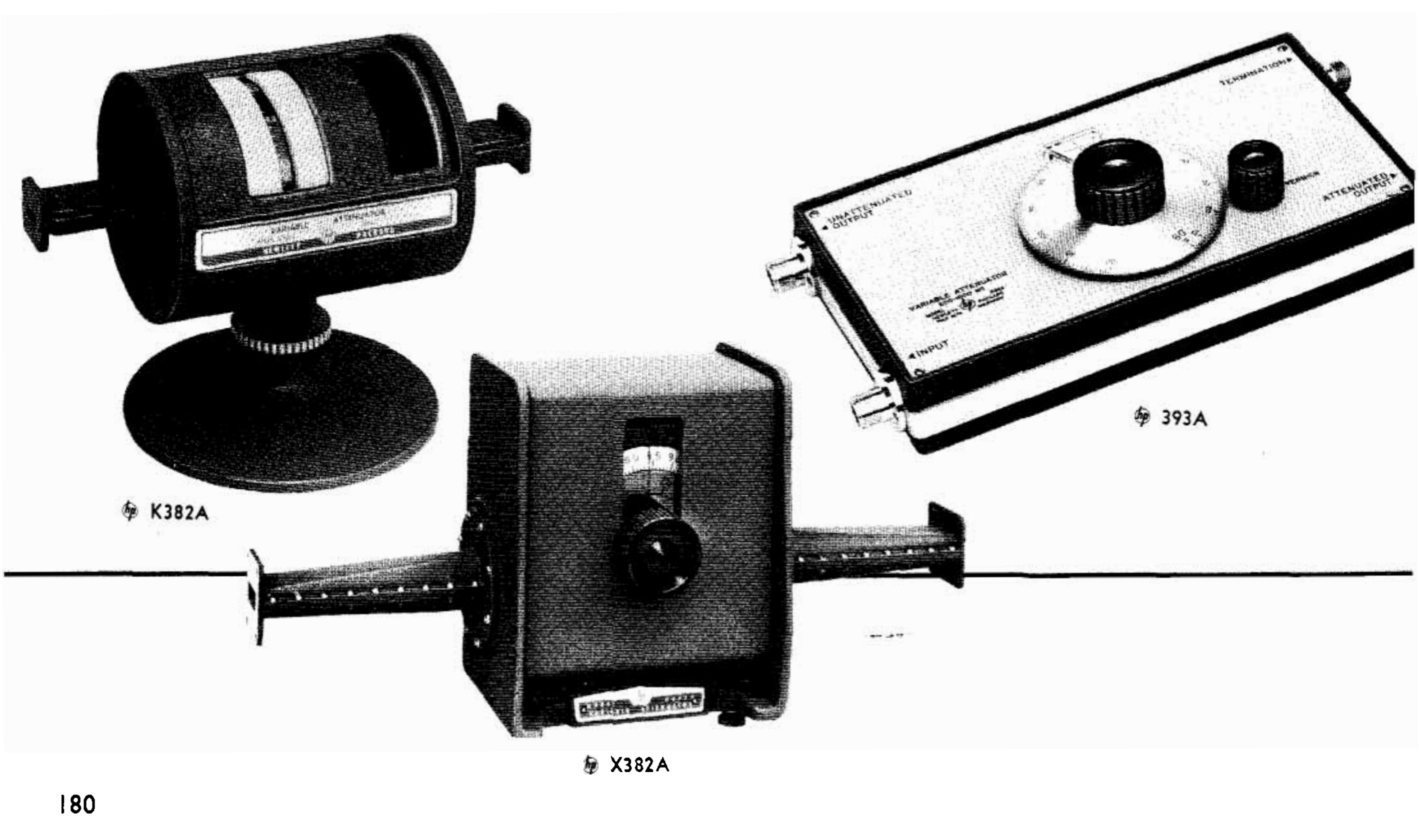
hp 393A/394A Coaxial Attenuators

These multi-purpose instruments provide a convenient means of obtaining accurate attenuation in high power coaxial systems in the 500 to 1,000 MC range (hp 393A) and the 1,000 to 2,000 MC range (hp 394A). They are designed to provide precise, continuously variable attenuation as high as 120 db. Good directivity in the 10 to 40 db range makes the instruments valuable for directional coupler power sampling in high power systems, or for variable isolated coupling of local oscillators in mixer applications.

Dials are direct-reading over the full frequency range. Two low power loads are furnished (hp 908A) for operating levels up to 0.5 watts.

Specifications

Model	hp 393A	hp 394A
Frequency Range	500-1,000 MC	1,000-2,000 MC
Attenuation or Coupling	5 - 120 db continuously variable	6 - 120 db, continuously variable
Accuracy (between matched generator and load)	±1 db or 1% of dial, whichever is greater	±1 db or 2% of dial, whichever is greater
Nominal Impedance	50 ohms	50 ohms
SWR: to 10 db 10-30 db 30-120 db	2.5 1.5 1.2	2.5 1.5 1.4
Directivity (dial setting between 10-40 db, loads less than 1.05 SWR)	15 db	10 db
Maximum Voltage	500 volts, peak	
Average Power	0.5 watts (with furnished loads)	
Maximum average power	200 watts (requires external high-power loads)	
Size and Weight	5½" x 12" x 2¾"; 6 lbs.	
Price	-hp- 393A, $420.00; -hp- 394A, $420.00	



hp 393A

hp K382A

hp X382A

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 low and attenuation constant over the full waveguide band. Accuracy over the band is within ± 20% of the nominal attenuation.

372 Precision Attenuators

Model 372 Precision Attenuators are rugged, ultra-dependable, broad band instruments, which remain precisely calibrated regardless of humidity, temperature or other ambient conditions—or aging of the instrument. Models with either 10 or 20 db of attenuation are offered. *(See table.)* Calibration within ± 0.1db may be obtained at 10 points across the band. (Extra cost option.) SWR is 1.05:1; mean attenuation is within ± 0.4 db (± 0.7 db for K and R-bands) from nominal; variation across band is less than ± 0.5 db from mean.

375A Variable Flap 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 a variable amount. The degree of strip penetration determines attenuation. A dial shows average reading over the frequency band, and a dust cover with shielded braid 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.

S380A Calibrated Variable Attenuator

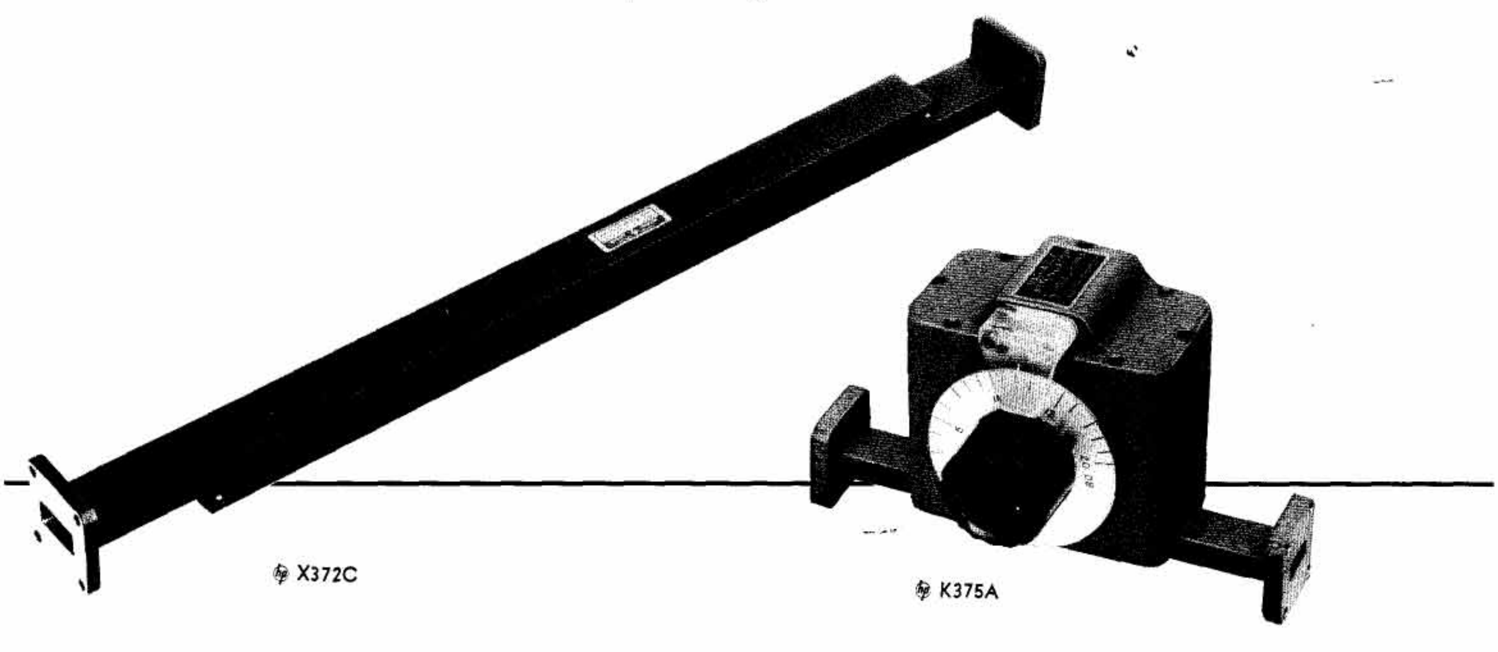
Model S380A, for setting exact power level or measuring attenuation, consists of a waveguide section with an attenuating plate parallel to the narrow face of the waveguide. A micrometer adjustment moves the plate across the waveguide, increasing attenuation from 0 to 10 db. Maximum average power is 1 watt, peak power, 1 kilowatt; frequency range 2.60 to 3.95 GC (KMC), insertion loss less than 0.5 db. Calibration accuracy is ± 0.3 db at 3 GC. Calibration for other frequencies available on request. Price $260.00.

Specifications, 370, 372, 375 Attenuators

Model 370*				Model 372*						Model 375A			
Model	Power Dissipation Watts	Length (in.)	Price	Model	Freq. GC (KMC)	Nominal Attenuation (db)	Fits Waveguide Size (in.)	Power Dissipation Watts	Price	Model	Power Dissipation Watts	Length (in.)	Price
S370	1.0	12	$100.00	S372	2.6 - 3.95	10/20	3 x 1½	2	$400.00	S375A	2.0	14⅛	$120.00
G370	1.0	10⅛	85.00	G372	3.95 - 5.85	10/20	2 x 1	2	275.00	G375A	2.0	13	110.00
C370	1.0	10	100.00	—	4.9 - 7.05	—	1.718 x 0.923	—	—	C375A	2.0	13	110.00
J370	1.0	8⅛	75.00	J372	5.85 - 8.2	10/20	1½ x ¾	1	165.00	J375A	2.0	13	100.00
H370	1.0	6⅜	75.00	H372	7.05 - 10.0	10/20	1¼ x ⅝	1	135.00	H375A	2.0	8¼	90.00
X370	1.0	5¼	65.00	X372	8.2 - 12.4	10/20	1 x ½	1	110.00	X375A	2.0	7-3/16	90.00
										M375A	0.5	7¼	190.00
P370	1.0	4⅛	80.00	P372	12.4 - 18.0	10/20	0.702 x 0.391	1	125.00	P375A	1.0	7¼	100.00
K370	0.5	3¼	115.00	K372	18.0 - 26.5	10/20	½ x ¼	0.5	240.00	K375A	0.5	4½	140.00
R370	0.5	3	115.00	R372	26.5 - 40.0	10/20	0.360 x 0.220	0.5	275.00	R375A	0.5	4⅜	180.00

Maximum SWR 1.15 for all models. (*Note: Model number suffix indicates db attenuation of 370 and 372 series attenuators. Suffix "A," 3 db. Suffix "B," 6 db. Suffix "C," 10 db. Suffix "D," 20 db. Model 372's are available in 10 and 20 db models only. K and R-band units are available with circular flanges (UG-425/U for K-band, UG-381/U for R-band). Specify by adding suffix "C" to model number; i. e., R370CC is a 10 db attenuator with UG-381/U flanges for 26.5 to 40 GC range.

Data subject to change without notice.



X372C

K375A

(hp) 532/536A FREQUENCY METERS

Precision General-Purpose Meters for Lab or Production Use

Specifications

Model No.	Overall Accuracy (%)	Frequency Range GC (KMC)	Dial Calib. Accuracy (%)	Calibration Increment (MC)	Max. Temp. Coefficient % per °C	Price
536A	0.14	1 - 4 (coax)	0.10	1	0.0016	$500.00
G532A	0.065	3.95 - 5.85	0.033	1	0.0012	325.00
J532A	0.065	5.30 - 8.20*	0.033	2	0.0012	300.00
H532A	0.075	7.05 - 10.0	0.040	2	0.0015	250.00
X532B	0.080	8.20 - 12.4	0.050	5	0.0010	175.00
M532A	0.085	10.0 - 15.0	0.053	5	0.0012	275.00
P532A	0.100	12.4 - 18.0	0.068	5	0.0012	210.00
K532A	0.110	18.0 - 26.5	0.077	10	0.0013	280.00
R532A	0.120	26.5 - 40.0	0.083	10	0.0017	300.00

K and R band models available with circular flange adapters; specify K532AC and R532AC respectively.

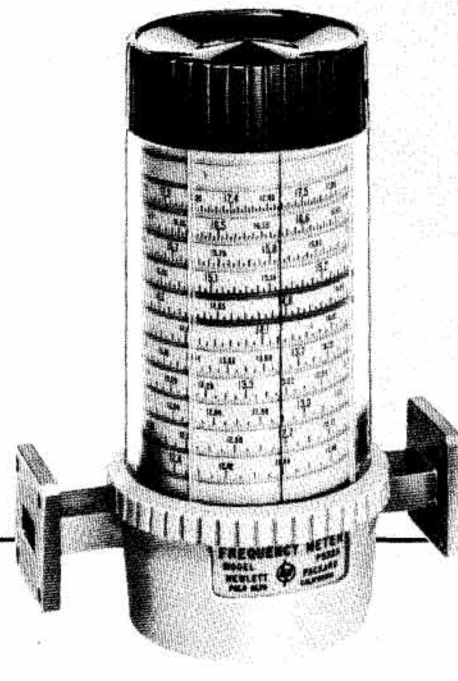
*Because of the wide frequency range of the J532A, frequencies from 7.6 to 8.2 GC can excite the TE_{112} mode when the dial is set between 5.3 and 5.6 GC.

Data subject to change without notice.

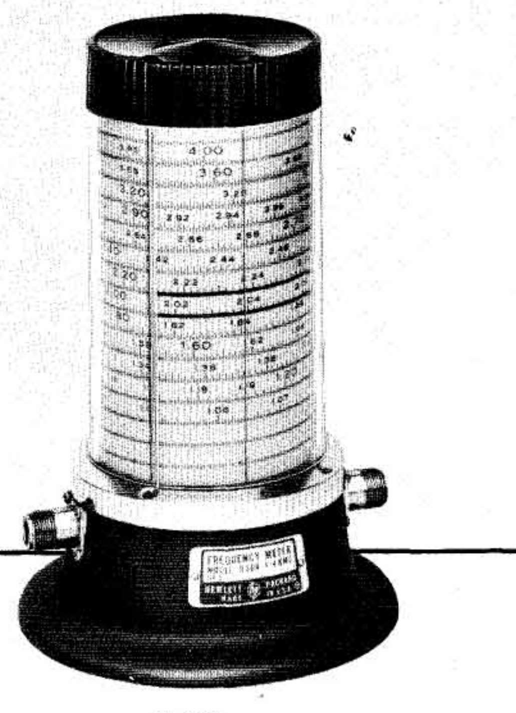
Model 532 and 536A Frequency Meters are wide band, direct reading instruments offering quality construction, convenience and outstanding value at low cost. Frequency is read directly in GC (KMC) with high accuracy as indicated on the adjoining table. No interpolation or charts are required. Overall accuracy includes a temperature variation of ± 10° C from 23° C and ± 0.02% for 0 to 100% humidity change.

The instrument comprises a special section mounting a high Q resonant cavity tuned by a choke plunger. No sliding contacts are used, and the waveguide section transmits virtually full power at resonance. A 1 db or greater dip in output indicates resonance. Tuning is by a precision lead screw, spring-loaded to eliminate backlash. Readability is enhanced by a long, effective spiral scale length and a scale calibrated in small frequency increments. For example, Model X532B has an effective scale length of 77" and is calibrated in 5 MC increments. Resettability is 0.01% (1 MC at 10 GC).

For measurements of 1 to 4 GC on coaxial circuits, (hp) 536A Coaxial Frequency Meter is offered. Specifications of this high resolution, broadband, direct reading instrument are listed in the table.



(hp) P532A



(hp) 536A

ⓗ 760D/761D DUAL DIRECTIONAL COUPLERS

New Two-Octave VHF-UHF Instruments; Also Single Octave Couplers

For power monitoring, mixing and power sampling with tightly controlled coupling, new ⓗ 760D/761D Dual Directional Couplers offer very broad band coverage of the vhf-uhf frequencies. Model 760D covers 250-1,000 MC; Model 761D, 1 to 4 GC (KMC). High directivity and flat frequency response make these units ideal for reflectometer systems.

With a power capacity of 50 watts CW and 10 kw peak, and low insertion loss, ⓗ 760D/761D Couplers can be installed permanently in coaxial systems for power monitoring. Since they are dual devices, the power meter or detector may be connected to either the "incident" or "reflected" terminals to simplify maximizing forward power.

Compact size and rugged aluminum construction add to the usefulness of these instruments.

ⓗ 764D/767D Dual Directional Couplers

Similar specifications are available in single octave coverage in the ⓗ 764D/767D Couplers. Four instruments collectively cover frequencies from 216 to 4,000 MC for applications requiring less bandwidth.

Specifications

Model	Frequency Range	Mean Coupling	Coupling Variation	Directivity (minimum)	Primary SWR (max)	Secondary SWR (max)	Price
760D	250 - 1,000 MC	20 ± ½ db	± ½ db	35 db	1.20	1.25	$200.00
761D	1 - 4 GC(KMC)	20 ± ½ db	± ½ db	30 db	1.25	1.30	185.00
764D	216 - 450 MC	20 ± ½ db	± 1 db	30 db	1.10	1.20	160.00
765D	450 - 945 MC	20 ± ½ db	± 1 db	30 db	1.15	1.20	160.00
766D	940 - 1,975 MC	20 ± ½ db	± 1 db	26 db	1.20	1.30	150.00
767D	1.9 - 4.0 GC	20 ± ½ db	± 1 db	26 db	1.25	1.50	150.00

Power handling capacity: all couplers 50 watts CW, 10 kw peak.
Type N connectors throughout. All couplers include ⓗ 803A-76G Shorting Plug for reflectometer calibration.

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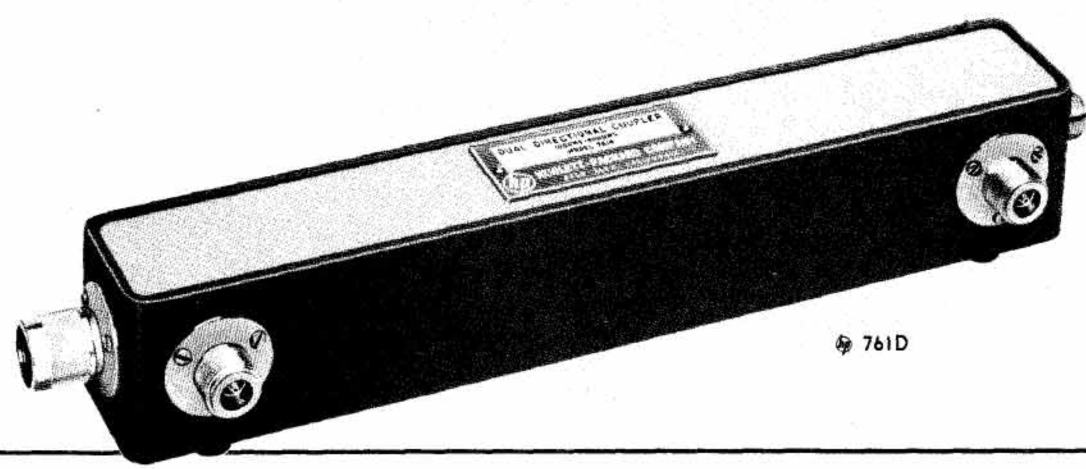


ⓗ 761D

752/750 DIRECTIONAL COUPLERS

Easy-to-Use, Precision Couplers Simplify Waveguide Measurements

Directional couplers such as 752 and 750 are important tools in waveguide measurements. They may be used to monitor power, measure reflections, mix signals or isolate signal sources or wavemeters.

Ideally, power flowing in one (the forward) direction of the main guide is coupled to the output of the auxiliary guide while power flowing in the other (reverse) direction is not coupled to the output of the auxiliary guide. The ratio, expressed in db, of forward power in the main guide to the power out of the auxiliary guide is the "coupling factor." *Example: 20 db coupling means a ratio of powers of 100:1.*

In practice, some reverse power in the main guide is coupled to the output of the auxiliary guide and the ratio, also in db, of the powers out of the auxiliary guide from equal forward and reverse powers in the main guide is the coupler's "directivity."

752 Multi-Hole Couplers

In this Coupler, the broad faces of two waveguides are joined together. Coupling is obtained from a series of graduated holes. *(Figure 1.)* These holes are accurately machined along the broad faces of the waveguides. Power flowing down the primary guide couples through the holes, exciting waves which propagate in both directions in the auxiliary. Directivity is explained by reference to the two-aperture coupler. *(See Figure 2.)* The coupling holes are spaced 1/4 wavelength apart, and thus waves traveling in the reverse direction are out of phase and cancel each other. Waves traveling in a forward direction reinforce each other. The power coupled into the auxiliary arm by a wave traveling in the main guide in the opposite direction is absorbed by a resistive termination.

The auxiliary guide of Model 752 is terminated in a low reflection load at one end and in a precision cover flange at the other end. Detection of power in the auxiliary arm can be achieved readily by connecting a crystal detector or bolometer mount to the open end.

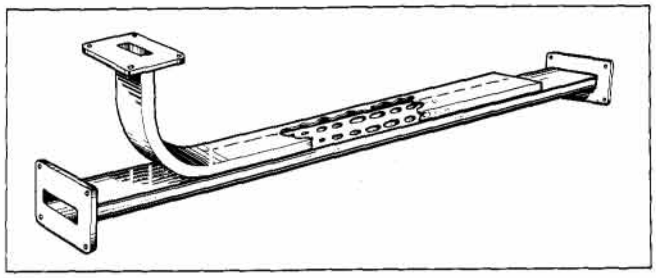


Figure 1. Construction, 752 Directional Couplers.

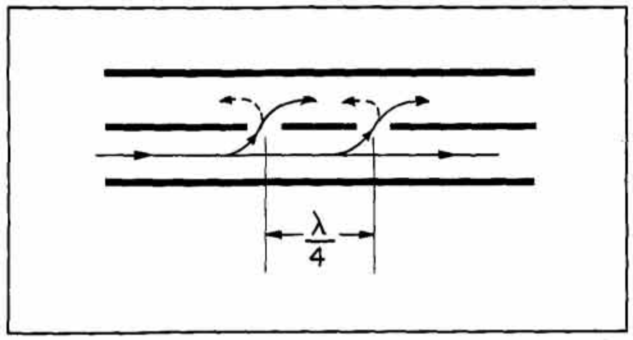
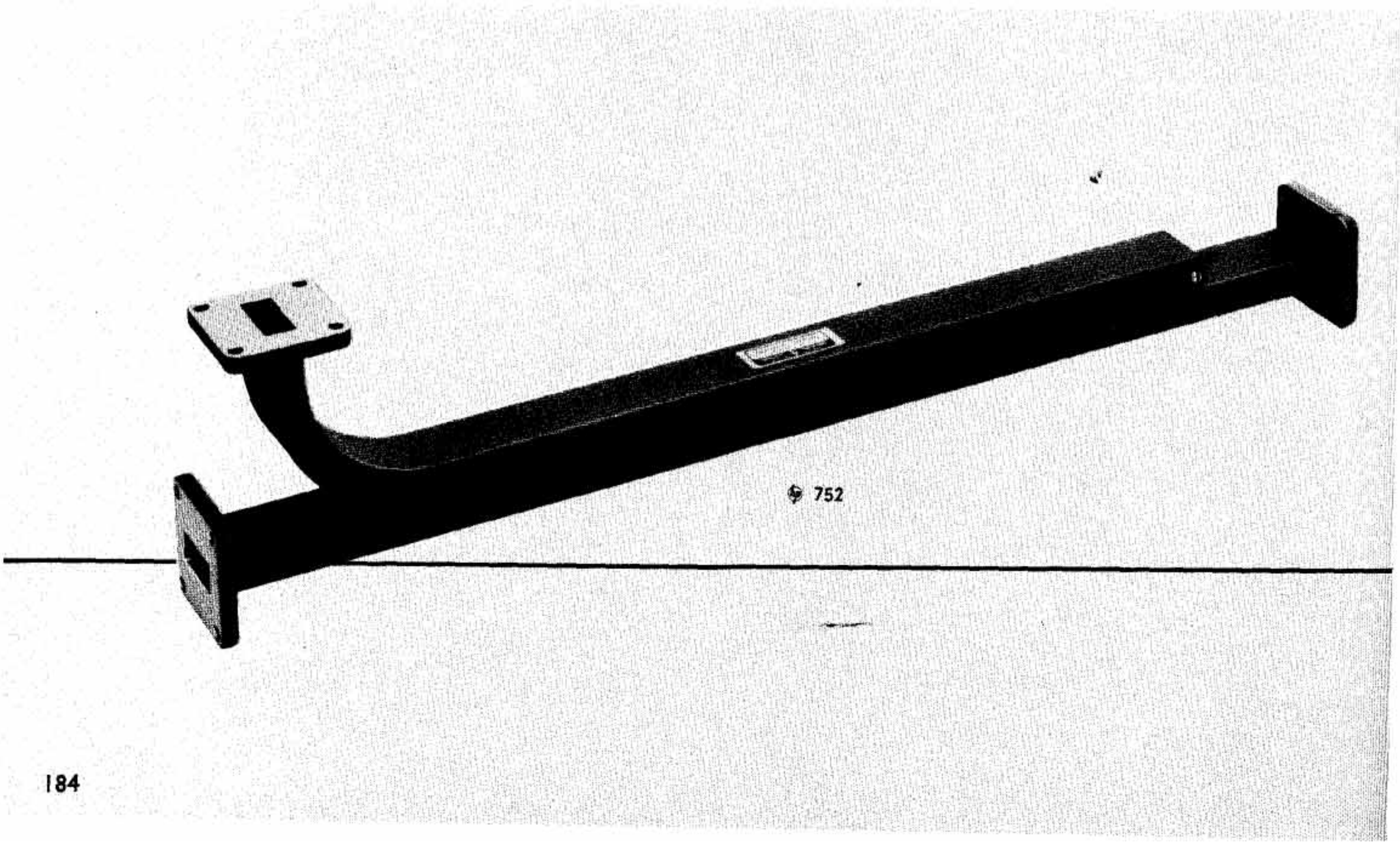


Figure 2. Cross-section, two-aperture coupler.



Ⓗ 752 has an overall directivity of better than 40 db (including reflection from built-in termination and flange) over the entire range of the guide. The coupling factors are 3, 10, and 20 db; accuracy of mean coupling level is ± 0.4 db (± 0.7 db for K and R band instruments) and frequency sensitivity of coupling is ± 0.5 db over the waveguide frequency range.

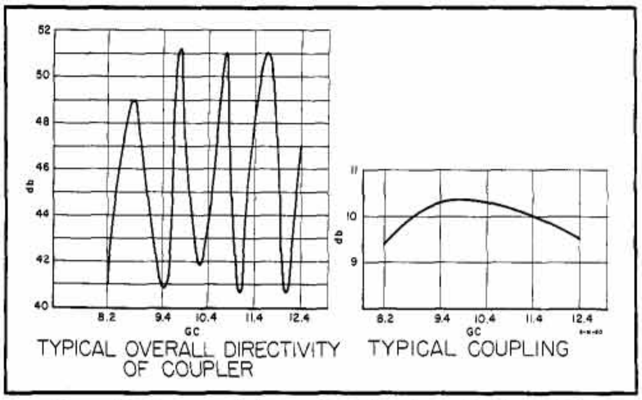


Figure 3. Characteristics, Ⓗ 752 Coupler – 10 db model.

Uses and Advantages

Because of its high directivity *(Figure 3)* this equipment is particularly suited for measurement of very small reflections, for rapidly adjusting transmission line flatness over the entire frequency range of the guide or for broadband reflectometer applications. *(See pages 163–165 for discussion of reflectometer measurements.)* With Model 752, a single oscilloscope presentation of SWR vs. frequency is easily made. In this operation, output of the auxiliary arm of the coupler is detected, amplified and applied to the vertical plates of the oscilloscope tube. The frequency applied to the system is swept and a voltage proportion to this frequency is applied to the horizontal plates of the oscilloscope. The resulting trace is a plot of reflection vs. frequency.

Ⓗ 750 Cross-Guide Couplers. For many applications the precision multi-hole coupler is not required. An inexpensive and compact instrument suited to numerous laboratory tests is Ⓗ 750 Cross-Guide Coupler.

It consists 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-terminal" network of maximum usefulness and versatility. The unit is well suited for power monitoring, for isolation and mixing powers.

Specifications

Ⓗ 750 Cross-Guide Couplers

Model	Coupling (db)	Frequency Range GC (KMC)	Wave-guide Size (in.)	Physical Size (in.)	Shipping Weight (lbs.)	Price
S750D	20	2.6 - 3.95	3 x 1½	9 x 9	18	$150.00
S750E	30	2.6 - 3.95	3 x 1½	9 x 9	18	150.00
G750D	20	3.95 - 5.85	2 x 1	6 x 6	7	120.00
G750E	30	3.95 - 5.85	2 x 1	6 x6	7	120.00
J750D	20	*5.85 - 8.20	1½ x ¾	5 x 5	4	85.00
J750E	30	*5.85 - 8.20	1½ x ¾	5 x 5	4	85.00
H750D	20	7.05 - 10.0	1¼ x ⅝	4 x 4	3	75.00
H750E	30	7.05 - 10.0	1¼ x ⅝	4 x 4	3	75.00
X750D	20	8.2 - 12.4	1 x ½	3 x 3	2	60.00
X750E	30	8.2 - 12.4	1 x ½	3 x 3	2	60.00

Directivity: Approximately 20 db or more.

Coupling Accuracy: Less than ± 1.7 db variation from nominal value over entire frequency range of guide.

*J750 couplers usable to 5.2 GC. Directivity same as above. Coupling within ±3 db of nominal value.

Ⓗ 752 Multi-Hole Couplers

Band[1] (Prefix)	Frequency GC (KMC)	Fits Waveguide Size (in.)	Mean Coupling Accuracy (db)[2, 3]	SWR Main Guide		Average Power Aux. Guide Load (w)	Length (in.)			Shipping Weight (lbs.)	Price
				752A	752C/D		A	C	D		
S	2.6 - 3.95	3 x 1½	± 0.4	1.1	1.05	2	50¼	48	48	40	$375.00
G	3.95 - 5.85	2 x 1	± 0.4	1.1	1.05	2	34⅝	33	33	19	250.00
J*	5.85 - 8.2	1½ x ¾	± 0.4	1.1	1.05	1	26½	25-9/16	25-9/16	16	140.00
H	7.05 - 10	1¼ x ⅝	± 0.4	1.1	1.05	1	18⅝	17½	17½	5	120.00
X	8.2 - 12.4	1 x ½	± 0.4	1.1	1.05	1	16-11/16	15-11/16	15-11/16	4	100.00
M	10 - 15	.850 x .475	± 0.4	1.1	1.05	1	16-5/16	15-11/16	15-11/16	4	130.00
P	12.4 - 18.0	.702 x .391	± 0.4	1.1	1.05	1	13¾	12¼	12¼	3	115.00
K‡	18.0 - 26.5	.500 x .250	± 0.7	1.1	1.05	½	10⅜	9-15/16	9-15/16	3	175.00
R‡	26.4 - 40.0	.360 x .220	± 0.7	1.1	1.05	½	11⅝	8⅝	7⅝	2	200.00

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. Mean coupling is the average of the maximum and minimum coupling values in the rated frequency range.
3. Coupling variation over rated frequency range is not more than ± 0.5 db about mean coupling.
4. Directivity is at least 40 db.

* J752 couplers operate to 5.2 GC with reduced performance.
Directivity: Greater than 40 db, 5.85 to 5.5 GC; greater than 36 db, 5.5 to 5.2 GC.
Variation of Coupling from nominal value: not more than —1.2 db at 5.5 GC, not more than —2 db at 5.2 GC.

‡ Circular flange (UG425/U for K-band, UG381/U for R-band) model available. Specify by adding suffix "C" to model number; ie., X752CC.

Data subject to change without notice.

ⓗⓟ 281A/290A/292A ADAPTERS, 360/362A LOW PASS FILTERS

ⓗⓟ **281A Waveguide-Coax Adapter,** for convenient transmission between waveguide and coax systems. Power may be fed in either direction. SWR less than 1.25 over full range of each adapter. Probes with low-loss dielectric sheath transform waveguide impedance into coax cable impedance. Type N and plain AN flange connections.

ⓗⓟ **290A Cover to Choke Flange,** a short waveguide section with precision cover flange on one end, choke flange on other. Simulates actual operating conditions when inserted between ⓗⓟ waveguide test equipment and choke flange system having a non-precision cover flange.

ⓗⓟ **292A Waveguide to Waveguide Adapter,** tapered lengths of waveguide to connect a given size waveguide to the next size larger or smaller. Five models provide band interchange as indicated on chart. Prefix letters indicate band mating.

ⓗⓟ 281A Adapters		ⓗⓟ 290A Adapters			Frequency Range GC(KMC)	Fits Waveguide Size (in.)	ⓗⓟ 292A Adapters				
Model	Price	Model	Price	Length (in.)			Model	SWR	Length (in.)	Frequency Range GC(KMC)	Price
S281A	$50.00	S290A	$65.00	3	2.60 - 3.95	3 x 1½	HX292A	1.05	1½	8.2 - 10.0	$25.00
G281A	40.00	G290A	55.00	2	3.95 - 5.85	2 x 1	MX292A	1.05	2⅜	10.0 - 12.4	40.00
J281A*	35.00	J290A	40.00	1¾	5.30 - 8.2	1½ x ¾	MP292A	1.05	2⅜	12.4 - 15.0	40.00
H281A	30.00	H290A	35.00	1½	7.05 - 10.0	1¼ x ⅝	NP292A	1.05	2⅜	15.0 - 18.0	40.00
X281A	25.00	X290A	20.00	½	8.2 - 12.4	1 x ½	NK292A	1.05	2⅜	18.0 - 22.0	40.00
		P290A	30.00	1⅛	12.4 - 18.0	.702 x .391					

*SWR 1.30 from 5.3 to 5.5 GC.

ⓗⓟ **360 Low Pass Filters,** eliminate harmonics, permit transmission of energy at a single known frequency, 700 to 4,100 MC. No spurious responses up to 3 times cut-off frequency. Type N fittings.

Cut-Off Frequency: Model 360A, 700 MC; 360B, 1,200 MC; 360C, 2,200 MC; 360D, 4,100 MC.

Insertion Loss: Not over 3 db throughout pass band.

Rejection: 50 db or more attenuation at 1.25 x (Cut-Off Frequency).

Nominal Impedance: 50 ohms through pass band. Should be matched for optimum performance.

SWR: Less than 1.6:1 to within 100 MC of cut-off for 360A and 360B, 200 MC of cut-off for 360C, 300 MC of cut-off for 360D.

Physical Dimensions:

Model No.	360A	360B	360C	360D
Length Overall	10⅞"	7-7/32"	10-25/32"	7⅜"
Outer Diameter	⅝"	⅝"	⅝"	⅝"
Center Line to Male End	2-5/16"	2-5/16"		
Center Line to Female End	2¼"	2¼"		

Accessories Available: AC-16F RF Cable Assembly, $15.00; AC-16C RF Cable Assembly, $13.00.

Price: ⓗⓟ 360A/B, $60.00; ⓗⓟ 360C/D, $50.00.

ⓗⓟ **362A Waveguide Low Pass Filters,** eliminate harmonics, permit transmission of energy at a single frequency, 8.2-40 GC(KMC).

Model	Pass Band (GC)	Stop Band (GC)	Length (in.)	Price
X362A	8.2 - 12.4	16 - 37.5	5-11/32	$325.00
M362A	10 - 15.5	19 - 47	4-15/32	350.00
P362A	12.4 - 18	23 - 54	3-11/16	350.00
N362A	15 - 21	27 - 63	3-1/32	350.00
K362A	18 - 26.5	31 - 80	2⅛	385.00
R362A	26.5 - 40	47 - 120	1-21/32	385.00

SWR (pass band): 1.5.

Pass Band Insertion Loss: Less than 1 db (1.5 db for R362A).

Stop Band Rejection: At least 40 db.

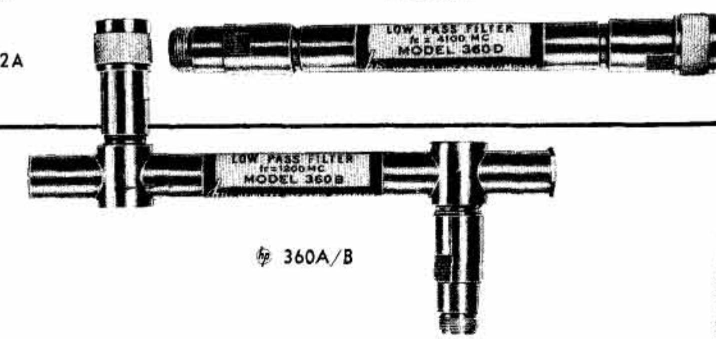
Flange: Flat cover.

Data subject to change without notice.

ⓗⓟ 362A

ⓗⓟ X281A

ⓗⓟ 360B/D



ⓗⓟ 360A/B

885A WAVEGUIDE PHASE SHIFTERS

Precision Phase Variation for J, X and P-Band Systems

Hewlett-Packard 885A Phase Shifters provide accurate, controllable phase variation in the J, X and P-band frequency ranges. They are particularly useful in measurement of transmission, attenuation and impedance in a microwave system, in introducing differential phase shift and in otherwise studying design of microwave systems and antennas. For example, the 885A Phase Shifter can be used to optimize performance of an antenna array, or to vary the directivity characteristics.

The instrument has a high accuracy over its entire phase range of —360 to +360 electrical degrees, has low power absorption, is simple to operate, and requires no charts or interpolation. It is sturdily built, comprising two rectangular-to-circular waveguide transitions with a dial driven circular waveguide mid-section. The instrument is housed in a cast aluminum container for rigidity and durability.

Specifications

Model	Frequency GC (KMC)	Accuracy	Insertion Loss	Loss Variation with Phase Setting	Max. Average Input Power	Approx. Length	Price
J885A	5.3 - 8.2	3°	2 db max.	0.4 db max.	10 watts	25"	$550.00
X885A	8.2 - 12.4	2° 8.2 - 10 GC 3° 10 - 12.4 GC	2 db max.	0.4 db max.	10 watts	15½"	425.00
P885A	12.4 - 18.0	4°	3 db max.	0.5 db max.	5 watts	12⅞"	600.00

All models. SWR (maximum): 1.35. For small phase differences accuracy is as tabulated or 10%, whichever is less.

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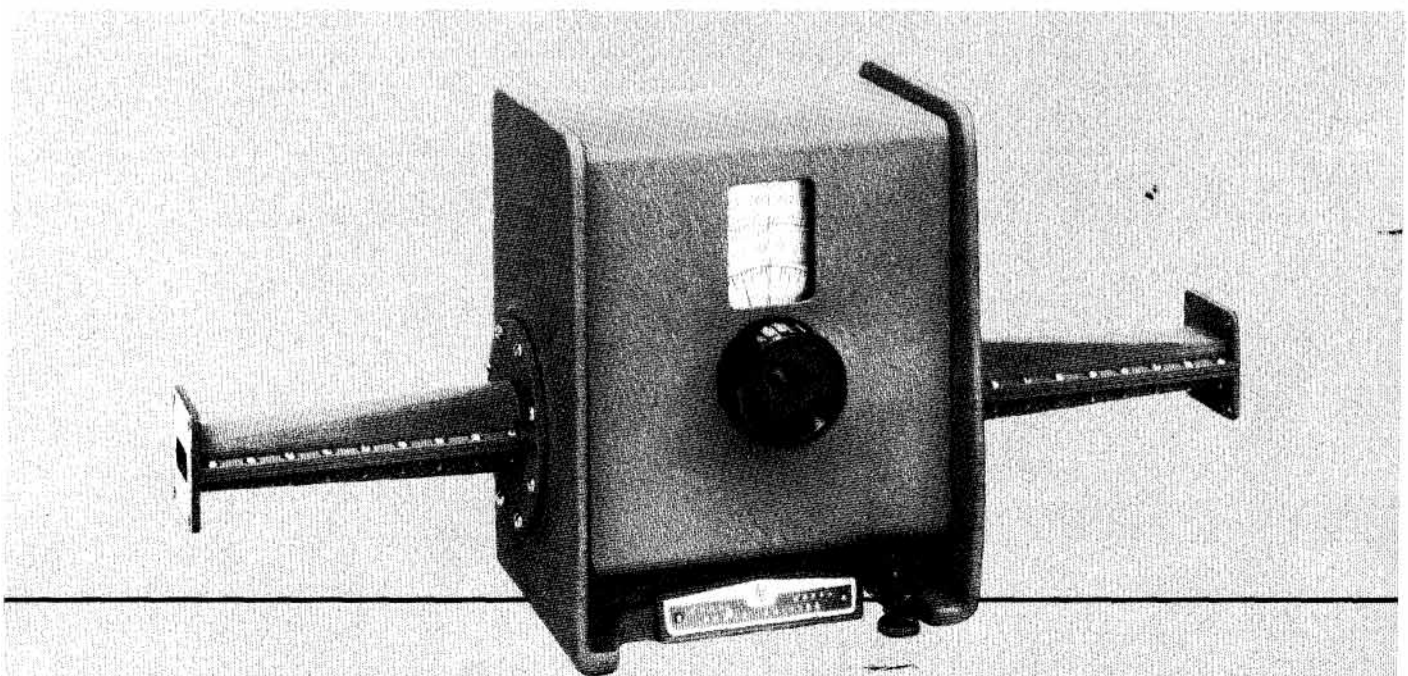

X885A

910A/B Low Power Termination

Model 910 is designed for terminating waveguide systems operating at average powers of about 1 watt. The terminations are carefully designed to absorb virtually all of the applied power and assure a low SWR. They may be used wherever a matched load is required, as in the measurements of reflection, discontinuities or obstacles in waveguide systems. They are also for use with directional couplers or hybrid tees.

912A High Power Termination

This termination is similar to Model 910A but is designed for waveguide systems operating at high powers. Since these terminations readily absorb large amounts of power, they are useful as dummy loads in testing vacuum tube characteristics, transmitter output, etc. Model 912A Terminations contain a high loss material which absorbs power and is carefully tapered to keep SWR low. Power is dissipated by cooling fins. When the termination is operated at 50% or more of rated power, fins should be forced-air cooled.

908A Coaxial Termination

Model 908A is a low reflection load for terminating 50 ohm coaxial systems in their characteristic impedance. From dc to 4,000 MC, its SWR is less than 1.05, facilitating use in terminating coaxial devices during most SWR measurements, or as a production line impedance standard.

908A is also a useful accessory for the 185A 1,000 MC Oscilloscope and 411A RF Millivoltmeter. When used with the T adapters available for those instruments, it allows the observation of waveforms or the measurement of voltage at the end of a cable with Type N fittings.

Specifications

Impedance: 50 ohms.
SWR: Less than 1.05.
Frequency Range: DC to 4,000 MC.
Power Rating: 1/2 watt.
Connector: Type N male.
Size: Length 2".
Weight: 3 oz.
Price: $35.00.

910 Low Power Termination					912A High Power Termination							
Model	Max. SWR	Average Power Watts	Length (in.)	Price	Model	Max. SWR	Average Power Watts	Peak Power KW	Length (in.)	Price	Frequency Range GC(KMC)	Fits Waveguide Size (in.)
S910A	1.04	2	10¼	$75.00	S912A	1.1	100	100	15¼	$200.00	2.60 - 3.95	3 x 1½
G910A	1.04	2	6⅝	65.00							3.95 - 5.85	2 x 1
C910A	1.02	1	8-9/16	75.00							4.9 - 7.05	1.718 x 0.923
J910A	1.02	1	8-3/16	45.00							5.30 - 8.20	1½ - ¾
H910A	1.02	1	5⅝	40.00							7.05 - 10.0	1¼ x ⅝
X910B	1.02	1	6⅞	35.00	X912A	1.1	50	50	8¼	75.00	8.20 - 12.4	1 x ½
P910A	1.02	1	4¼	40.00							12.4 - 18.0	.702 x .391

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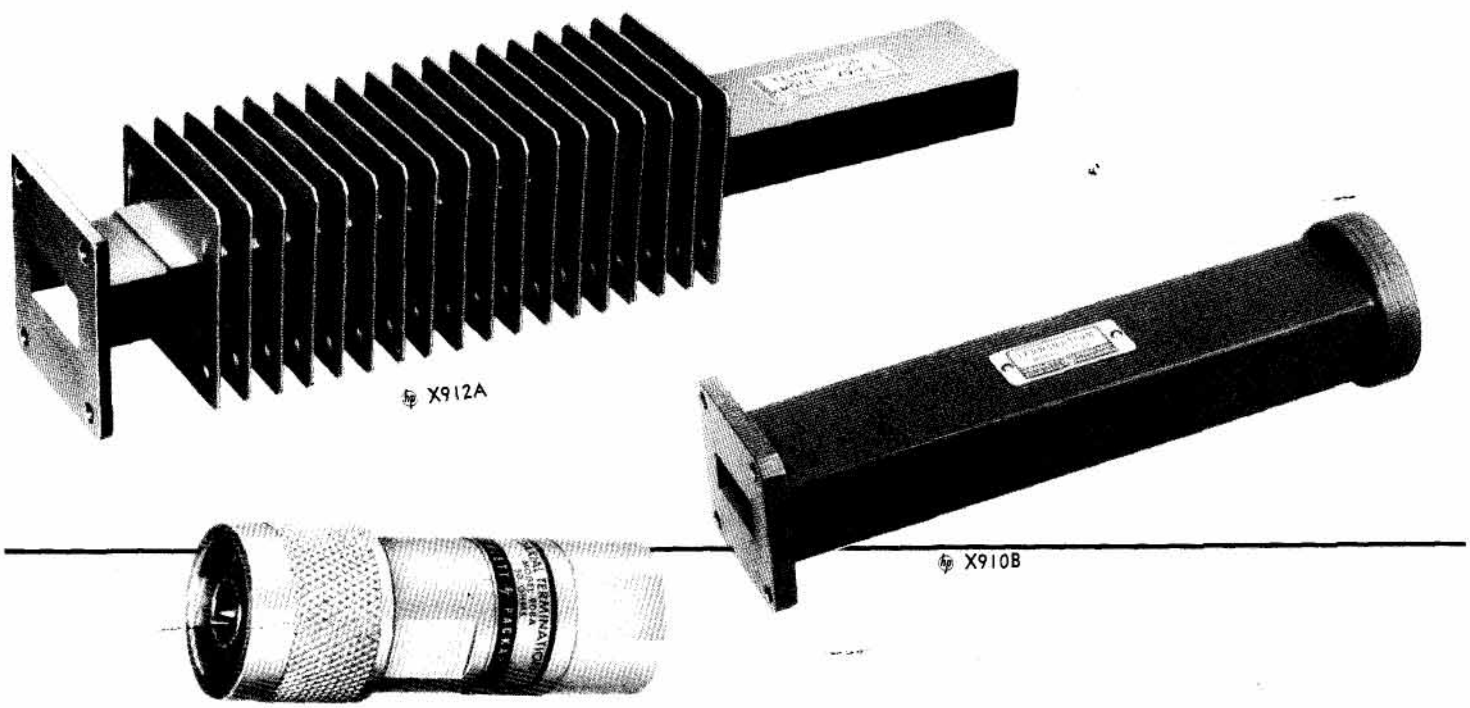

X912A

X910B

908A

914A/B Moving Loads

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 which is variable at least ½ wavelength at the lowest waveguide frequency. This permits reversing the phase of the residual reflection so that this reflection can be separated from the other small reflections in the waveguide system.

In Model 914A the reflection of the load is less than 0.5% (1% for K and R-bands) over the full frequency range of the waveguide. The X914B, K914B, R914B are similar to the 916 series.

Specifications

Model	Frequency Range GC(KMC)	Fits Waveguide Size (in.)	Approx. Overall Length (in.)	Average Power (watts)	Shipping Weight (lbs.)	Price
S914A	2.60 - 3.95	3 x 1½	25¾	2	21	$100.00
G914A	3.95 - 5.85	2 x 1	17	2	10	75.00
J914A	5.30 - 8.20	1½ x ¾	13½	2	9	70.00
H914A	7.05 - 10.0	1¼ x ⅝	11¼	1	4	60.00
X914B	8.20 - 12.4	1 x ½	10	1	3	50.00
M914A	10 - 15	.850 x .475	8-1/16	1	1	65.00
P914A	12.4 - 18.0	.702 x .391	9¾	½	1	55.00
K914B[1]	18.0 - 26.5	.500 x .250	8¼	½	1	250.00
R914B[1]	26.5 - 40.0	.360 x .220	7	½	1	250.00

[1]Circular flanges (UG-425/U for K-band, UG-381/U for R-band) are available. Specify K914BC or R914BC respectively.

916 Standard Reflections

Model 916 Standard Reflections are precision loads used to set up exact reflections for standardizing SWR measuring setups.

The instruments consist of a precision machined aluminum casting whose inside wide dimension is the same as that of a standard X-band waveguide but whose inside narrow dimension is reduced by the exact amount necessary to establish the required power reflection at the junction of the waveguide.

Specifications

Model*	Nominal Reflection Coefficient	Accuracy (Reflection Coefficient)	Price
X916B	0.05	±0.0025	$125.00
X916C	0.10	±0.0035	125.00
X916D	0.15	±0.0045	125.00
X916E	0.20	±0.007	125.00

*X916A is replaced by the X914B (see table opposite).

Waveguide Size: 1" x ½", OD flat cover flanges.
Frequency Range: 8.2 to 12.4 GC(KMC).
Dimensions: 1⅝" x 1⅝" x 8⅜" long.
Weight: Shipping 2 lbs.

906A Coaxial Load

906A Sliding Coaxial Termination is a movable, low reflection load for terminating 50-ohm systems in their characteristic impedance. The load moves at least ½ wavelength at its lowest rated frequency, to reverse the phase of the reflection and separate it from other reflections in a system. Model 906A includes adapters for Type N male or female connectors, and features a movable center conductor which insures proper seating in the mating conductor. An attractive storage case is provided.

Specifications

Frequency Range: 1 to 12.4 GC(KMC).
Load SWR: Less than 1.05.
Power Rating: 1 watt.
Travel: Greater than ½ wavelength at 1 GC.
Size: ¾" diameter, 31" long.
Weight: Net weight, 2 lbs.
Price: 906A, price on request.

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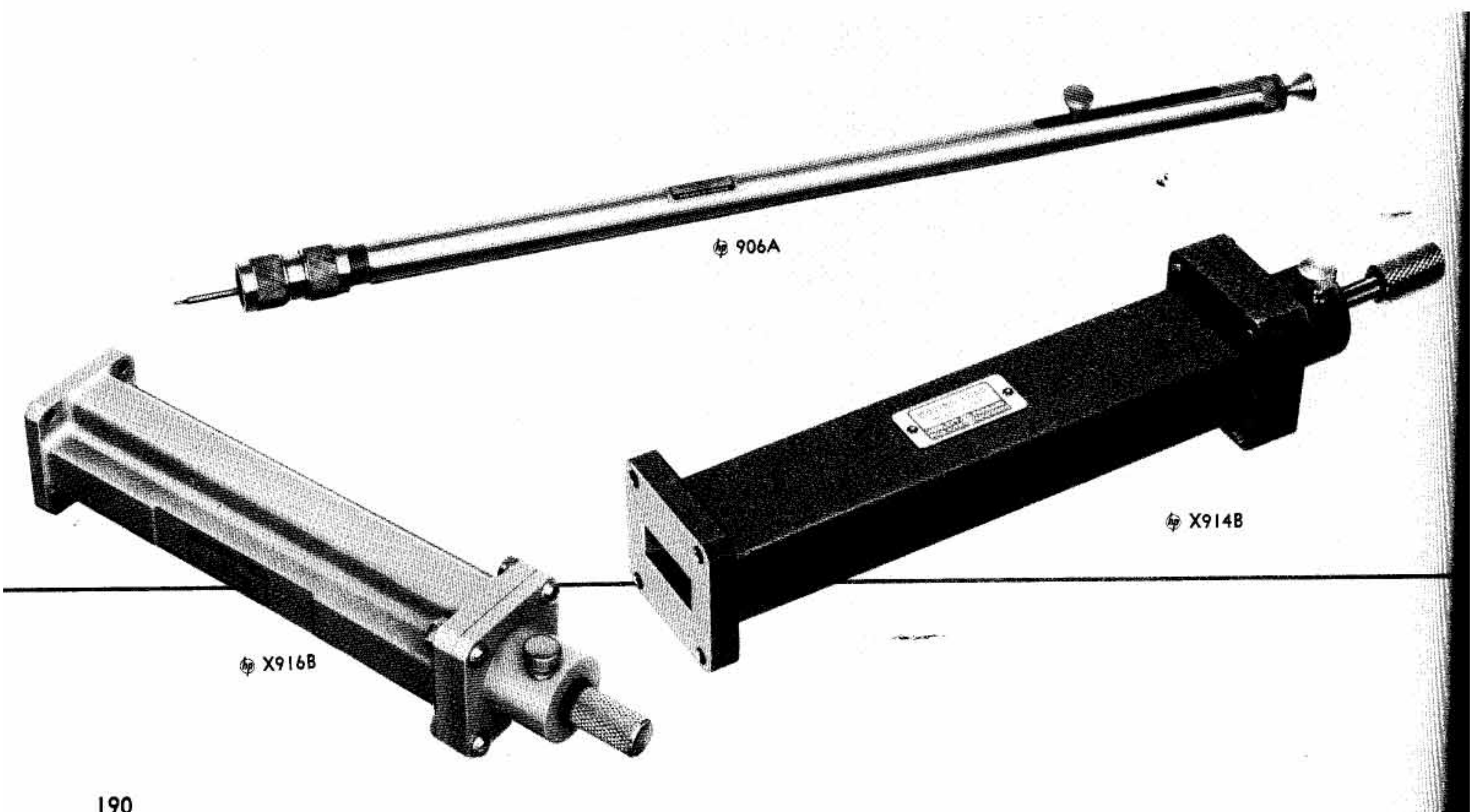


920 Adjustable Shorts

Adjustable shorts are convenient instruments for introducing a variable element in waveguide systems. In conjunction with a slotted section, they can be used to provide a variable short-circuit reference point. With a waveguide tee section, they can form a stub-transformer or tuner providing variable reactance. They may also be used as a convenient tuner for crystal or bolometer mounts.

Mechanically, 920A Shorts are a waveguide section containing a movable low-loss contacting finger wiper.* Position of the short is varied by a fine tuning control.

Specifications

Model	Approx. Length (in.)	Frequency Range GC (KMC)	Fits Waveguide Size (in.)	Shipping Weight (lbs.)	Price
S920A	10-7/16	2.60 - 3.95	3 x 1½	10	$150.00
G920A	7-13/16	3.95 - 5.85	2 x 1	4	125.00
J920A	6¼	5.30 - 8.20	1½ x ¾	3	100.00
H920A	4⅞	7.05 - 10.0	1¼ x ⅝	2	75.00
X920A	4⅞	8.20 - 12.4	1 x ½	2	75.00
M920A	4-13/16	10.0 - 15.0	.850 x .475	2	75.00
P920B	5¾	12.4 - 18.0	.702 x .391	2	125.00
K920A/BC**	5½	18.0 - 26.5	.500 x .250	2	155.00
R920A/BC**	4½	26.5 - 40.0	.360 x .220	2	155.00

*In the P, K, and R bands a choke-type short is employed. Position of the choke is varied by a micrometer adjustment.

**Also available with circular flanges, UG 425/U for K-band, UG 381/U for R-band, specify K920BC or R920BC.

X930A Shorting Switches

The Waveguide Shorting Switch is a time-saving means of establishing a removable short-circuit in a waveguide system. It is especially useful in power measuring setups where it can temporarily interrupt the power flowing into a bolometer mount for zero-setting a Microwave Power Meter such as the 430C. It can also be used to establish a reference reflection coefficient of 1.00 for calibrating Ratio Meters such as the 416A. The low insertion loss and SWR of the X930A make it adaptable to nearly all measuring applications of this type.

Specifications

SWR: Less than 1.02 in "open" position; greater than 125 in "short" position.

Insertion Loss: Less than 0.05 db in "open" position.

Waveguide: 1″ x ½″, RG-52/U; Flanges UG-39/U.

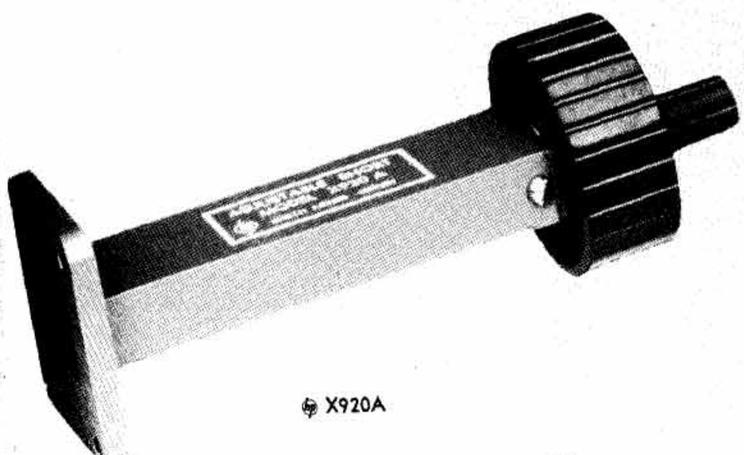
Frequency Range: 8.2 to 12.4 GC (KMC).

Length: 3 - 11/16″.

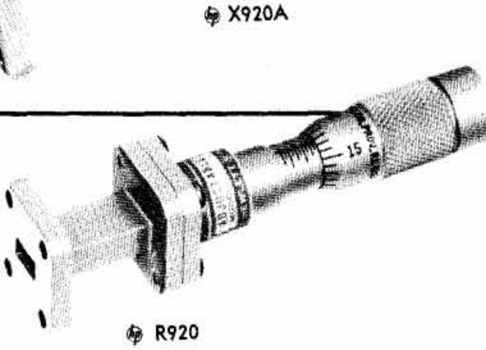
Shipping Weight: Approximately 2 lbs.

Price: X930A, $160.00.

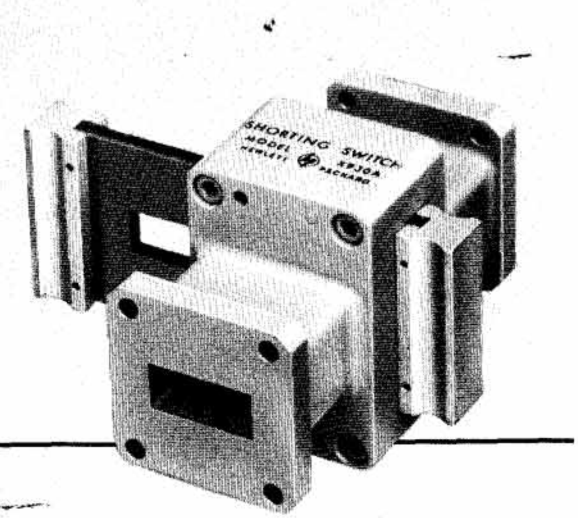
Data subject to change without notice.



X920A



R920



X930A

hp AC-60A/B Line Matching Transformers

Model AC-60A is specifically designed to connect a balanced system to hp 200 series audio oscillators, 400 series vacuum tube voltmeters, or similar equipment, for carrier current or other measurements between 5 and 600 KC. With hp 200CD it provides fully balanced 135 or 600 ohm output with attenuator in use. With an hp 400 it provides voltage measurements on either a 135 or 600 ohm balanced line without grounding one side, and permits bridging or terminated voltage measurements on both 135 and 600 ohm lines. Maximum level + 22 dbm. Shipping weight 2 lbs. $60.00.

Model AC-60B is similar to the AC-60A except that it is for use in audio systems, being specifically designed for connecting hp 330 Noise and Distortion Analyzer to a balanced line. Frequency range is 20 cps to 45 KC; maximum level is + 15 dbm. Shipping weight 6 lbs. $80.00.

hp AC-10C/D Binding Posts

Designed by hp, these posts insure a positive connection that can be changed quickly and easily. The recess for "banana" plugs is in the main body of the post to eliminate excessive contact resistance. The cross-hole for permanent connection may be used even when a plug is inserted. The posts have a nylon insulated ferrule. AC-10C (black), $.40; AC-10D (red), $.40.

hp AC-54 Insulators

These binding post insulators are of four standard designs. All insulators are 1/4″ thick. Holes are spaced 3/4″ apart, have a minimum diameter of 0.190″ and a 7° taper. AC-54C and AC-54G are made of nylon, others are polystyrene. Black only. AC-54E, F, G and H are similar, respectively, to AC-54A, B, C and D, but have locating pins to prevent the bodies of the AC-10 Binding Posts from turning.

hp 24 Waveguide Stand

Model 24 Waveguide Stands are cast and machined from aluminum alloy. They are designed for hp 25 Waveguide Clamps and lock the clamps at any height from 2 3/4″ to 5 1/4″. Model 24 is 2 1/2″ high and its base measures 4 3/4″ in diameter. $3.00 each.

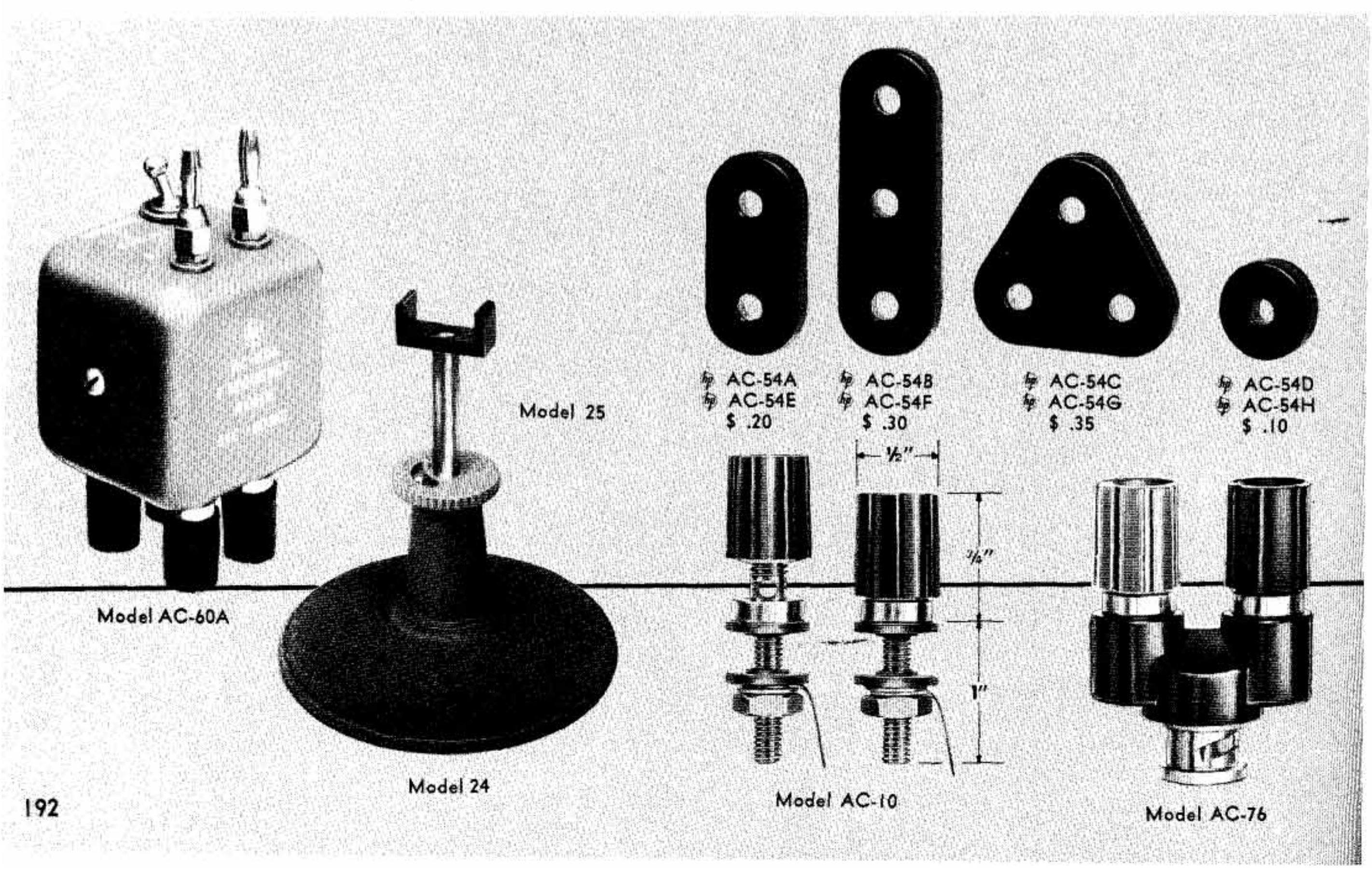
hp 25 Waveguide Clamps

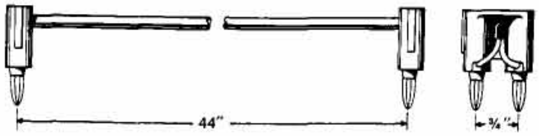
These clamps consist of a rubber molding with a steel insert. They are offered in 8 sizes to fit waveguide equipment covering frequencies from 2.6 to 40.0 GC (KMC). They are designed for use with hp 24 Waveguide Stand, and when mounted in the Stand can be adjusted upward or downward to conform with a waveguide setup. When ordering, specify waveguide size. Model S25, 3″ x 1 1/2″; Model G25, 2″ x 1″; Model J25, 1 1/2″ x 3/4″; Model H25, 1 1/4″ x 5/8″; Model X25, 1″ x 1/2″; Model P25, .702″ x .391″; Model K25, .500″ x .250″; Model R25, .360″ x .220″. $2.50 each.

hp AC-76A BNC-to-Binding-Post Adapter

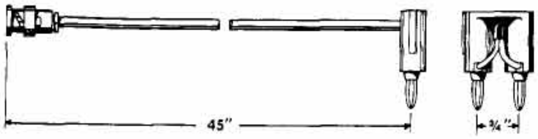
This hp adapter mates with a BNC receptacle, providing an easy method of connecting clip leads, banana plugs or wires to instruments having BNC receptacles. The nylon ferrule of the center conductor binding post is colored red; the other ferrule is black. Spacing between the banana jacks is 3/4″. $5.00 each.

Data subject to change without notice. Prices f.o.b. factory. Quantity discount prices on request.

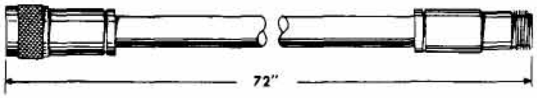




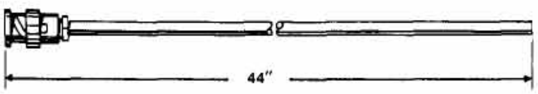
AC-16A Cable Assembly. Equipped with two dual banana plugs, this assembly is a section of RG-58C/U 50 ohm coaxial cable measuring 44 inches overall. Plugs are for binding posts spaced ¾ inch between centers. Each, $4.50.



AC-16B Cable Assembly. Identical with AC-16A except has dual banana plug (¾ inch center) on one end and UG-88/U Type BNC male connector on other end. Length overall, 45 inches. Each, $5.50.

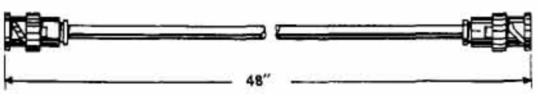


AC-16C Cable Assembly. This cable consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on one end with UG-21B/U Type N male connector and UG-23B/U Type N female connector at opposite end. For use at frequencies below 4,000 MC. Each, $13.00.

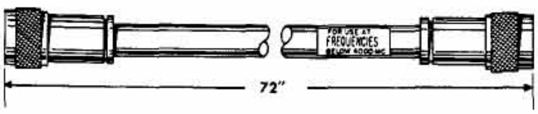


AC-16D Cable Assembly. This cable consists of 44 inches of RG-58C/U 50 ohm coaxial cable terminated on one end only. Termination is UG-88/U Type BNC male connector. Each, $3.50.

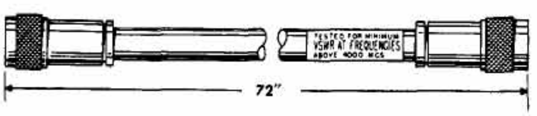
AC-16E Cable Assembly. A short cable of 9 inches length consisting of RG-58C/U 50 ohm coaxial cable terminated on both ends with UG-88/U Type BNC male connectors. Each, $5.50.



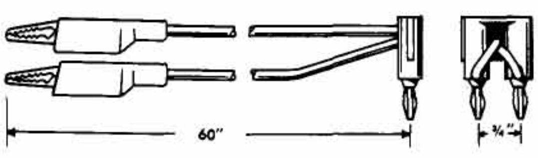
AC-16K Cable Assembly. This cable consists of 4 feet of RG-58C/U 50 ohm coaxial cable terminated on each end with UG-88/U Type BNC male connectors. Each, $6.50.



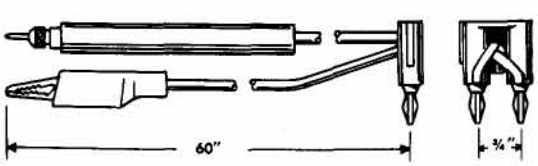
AC-16F Cable Assembly. For use at frequencies below 4,000 MC. Consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on each end with UG-21B/U Type N male connectors. Each, $15.00.



AC-16Q Cable Assembly. For use at frequencies above 4,000 MC. Consists of 6 feet of specially treated RG- 9A/U 50 ohm coaxial cable terminated on each end with UG-21D/U Type N male connectors. The cable is designed for low SWR in the 4,000 to 12,400 MC range. Each, $18.50.



AC-16S Test Leads. Dual banana plug to alligator clips. Five feet long, one red lead, one black lead. Each, $7.50.



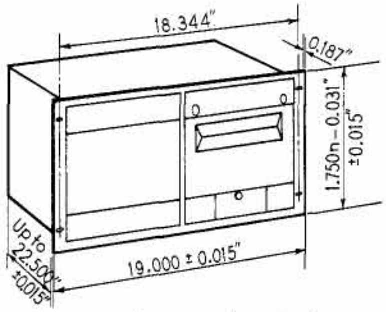
AC-16T Test Lead. Dual banana plug to probe and alligator clip. Five feet long. Each, $10.00.

Prices f.o.b. factory.
Data subject to change without notice.

hp CABINETS AND MOUNTING METHODS

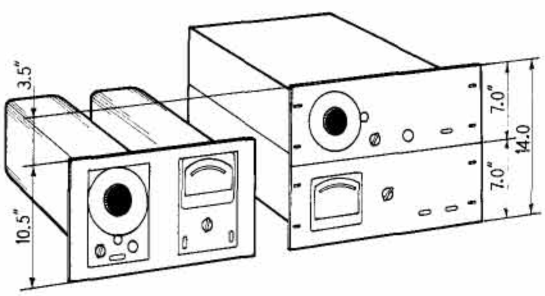
Most hp instruments are available either factory mounted in hp portable cabinets or ready for mounting in standard EIA* relay racks. Basic dimensions are indicated below. Rack-mounting models are also available with telescoping slides at slight additional cost.

EIA* Modular (Rack) Mounting



In addition, most rack-mounting hp instruments which have 10½" by 19" panels may be quickly converted to bench use by installing the instrument in an hp AC-44 Cabinet or by attaching hp AC-17 End Frames.

hp AC-2A/B Dual-Mounting Modular Adapter



hp instruments which are normally supplied with either 7" x 19" control panels (for standard EIA modular mounting) or 9.875" x 7" panels (for small portable cabinets) can also be mounted side-by-side in hp AC-2A/B Adapter Panels. These panels measure 10.5" high x 19" wide. Thus instead of the 14" height of two conventional 7" high rack mount instruments, the same two hp instruments in "cabinet" configuration can be rack-mounted side by side at a height saving of 3.5".

New Instrument Packaging

Beginning with the calendar year 1961 many new hp instruments will be packaged according to a system derived from EIA Standard SE-102. The basic intent of this system is to provide a new degree of versatility in mounting, as well as improve compactness and interior accessibility.

These trim, efficient-looking new instruments are ideal for bench use, either singly or stacked; they are easily rack-mountable, either with or without extension slides; and they are conveniently portable for field applications.

These instruments fall into two classes:

1. Those units which, by reason of control panel area, volume, and thermal dissipation, lend themselves to the full EIA rack width. This class is directly mountable in racks through the addition of the two brackets and a filler-strip which are provided. Or, if preferred the included feet and tilt-stand may be attached for bench use. See Figure 1.
2. Those units which dictate a greater height-to-width ratio than the first group, but do not justify the full rack width. A convenient 6-31/32" high modular adapter (hp AC-146A) is available for mounting these units in racks. See Figures 2A and 2B. These modular adapters can also be used for combining instruments neatly on the bench, merely by attaching the feet provided.

The hp AC-146A Modular Adapter is supplied with two partitions so that three instruments 5⅛" wide or two instruments 7¾" wide may be placed side by side.

Any unused space in the Modular Adapter may be converted into a convenient storage compartment by adding one or more standard accessory drawers.

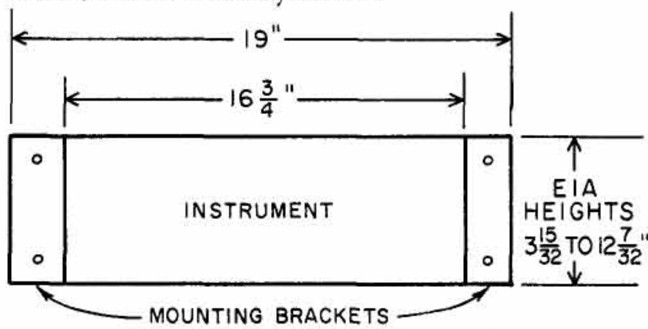


Figure 1. Rack Mounting Instrument.
Mounting brackets detach and feet are added for bench use.

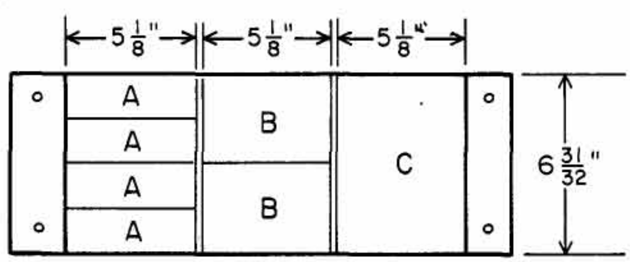


Figure 2A. AC-146A Modular Adapter
with two partitions for instruments 5⅛ inches wide.

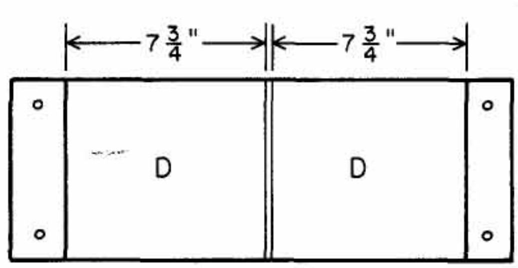


Figure 2B. AC-146A Modular Adapter
with one partition for instruments 7¾ inches wide.

*Electronics Industries Association (formerly RETMA).

CATALOG OF SYSTEMS AND INSTRUMENTS, 1961

Programmable Systems for Data Handling, Component Testing, Automatic Measurement and Control Applications

Dymec's digital instrumentation design concepts based upon "off-the-shelf" building-block modules provide reliable, inexpensive systems to quickly meet your exact requirements. Units are available to accept input signals from most types of transducers. Output information is available on punched cards or tape, typewritten or printed record, or visual display as required for most convenient analysis and handling.

RF and Microwave Checkout Equipment for Production, Maintenance, Field Support

Program controlled doppler radar simulators, signal generators, receiver testers and complete system check-out devices are designed and built by Dymec to prove operational readiness of missiles, satellites, ground support and airborne systems. Hewlett-Packard- and Dymec-developed advanced engineering techniques for signal generation, modulation, frequency control and attenuation are combined to provide reliability and accuracy.

Special Purpose Instruments for Test, Measurement and Performance Monitoring

Dymec digital and RF system building-blocks are available to you for specialized applications. In addition, Dymec produces a variety of special-purpose test sets and broadcast monitors for performance monitoring. These devices, described on the following pages, feature the same high reliability and economy available in "off-the-shelf" Dymec and Hewlett-Packard equipment.

dy® DYMEC

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DYMEC DIGITAL SYSTEMS

Engineered Assemblies of "Building-Block" Units Assure Economical, Reliable Data Handling Systems

Dymec builds digital systems for automatic data logging, component testing, missile/aircraft checkout, and many other applications. Building-block assembly and a unique digitizing method provide high accuracy and design flexibility at minimum cost.

Size, cost and complexity of a Dymec system depend on the functions to be performed. A simple data processing system may include only a digital voltmeter, a coupler/translator, and a tape punch or electric typewriter. Total cost—a few thousand dollars. A more elaborate system, such as an automatic component test set, may include automatic scanning, programming, multiple measuring devices, buffer storage, tolerance comparators and high speed output recording equipment. Total cost—depends on requirements.

In every case, Dymec will provide you with a system to meet your specific needs.

Elements of Dymec Systems

Essential elements of a Dymec digital system are shown in the diagram below. Basic system elements are (1) input scanner, (2) programmer, (3) digital voltmeter or analog-to-digital converter, (4) output coupler/translator, and (5) recorder. All or any combination of these elements may be included for your individual system, depending on the exact measurements to be made.

Dymec Input Scanners accept one or more assorted electrical inputs in the form of dc or ac voltage, current, resistance, time or frequency.

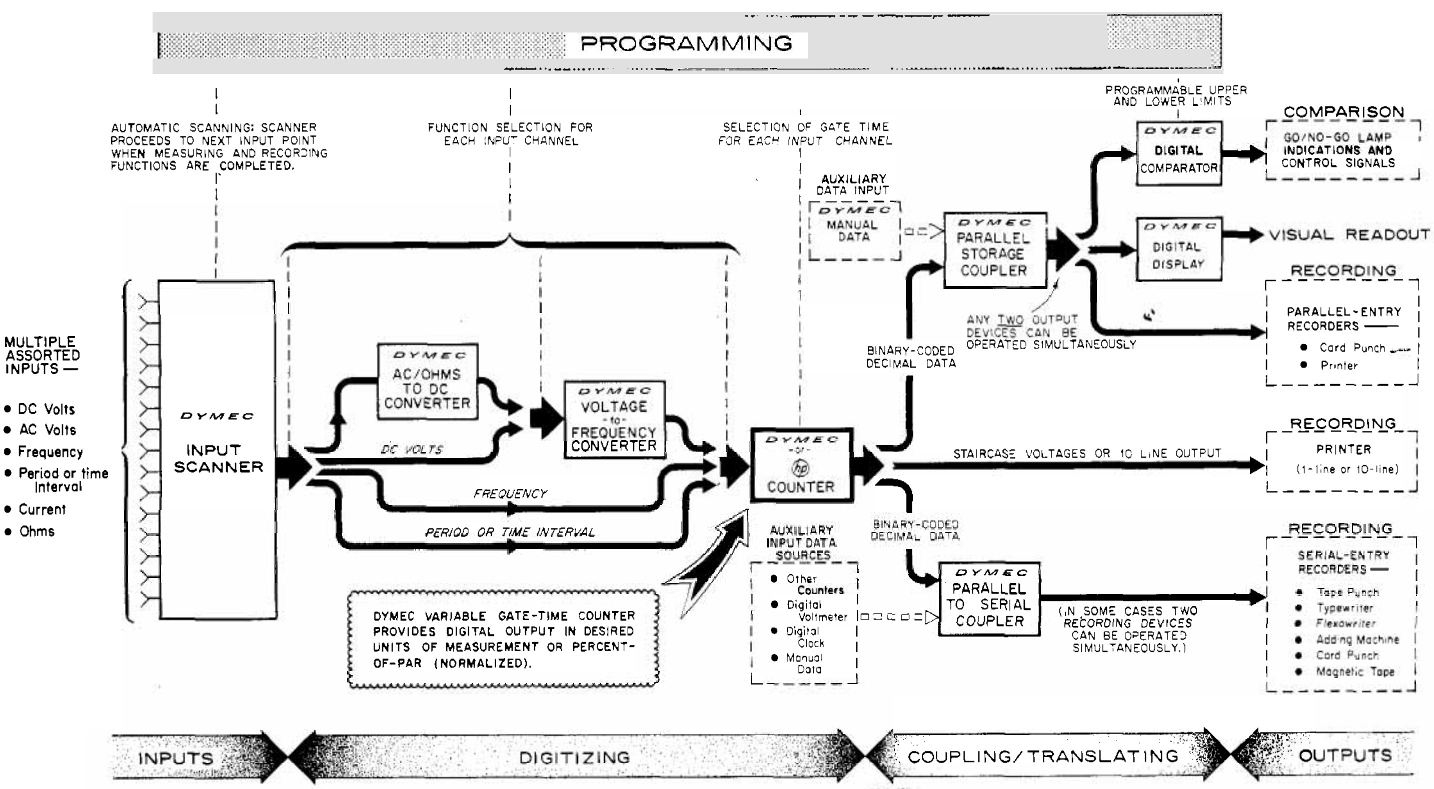
Dymec Digitizing Equipment will count an input frequency directly, or convert an input voltage, current or resistance to a precisely proportional frequency which can then be counted. Dymec systems provide accurate and versatile data processing because all inputs are converted to frequency to take advantage of the inherent accuracy provided by any of a wide range of Dymec or ⓗⓟ standard counters.

Dymec Output Coupler/Translators receive information from counters and other digitizing equipment and translate it to the proper form for direct recording.

Output Devices such as remote Digital Displays and Digital Comparators are also supplied.

Recorders, including electric typewriters, printers or adding machines, tape and card punches and magnetic devices are available with Dymec systems.

Programming of system operation is done by built-in circuitry in standard Dymec system counters and scanners. For more complex operations, custom programmers are designed and furnished.



Elements of Dymec Automatic Digital Systems for Data Handling. Other systems for component testing and various measurement and control functions are assembled from the same basic building-block components.

DYMEC DATA HANDLING SYSTEMS

Dymec Digital Systems will measure and process any information which can be transduced into an electrical quantity. Input information can correspond to temperature, pressure, speed, size, volume, position, or virtually any measuring parameter. The desired data, after being digitized within the system, can be recorded on a printer, typewriter, punched paper tape or cards, or magnetic tape for efficient handling and analysis. Local or remote visual displays are also available for conveniently monitoring system measurements. The Dymec system may include programming to control automatically such factors as speed and sequence of data accumulation. Because problems of data handling and recording are seldom identical, most Dymec systems are tailored to the specific use. The two typical systems shown below are indicative of the approach used for data handling applications.

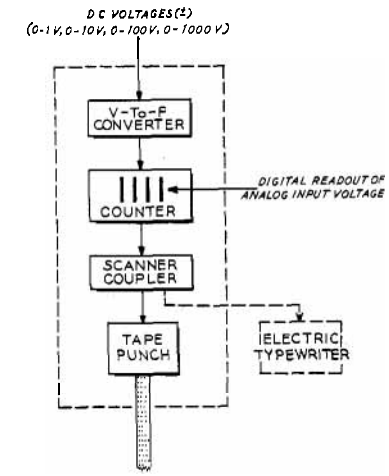


Figure 1-A

A Simple, General-Purpose Data Recording System

Digital records of voltage variation can be maintained accurately and reliably with the simple digital system shown in Figures 1 and 1A. Consisting of only four building-block instruments, the system accepts a dc input voltage, digitizes the value, translates the digital information and couples it to a tape punch or printer to obtain a permanent record. Using Dymec's proven voltage-to-frequency converter and a standard counter as the digitizing element, the system provides accurate measurements essentially unaffected by input noise. By appropriate choice of building blocks, the system can provide four-or-five digit resolution with overall accuracy to within 0.02%. Additional building blocks can be added to permit accumulation of data from more than one input, recording of other information such as time with measured data, and programming of the measurement and recording sequence. Price of the basic DY-5552 system, including voltage-to-frequency converter, counter, output coupler, cabinet, and tape punch is about $3,600.00.

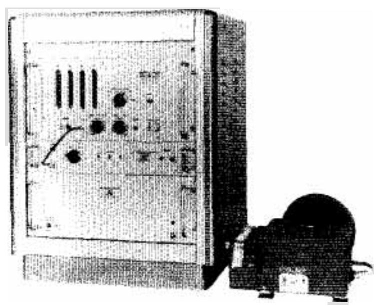


Figure 1. Simple data logging system for collecting digital records of an analog variation. Voltage-to-frequency converter and counter provides high accuracy at less cost than other digitizing techniques. *(See also Figure 1-A alongside.)*

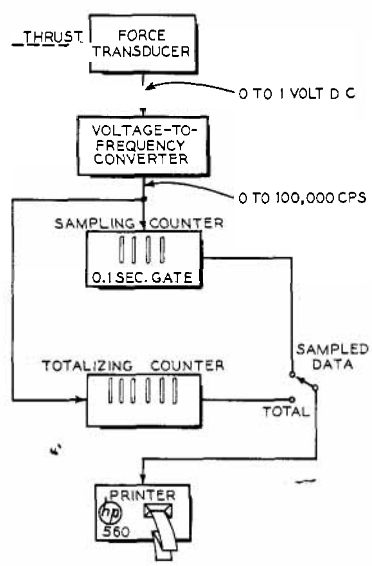


Figure 2-A

Data Logging System with Automatic Totalizing

In many applications, records are needed not only on the variations in magnitude of a variable but also on the accumulated value of the variable over a specific time interval. A typical example of this is in rocket engine tests where both total thrust developed and variation of thrust with time are important. A simple logging system based on the integrating capability of the Dymec voltage-to-frequency converter provides both of these desired results automatically and accurately.

In such an application, Figures 2 and 2A, a varying dc voltage proportional to the rocket engine's thrust is developed by a force transducer and applied to a Dymec voltage-to-frequency converter. Two counters are connected across the converter output. One samples the converter frequency output for short intervals so that the thrust vs. time curve can be derived. The other counter accumulates the total number of pulses generated by the voltage-to-frequency converter during the test to indicate the total thrust developed during the burning interval. A digital printer provides a record of thrust variations during the test; when the test is completed the printer records the stored reading on the totalizing counter. Cost of this straight-forward system, including voltage-to-frequency converter, two counters, printer, and cabinet, is less than $4,500.00.

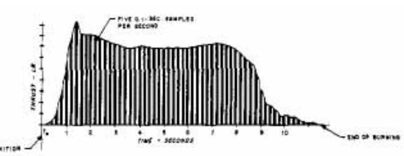
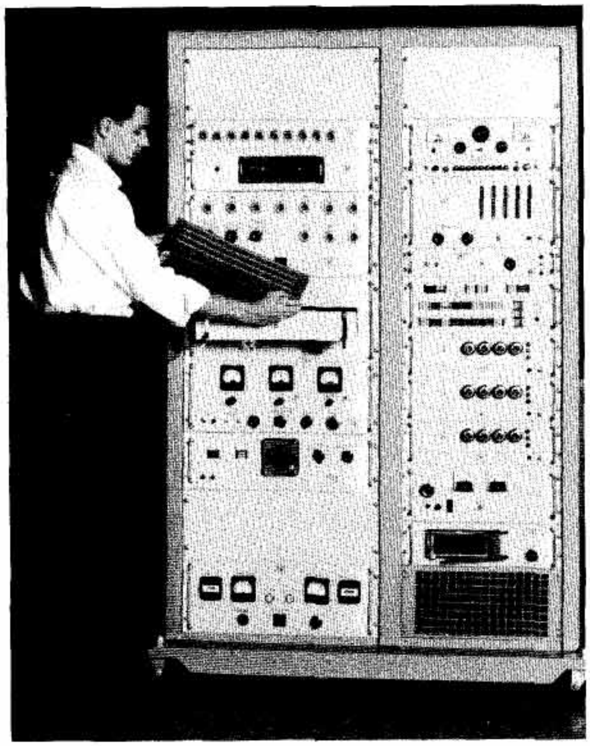
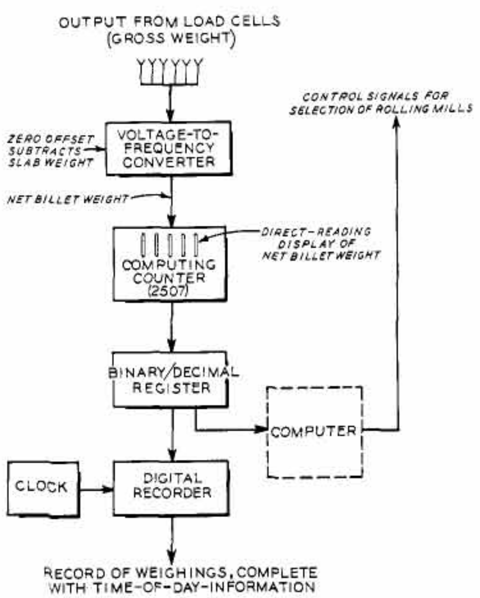


Figure 2. Integrating principle of Dymec voltage-to-frequency converters provides simple, accurate means for recording both rate-of-change and total change in applications such as thrust measurement. *(See also Figure 2-A above.)*

Examples of
DYMEC DIGITAL SYSTEMS



Automatic programmable component testing system speeds reliability studies on resistors, capacitors, diodes, Zener diodes.



Dymec voltage-to-frequency converter automatically provides net weight information to process control computer.

Automatic Component Testing

By automatically measuring and recording component values, Dymec component testing systems provide important time and money savings for manufacturers and users of electronic components. Human errors are eliminated, high measuring accuracies are easily achieved and component test rate is sharply increased. Using the same "building-block" approach as for simple data logging systems, *automatic component test sets* can be programmed to make a wide variety of tests and measurements on resistors, capacitors, diodes and other basic electrical components.

The system shown here is one of two designed for reliability studies on large numbers of components. Up to 200 individual components are mounted on etched-circuit boards which are inserted into the test set. Test voltages and currents, and GO/NO GO limits are set manually, and the desired testing sequence is programmed on the control panel. The complete test sequence is then performed automatically at the rate of about one component per second. Both measured data and pre-established identification data are recorded on punched cards.

Component testing systems utilizing similar techniques can automate production test and incoming inspection activities of any component manufacturer or user.

Digital Control System Automates Rolling Mill

High measurement accuracy, simple operation and convenient handling of output data are key reasons why Dymec Digital Systems are used in process control installations. Since Dymec systems are assembled from modular units, individual requirements of each installation can be met quickly without excessive costs for special engineering.

A typical application of Dymec digital techniques in a process control system is shown here. The Dymec equipment assists *in computer control of rolling mill operations* by automatically providing net weight in digital form for each steel billet passing over a weighing table. The digital information is supplied to a computer that determines which rolling mill the billet must pass through to meet predetermined size requirements. Combined dc voltage output of load cells in the weighing table is converted to frequency in a Dymec voltage-to-frequency converter. A zero offset feature included in the voltage-to-frequency converter automatically subtracts the tare weight of the table from the gross weight information supplied by the load cells. The frequency output of the converter is counted by a Dymec computing counter to provide an output reading directly in net weight. The weight information is supplied to the control computer and also printed on paper tape with a record of the time the measurement was made.

The systems shown here are working examples of the hundreds of Dymec package combinations possible to meet your needs for data logging, component testing, system checkout, and process control. Ask Dymec or a Dymec representative to show you how these "designed-for-systems" units can be assembled to meet your needs.

INPUTS for DATA HANDLING SYSTEMS

Dymec data handling systems will accept electrical inputs in the form of dc voltage, ac voltage, frequency, time interval or period, resistance, and current. Up to 100 inputs are accommodated by standard system components; specially engineered input devices can be provided when more inputs are needed. Output information is furnished in any format needed for visual display or for operation of tape punches, card punches, digital printers, electric typewriters, or magnetic tape recorders.

Any desired measurement sequence can be programmed into the system. In addition, Dymec systems can be programmed to provide necessary scaling, normalizing and ranging of measured quantities.

Input Types and Ranges

DC Voltage: From a few millivolts to 1000 volts or higher.

AC Voltage: From a fraction of a volt to 500 volts rms, 20 cycles to 100 KC or more.

Frequency: DC to 10 megacycles or more.

Time Interval or Period: From less than a nanosecond to 100 days.

Resistance: Fractions of an ohm to 100 megohms or more.

Current: From 10^{-9} amperes to 10 amperes or more.

Programmable Functions

Scaling: Separate multiplying factor can be supplied for each measurement to provide digital readings in desired measuring units. (psi, gpm, rpm, etc.)

Scale Expansion: Zero offset provides high measurement resolution by utilizing full accuracy of voltage-to-frequency converter on each range.

Ranging: Measuring equipment can be set automatically to desired range for each channel measured.

Normalizing: Separate multiplying factor can be supplied for each channel to equate all measurements to some par value.

Sequence: Channels can be measured in any desired sequence or omitted from any measurement cycle.

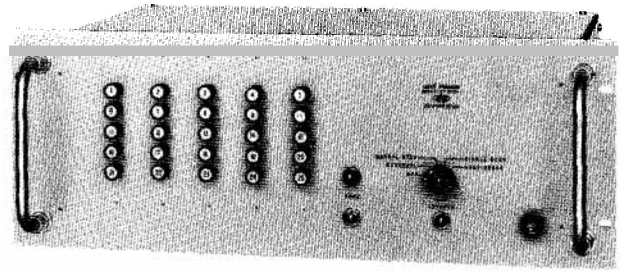
Other Features

Polarity: Automatic indication of positive or negative input.

Channel Identification and Auxiliary Data: Channel identification codes are automatically generated and recorded with each measurement. Additional manually entered data may be recorded simultaneously.

Interlocked Operation: System building blocks are synchronized to conserve time and assure reliability.

Input Connections: Convenient-access input connectors accept any electrical input given above including very low level input signals.



DY-2901/2/3/4 INPUT SCANNERS

Major savings in equipment costs are obtained by connecting up to 100 inputs to a single set of digitizing equipment with DY-2901/2/3/4 Input Scanners. Model DY-2901 scanner accepts up to 25 inputs, and Models DY-2902/3/4 scanners may be added and operated in combination as slave scanners. Expansion capability of the DY-2901 lets you add more channels as needed, if fewer than 100 inputs are connected initially. Built-in programming in the DY-2901/2/3/4 gives you additional savings in system cost. Channels to be measured are selected by front-panel push buttons, and an internal pin board selects the desired sequence and timing of the measurement cycle. Scanning sequence can be controlled manually or automatically, and the scanning cycle can be initiated locally or remotely.

Accurate and dependable operation, even with very low level inputs, is assured by high quality features such as gold-plated stepping switch terminals and premium-quality connectors for input signal connections.

Brief Specifications

Scanning Modes: 1. Continuous
2. Single 25-point cycle
3. Manual step
4. External step

Scanning Rate: Controlled by the measuring/recording equipment through a fully closed loop interlocked operation or manual command. Programmable delay circuit allows for stabilization of amplifiers and ac measuring devices in system.

Inputs: Accepts types and ranges of inputs indicated at left. Any combination of input types and ranges may be used.

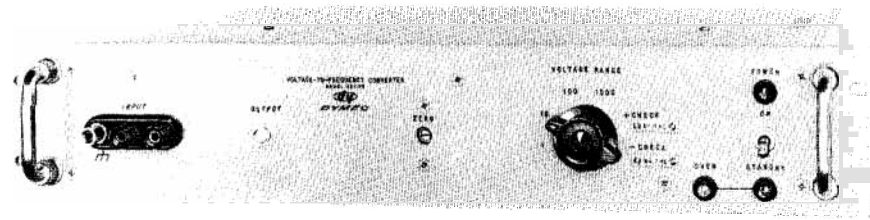
Scanner Advance: Steps to next programmed channel automatically on command.

Stepping Switch Levels For:
Floating Signal pairs and shield
Control of channel identification lamp on front panel
Scan-control circuit
External programmer or internal pin board
Programmed delay of read command
Plug-in boards which provide channel identification codes to the system

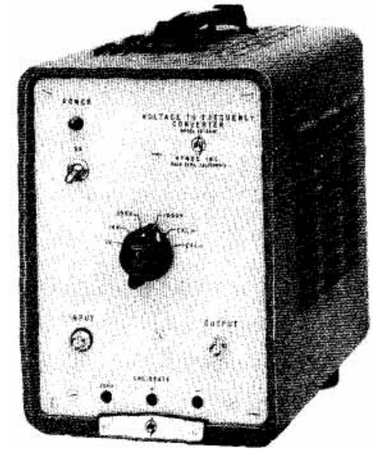
Dimensions: 19″ wide x 7″ high x 16½″ deep. (Excluding connectors.)

Price: Typically $1950.00 for DY-2901 master, $1750.00 for DY-2902/3/4 slave units, depending on application.

DYMEC DIGITIZING DEVICES



DY-2211AR/BR (Rack Mount)



DY-2210 (Cabinet Mount)

VOLTAGE-TO-FREQUENCY CONVERTERS

Advantages:

- Provides accurate, inexpensive digital voltmeter with any gated counter.
- Inherent noise averaging characteristic assures accuracy, even in presence of noise or hum.
- Converting voltage to frequency provides high accuracy, good resolution in digital system applications.
- Operating principle permits direct integration of input to measure "area under the curve."

Models DY-2210 and DY-2211AR/BR Voltage-to-Frequency Converters are all-electronic measuring instruments which average out noise or hum on the input to provide high accuracy voltage measurements at lower cost than with other conversion techniques.

An input dc voltage is converted to a proportional frequency of constant amplitude, which is applied to a gated electronic counter. The counter provides a direct digital indication of the input analog voltage.

Voltage-to-frequency converters are useful both individually and as a basic building block for digital systems. On an individual basis they are used with any electronic counter to provide an inexpensive digital voltmeter. As part of a digital system they convert the electrical input into a precisely proportional frequency which is easy to count with proven and inexpensive electronic techniques. The combination of a voltage-to-frequency converter and electronic counter is an all-electronic digitizing method which is accurate, has high resolution, and is compatible with all types of display and recording equipment.

All three Dymec voltage-to-frequency converters operate on the basic principle of continuously integrating the applied input voltage to produce an output frequency always instantaneously proportional to the input. The output frequency is sampled over a precisely controlled counter gate time to provide a digital measure of the input voltage.

Models DY-2210 and DY-2211AR have full scale frequency output of 10 KC to provide four-digit resolution when used with a 1 second counter gate, or three-digit resolution with a 0.1 second gate. Model DY-2211BR has full scale output of 100 KC to provide an additional digit of resolution.

The integration principle of Dymec voltage-to-frequency converters provides two major advantages over other types of analog-to-digital conversion. First, because applied voltage is measured for a discrete time interval, as determined by the counter gate time, the reading obtained is an average rather than an instantaneous value. The reading is therefore largely independent of noise or hum level on the applied signal. A second major advantage of integration is that a record of total input voltage (integral of voltage with respect to time) can be obtained in addition to the usual record of input variations.

Brief Specifications

	DY-2210/2210R	DY-2211AR/BR
Ranges: (Positive or Negative)	0 - 1, 0 - 10, 0 - 100, 0 - 1000; 0 - .1, 0 - 1, 0 - 10, 0 - 100*	0 - 1, 0 - .1 Volt*; 0 - 10, 0 - 100, 0 - 1000*; 0 - 1, 0 - 10, 0 - 100*
Output Frequency:	0 - 10 KC	2211AR 0 - 10 KC 2211BR 0 - 100 KC
Accuracy:†	0.06%	2211AR 0.02% 2211BR 0.03%
Dimensions:		
Cabinet:	7¼" wide, 11¼" high, 11½" deep.	
Rack:	19" wide, 3-15/32" high, 10-3/16" deep	19" wide, 3-15/32" high, 19½" deep
Net Weight:	13 lbs.	26 lbs.
Price:	DY-2210, $660.00 (cabinet) DY-2210R, $650.00 (rack)	DY-2211AR/BR $1,250.00 (rack)

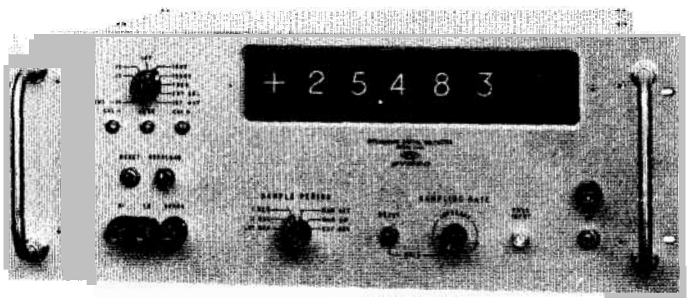
*Available at extra cost.

† Accuracy is affected by frequency and accuracy of calibration, line voltage variations, temperature changes, and accuracy of multi-range input attenuators. Figures given are typical of performance under normal operating conditions.

Voltage to Frequency Converters ■ Digital Voltmeters

DY-2401 INTEGRATING DIGITAL VOLTMETER

Range and Sampling Rate Programmable for Systems Flexibility.
Input Guard Circuitry Gives High Common Mode Rejection.
Automatic Noise Averaging Through Integration



New Model DY-2401 Integrating Digital Voltmeter provides more measuring convenience, greater measurement capability, and higher realizable accuracy in systems than any previously available digital measuring instrument.

A unique measurement advantage of the DY-2401 is that it reads the average value of voltage applied over a definite, selected sample period. This is especially important since it helps to increase accuracy in system use where noise and hum pick-up are likely to be encountered.

Range, sample period and sample rate of the DY-2401 are externally programmable by contact closures to assure maximum flexibility in system applications.

The DY-2401 is also an extremely versatile laboratory instrument. Its high accuracy and contact-closure control features assure a high order of flexibility in lab bench set-ups.

Applications of the DY-2401 are even further extended by the dual nature of the instrument which is actually two instruments combined in a single package. A voltage-to-frequency converter similar to those described on the opposite page converts the applied analog voltage to a precisely proportional frequency which is counted by a transistorized 300 KC electronic counter. The DY-2401 becomes a standard multi-purpose 5-digit electronic counter simply by setting the convenient front panel control to FREQ.

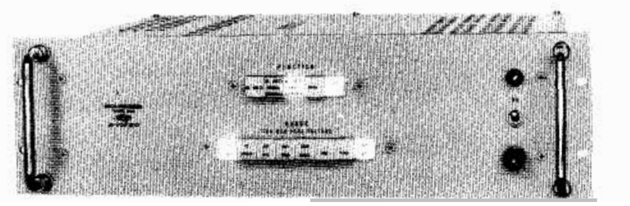
Input guard circuitry greatly reduces the effect of common mode ac pick-up between the signal source and the DY-2401. Both the input signal pair and the guard circuit may be operated at up to 500 volts above chassis ground to permit voltage measurements referenced above instrument ground.

Over-ranging measurements of up to 300% of nominal full-scale value can be made on all but the highest voltage range. The input circuit is automatically opened when the input voltage exceeds 350% of full scale to prevent damage to the digital voltmeter.

Brief Specifications, DY-2401

DC Voltage Ranges: ±0.1, 1, 10, 100, 1,000 volts nominal full scale. Over-ranging capability to 300% of nominal f.s. on all but 1,000 volt range.
Overall Accuracy: 0.05% nominal. (See DY-2401 Engineering Data Sheet for detailed accuracy specifications.)
Stability: Better than 0.01%/day, 1 v range and above.
Input Impedance: 1 megohm on 1 v and higher ranges. 100,000 ohms on 0.1 v range.
Sampling Period: 10 ms, 100 ms, 1 sec (crystal determined), or manual by local or remote control.
Sampling Rate: Externally programmable to 90/sec with 10 ms sampling period to 9.8/sec with 100 ms sample period. Display time adjustable 100 ms to 8 sec, or continuous until manually reset.
Display: 5-digit In-Line Nixie plus Polarity Indicator. Range and Sampling Period Controls determine decimal point position.
Output: Binary-Coded-Decimal for each digit; two lines for polarity indication; one line for each range and operating mode.
Power Supply: 115/230 v ±10%, 50/60 cps, 200 watts.
Dimensions: Rack Mount: 19" wide, 7" high, approx. 16½" deep.
Weight: Net 40 lbs., shipping 60 lbs. (Approx.)
Price: Model DY-2401, $3,750.00.

DY-2410 MULTI-CONVERTER



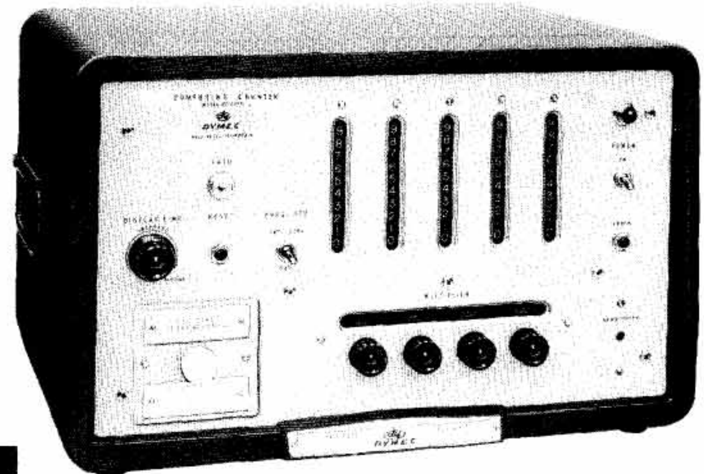
Model DY-2410 converts ac volts, resistance, and dc volts to a proportional dc voltage with 1 volt nominal full-scale output. Function and range are selected by illuminated front panel pushbuttons. The instrument also features complete external selection of function and range by contact closures. All measurement circuits are floating and guarded for rejection of common mode ac pick-up. Programmable dc attenuator optionally available for measuring dc voltages with DY-2210/2211. Attenuator not needed if DY-2410 is used with DY-2401.

Brief Specifications, DY-2410

AC-to-DC:
Input Ranges: 0.1, 1, 10, 100, 1,000 (usable to 750 v absolute peak) volts rms nominal full scale. 100% overrange capability except on 1,000 v range.
Accuracy: ±0.4% of reading ±0.1% of nominal full scale, over inputs of 20 cps to 50 KC, and 1 mv to 500 volts rms. ±0.9% of reading ±0.1% of nominal full scale, over inputs of 50 KC to 100 KC, and 1 mv to 100 volts rms.
Resistance-to-DC:
Input Ranges: 100, 1,000, 10,000, 100,000 ohms; 1, 10 megohms nominal full scale.
Accuracy: ±0.04% of reading ±0.01% of nominal full scale.
Price: Model DY-2410, $1,975.00; optional attenuator $200.00.

DYMEC DIGITIZING DEVICES

- Automatically translates Digital Data to Desired Measurement Units (psi, gpm, fps, etc.)
- Variable gate-time provides computing function to furnish data in most usable form.
- Dual inputs permit ratio measurements.
- Numerous options and simple modifications reduce system costs.



COMPUTING COUNTER DY-2500

Pulse rate information from transducers or voltage-to-frequency converters is counted and displayed in any desired measuring units by the DY-2500 Computing Counter. For example, rotational speed can be measured and read directly in rpm or rps. Information on flow, volume, or pressure can also be read directly in desired units such as gallons per minute or psi. With data supplied in standard engineering units, subsequent handling is simplified and transcribing errors are eliminated.

The DY-2500 is particularly well suited for measuring rotational rate or speed in conjunction with the DY-2504 Photoelectric Tachometer or other tachometer generators manufactured by Dymec and Hewlett-Packard. For measuring other analog quantities, the DY-2500 is often used with a Dymec Voltage-to-Frequency Converter and a suitable transducer.

Visual and Electrical Readouts

The DY-2500 provides visual readout plus electrical outputs to drive digital recorders such as the hp 560A. With auxiliary Dymec units, the output of the DY-2500 can be coupled to other recording devices such as tape punches, card punches or typewriters.

Variable Gate-Times

Application of the DY-2500 is more flexible than that of standard electronic counters which have a limited selection of gate times in decimal ratios of one second. The DY-2500 gate time is adjustable by front panel controls in unit steps of one from 00001 to 99999. For systems applications, the counter gate time can be externally programmed by providing decade contact closures to the front-panel receptacle. Thus, the reading for each input channel to the system can be recorded in the appropriate measuring units, or normalized. Only a simple preliminary computation is needed to determine the proper setting of the front panel controls to provide output information in the desired engineering units.

Ratio Measurements

Efficiency of a machine or process can be determined directly by utilizing the ratio measuring capability of the DY-2500 Computing Counter. This is done by applying two different frequencies simultaneously and displaying their ratio. If, for example, the two inputs represent fuel flow and engine speed, the DY-2500 will provide output information in the form of revolutions per gallon which is indicative of engine efficiency.

Brief Specifications

Range: Input A: 1 cps to 120 KC (220 KC optional).
Input B: 1 cps to 10 KC (used for ratio measurements or external time base).

Multiplier Dials: DY-2500-4: Four multiplier dials, adjustable in steps of 1 from 0001 to 9999. Using internal time base, multiplier adjusts the gate time from 0.0001 seconds to 0.9999 second in 0.0001-second increments.

Optional gate times are: 0.001 to 9.999 seconds in 0.001-second increments, or 0.01 second to 99.99 seconds in 0.01-second increments.

DY-2500-5: Five multiplier dials, adjustable in steps of 1 from 00001 to 99999. Using internal time base, multiplier adjusts gate time from 0.0001 second to 9.9999 seconds in .0001-second increments.

Optional gate time is .001 second to 99.999 seconds in .001-second increments.

Outputs: Staircase and BCD.

Power Supply: 115/230 v ± 10%, 50/60 cps, 260 watts.

Dimensions: Cabinet Mount: 20¾" wide, 12½" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 14½" deep.

Weight: Cabinet Mount: 50 lbs. net, shipping weight 95 lbs. Rack Mount: 45 lbs. net, shipping weight 90 lbs.

Price: DY-2500-4, cabinet mount, $1350.00; rack mount, $1330.00. DY-2500-5, cabinet mount, $1425.00; rack mount, $1405.00. See DY-2500 Data Sheet for complete list of options, detailed specifications and prices.

Computing Counters ■ Accessory Equipment

TELEMETERING COUNTER DY-2503BR

Typical of special-purpose computing counters using DY-2500 Techniques.

Speeds, Simplifies Measurement of Telemetering Sub-Carrier Signals.

The DY-2503BR is typical of the special-purpose counters which Dymec can furnish by using the basic principle of the DY-2500 Computing Counter. In this case the front panel push-buttons simply select a predetermined gate time calculated to provide a reading in percent of period of any one of 18 IRIG (RDB) channel mid-band frequencies. Model 2503BR also provides the flexibility of front panel gate time selector dials so that the counter can be used for other applications or for measuring other than the standard RDB channels.

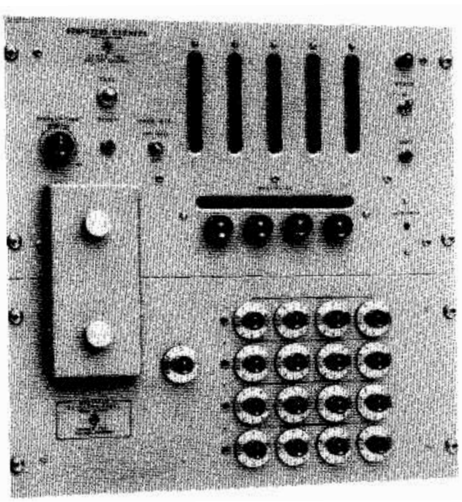
Brief Specifications

Generally comparable to DY-2500. Measures 1 cps to 100 KC. DY-2503BR also measures (1) input signals for gate times of .0001 to 0.9999 seconds in 0.0001 second intervals, plus fixed times of 1 and 10 seconds, (2) period for 1 to 9999 periods of input signal and (3) ratio from 1 to 9999.

Price: DY-2503BR (rack mount), $1,950.00.

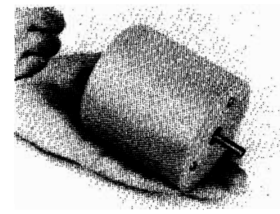
Computing Counters for Individual Applications

Dymec manufactures large or small quantities of variable or fixed gate counters similar to the DY-2500 for specific measurement requirements. The measuring system shown below, and the DY-2503BR special-purpose counter described above are typical of requirements met in the past. Dymec's field engineers or your Dymec engineering representative will be glad to discuss your individual application.



Computing counter with multichannel programmer to provide different gate time for each measurement channel as might be required in a system application.

PHOTOELECTRIC TACHOMETER DY-2504A



Shaft rotational speed from 0 rpm to 10,000 rpm, and accumulated shaft rotation can be measured easily and accurately with the DY-2504A Photoelectric Tachometer. Low friction and low moment of inertia of the DY-2504A assure extremely light loading of the driving shaft to provide rapid response to speed changes, even with low input torque.

Rotational speeds are measured by counting the number of pulses produced by the tachometer within a specified time interval. Accumulated shaft rotation is determined by counting the total number of pulses from a specified starting point. (Several options are available to provide from 60 to 360 constant amplitude and duration pulses for each shaft rotation in either direction.)

Brief Specifications

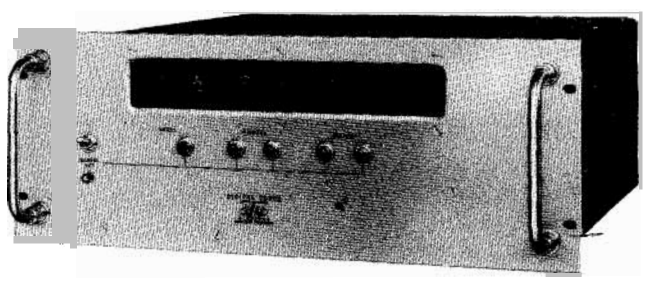
Output Pulses per Revolution: 60, 100, 120, 180, 200, 360

Speed Range: 0 to 10,000 rpm

Resolution: ±1 to ±6 degrees.

Size: Cylindrical case, 3¾" long, 3¾" diameter; ¼" dia. 1" long, flatted shaft.

Weight: Approximately 1¾ pound.



DIGITAL CLOCK DY-2508A

Accurate time information in seconds, minutes and hours is provided by the DY-2508A Digital Clock. The instrument provides both an easily read in-line visual readout and multiple electrical contacts to drive standard data recording devices. This permits precise time information to be recorded along with data from any Dymec or Hewlett-Packard electronic counter or digital voltmeter. Time information from the DY-2508A is also used for programming system functions.

Time signals can be obtained from line-frequency or optional crystal-controlled time bases, or from external sources. Numerous options are available to meet individual requirements for accuracy, number of outputs, and type of output code (staircase, ten-line, BCD). Price range is typically $1,600.00 to $2,000.00, depending on options selected.

DIGITAL SYSTEM OUTPUT DEVICES

Output information from Dymec Digital Systems may be in any form desired for fast, convenient handling and analysis of data. Dymec's flexible output couplers will operate electric typewriters or digital printers where a written record only is needed; or they will drive card or tape punches where data is to be entered into a computer or transmitted to a remote location for further processing. Display panels are also available for convenient visual readout. For control applications, output data can be compared against predetermined or programmed HI-LO limits to furnish GO/NO-GO signals. In most cases a combination of output handling devices can be operated simultaneously.

Output Couplers and Accessories. Five standard output couplers are used in Dymec systems to meet the many code and format requirements of different output devices. They provide the necessary translations and conversions to operate typewriters, digital printers, card punches or tape punches, and accessory devices such as visual readouts and comparators.

Model DY-2540 Coupler transfers information from parallel four-line binary data sources to serial-entry recorders. Up to 50 digits of information can be accepted from as many as six sources by one DY-2540 Coupler. More digits and data sources can be accommodated by using additional couplers connected on a master/slave basis. Two recording devices normally can be operated simultaneously even though they require different codes. Price of the DY-2540 Coupler depends on the number of inputs and outputs, code and format, and on the programming desired. Prices range typically from $1,200.00 to $2,500.00.

Model DY-2542 Tape Punch Set electronically scans and translates information from a digitizing device to punched paper tape at a rate of up to 60 characters per second. Model DY-2542 operates from a staircase voltage input (one-line) and provides any 5-, 6-, or 7-level perforating code to the tape punch. Price of the DY-2542 Tape Punch Set including coupler, power supply and punch is typically $5,000 to $5,500. Exact price depends on code, format, and number of punch levels.

Model DY-2512 Card Punch Coupler transfers information from any digitizing device with one-line (staircase voltage) output to an IBM Model 523 Summary Card Punch. Up to eight digits of identification data can be manually pre-set for entry onto cards along with the data from digitizing equipment. Price of the DY-2512 Card Punch Coupler is typically $3,000. Exact price depends on the nature of the digitizing device from which information is transferred.

Model DY-2513A Counter Scanner automatically scans and transfers staircase voltage information from any combination of up to six digital data sources to a single digital recorder such as the hp 560A, or to a DY-2512 Card Punch Coupler. Six digits of counter information plus a channel identifying number are supplied to the recording device. Front panel switches permit selection of the data sources to be recorded or omitted during the scanning cycle. Price of the DY-2513A is typically $2,-500.00, depending on type and number of data sources scanned.

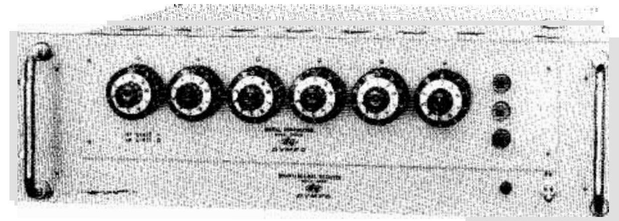
Model DY-2530 Binary/Decimal Register serves two functions. It serves as a buffer/storage unit and also translates and couples data from parallel binary voltage input sources to parallel-entry recorders, comparators, and visual readouts. The storage feature permits the Model DY-2530 to receive, store and translate measurement data before sending it to the recording and handling equipment. A single DY-2530 transfers up to seven digits of four-line information from a counter or other data source to card punches or parallel entry digital printers. Price of the DY-2530 Binary/Decimal Register is typically from $695.00 to $1,435.00, depending on the number of digits to be transferred.

Model DY-2532A Digital Comparator automatically compares six digits of measured data against pre-selected HI-LO tolerance limits. Dual concentric switches on the front panel are individually set for each of the six digits compared. "HI," "LO," or "GO" condition is indicated on panel lamps. Corresponding relay contact closures control external equipment or convey the information to a recorder. The DY-2532A may be used separately or plugged into the front panel of the DY-2530 to save front-panel space. Price of the DY-2532A is $550.00 for mounting in DY-2530; $565.00 for rack mounting.

Models DY-2533 and DY-2536 One-Line Digital Displays visually monitor measured data. DY-2533 uses long-life Nixie tubes; DY-2536 uses projection-type incandescent lamp indicators. Price of the DY-2533 is $250.00 for five-digit display; additional digits are $40.00 each. Price of the DY-2536 is $275.00 for five-digit display; additional digits are $40.00 each.

Model DY-2538 Programmed Digital Comparator is used with the DY-2530 for comparison of digital measurements against any one of five sets of automatically selectable pre-set tolerance limits. The desired set of limits against which each measurement is compared is individually selected by external programming equipment such as the DY-2901 input scanner. Price of the DY-2538 is $1,350.00.

Prices F. O. B. Factory, Palo Alto, California. All data subject to change without notice.



Model DY-2532A Digital Comparator mounted in Model DY-2530 Binary/Decimal Register.

DYMEC RF CHECKOUT EQUIPMENT

For Missile, Satellite and Airborne Electronic Systems, Radar and Communications Equipment

- Production and field testing, as well as performance monitoring is speeded and simplified by using Dymec's advanced techniques for programmed measurements.
- Dymec radar simulators evaluate operational readiness of missile and ground-based radar equipment by precisely duplicating signals encountered under actual operating conditions.
- Dymec's programmed signal generators provide rapid evaluation of complex airborne electronic countermeasures equipment, minimizing downtime of aircraft and the probability of unsuccessful missions.
- Dymec test sets allow rapid checkout and alignment of microwave communication systems to increase efficiency and increase in-service time.
- The advanced engineering techniques continually under development in Hewlett-Packard laboratories are uniquely available to Dymec for incorporation into equipment designed for specific system requirements.

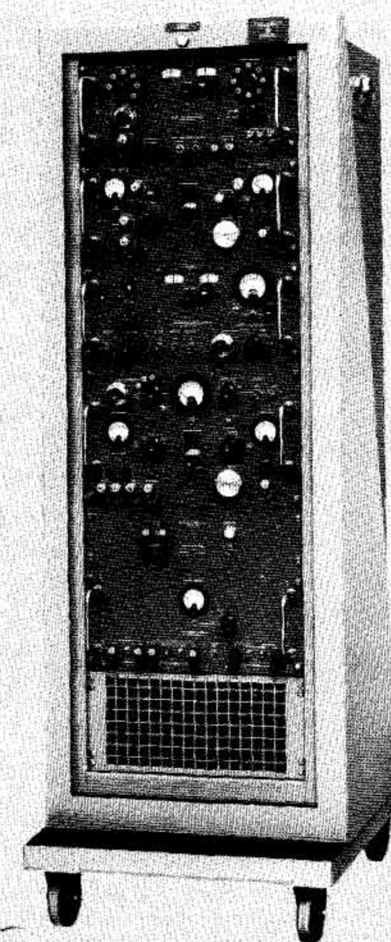
Test Sets. Complete facilities for test and maintenance of radar and microwave communication systems are provided by Dymec's compact, easy to operate test sets. A simple self-contained system in itself, each microwave test set includes coordinated instrumentation for generating microwave signals, measuring power level and frequency of transmitted and received signals, and modulating the microwave carrier to simulate actual system operation. Four standard microwave test sets and a high power signal generator are described in this catalog. Comparable devices can be designed and delivered in any quantity required to meet individual system needs.

System Building-Blocks. Many special-purpose microwave components are available to meet requirements for automatic control and programming of microwave test conditions such as frequency, power level, and modulation. In addition to its own proprietary skill and know-how, Dymec has available for its use the broad experience in microwave techniques of the Hewlett-Packard Company.

Special-Purpose Instruments Broadcast monitors and sweep generators are typical of the individual instruments available from Dymec for specialized test and measurement requirements. Utilizing the wide range of Hewlett-Packard general-purpose instrumentation as a base, Dymec can provide small or large quantities of individual instruments specially adapted for a given measuring task.

Radar Simulators. A typical Dymec radar simulator system is shown at right. Designed to speed and simplify factory and field testing of CW-Doppler radar equipment, the DY-5130 system simulates relative range, direction and velocity of a target. The signal generator portion of the system may also be used to provide other test signals. Techniques used in this and other complex radar simulators are described on the following pages. They indicate the diversity of Dymec system engineering capability for resolution of problems in the general field of rf and microwave system design, development, and manufacturing.

Automatic System Checkout Equipment. Dymec's capability in the digital data handling field, when coupled with its advanced rf and microwave measuring techniques, makes possible creation of fully automatic equipment for complete system checkout. Dymec's experience in the design and manufacture of both simple and complex systems covers the spectrum from low rf frequencies through all microwave bands to 40 GC and above. Frequently, Dymec can adapt its own off-the-shelf digital devices and standard Hewlett-Packard instruments to meet exacting system needs, thereby providing economy, reliability and expedited delivery of specialized measurement systems.



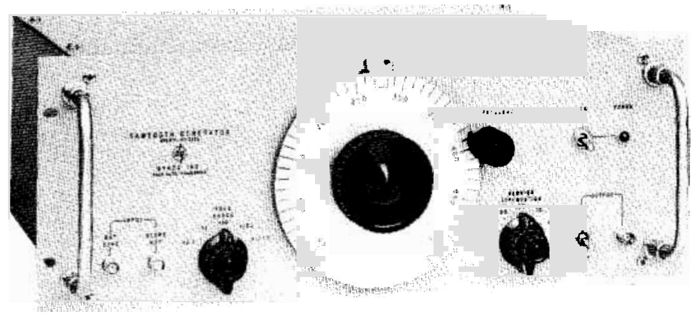
DY-5130 Radar Simulator duplicates actual operating conditions.

DYMEC RF CHECKOUT EQUIPMENT

A solid background in basic engineering techniques developed at Hewlett-Packard and Dymec provides a sound base for designing and building numerous special-purpose rf test and measurement systems. Here are brief descriptions of some of the specialized techniques pioneered or refined by Dymec, with examples of how they are used in test systems components.

Simulation of Doppler Effect. Modern FM, CW and pulsed doppler radar systems extract valuable information from doppler shift of the returned signal. Through the use of serrodyne modulation techniques, Dymec provides stable test signals to monitor and maintain such equipment. Frequency offset, simulating a doppler shift, is accomplished by applying a sawtooth voltage, precisely controlled in frequency, to a traveling-wave tube helix. Clean spectrums with offsets of up to 500 KC have been obtained without difficulty.

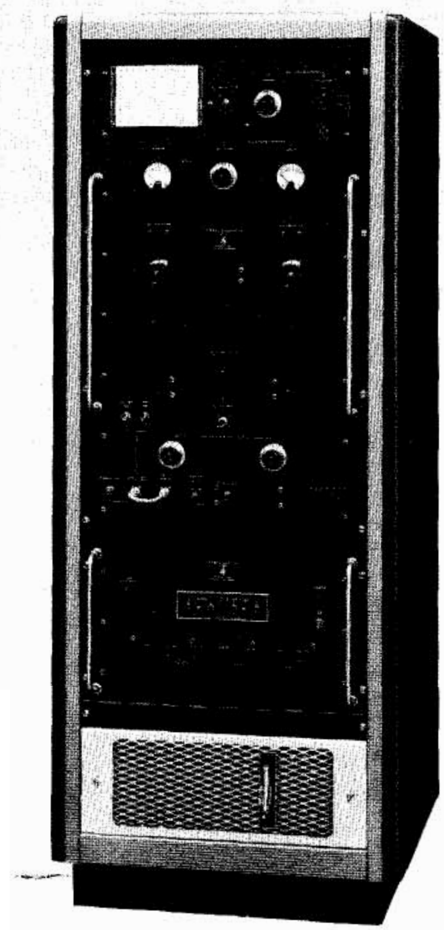
The DY-2222 Sawtooth Generator is a typical system building block for serrodyne modulation of TWT amplifiers. It provides a signal for generating doppler offset frequencies from 5 CPS to 500 KC. In addition, it allows the offset frequency to be modulated for simulation of acceleration effects.



DY-2222 Sawtooth Generator provides a precision output for serrodyne modulation of TWT amplifiers. High linearity and low flyback time assure accurate simulation of doppler shift.

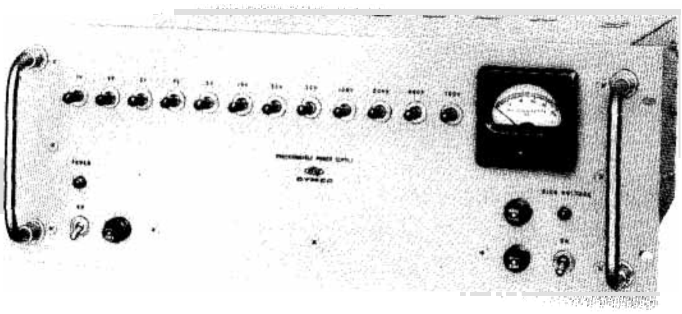
Frequency Stabilization and Control. An efficient technique for increasing radar and communication range depends upon coherent detection and employs extremely stable frequency sources. Dymec has developed both open and closed-loop frequency generation and stabilization circuits for testing such coherent systems. The DY-5156 Microwave Signal Generator, for example, provides high frequency stability over extended periods through a temperature range of 40 to 100°F. In a similar system, residual FM has been held to less than 10 KC. Dymec also can provide generators incorporating a cavity or crystal reference where extremely high stability is required.

Dymec has also developed simple methods for assuring high frequency accuracy in generated signals. One technique which has proven reliable and economical utilizes continuously visual comparison of the generated frequency against a crystal reference. Resettability and accuracy are limited only by the accuracy of the crystal oscillator reference. In the DY-5156 Microwave Signal Generator, this straightforward method of adjustment provides tuning accuracy of one part in 10^6 for eight discrete frequencies in X-band.



DY-5156 Microwave Signal Generator is typical of Dymec radar beacon performance evaluation equipment. It provides two phase-coherent signals with precisely controlled frequency separation. A third output frequency, the arithmetic average of the two generated frequencies, is also provided. The system features low residual FM, high frequency stability, and a high degree of resettability.

Proven techniques assure reliability, economy, performance

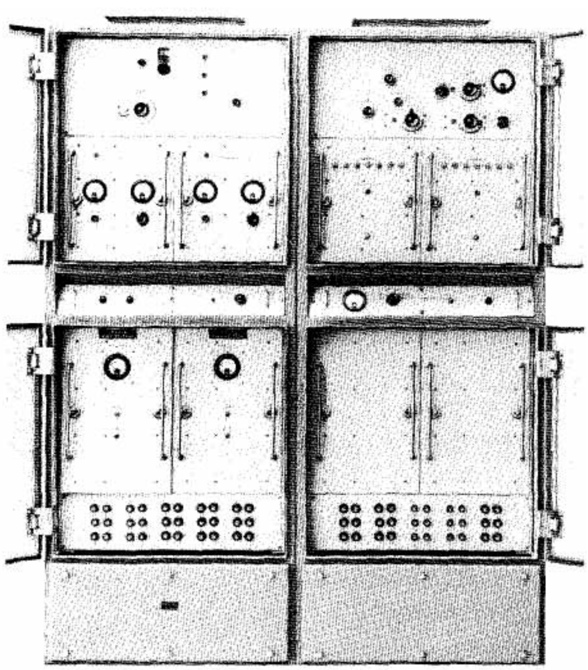


The DY-5783 Programmable Power Supply is typical of Dymec voltage-tuned power supplies. It enables rapid programmed selection of pre-selected microwave frequencies.

Programmable Frequency Control for Voltage Tuned Oscillators. In providing stimuli for automatic checkout of wide-band equipment such as countermeasures receivers, microwave components, and for rf interference and vulnerability checking, rapid, programmable tuning of rf signals is required. Often, the use of digital techniques improves the efficiency and utilization of such checkout equipment. Vacuum tube oscillators such as backward wave oscillators, carcinotrons, or voltage-tuned magnetrons are operated from Dymec programmable power supplies to provide signal sources capable of rapid setting to any required frequency within their range. A typical BWO frequency control unit provides a stable ($\pm 0.1\%$) control voltage over the range of 150 to 1500 v dc. Since this unit has a built-in reference, it can be accurately programmed externally by potentiometers or relay-selected resistances (as well as by external reference voltages). The control unit has a response range up to 10 KC to provide rapid and precise changes in BWO frequency with simultaneous wide-range frequency modulation.

Programmable Output Levels. For automatic sensitivity testing of complex receivers, Dymec has manufactured a number of programmable waveguide attenuators for accurately adjusting signal levels to predetermined values. Using ⓗⓟ precision rotary vane attenuators as the basic element, Dymec provides both mechanical and servo shaft positioning devices to remotely or automatically control signal levels within a checkout system.

In a typical programmable attenuator, the amount of attenuation can be remotely changed through as many as seven preset positions. Full accuracy of the dial is retained to $\pm 2\%$ or 0.1 db over a 50 db range or, by combining two attenuators in one assembly, over a 100 db range. Units are provided for all waveguide bands from 4 to 40 GC (KMC). Attenuator position can be controlled by local or remote pushbutton or contact closure, with each new position reached within 3 seconds. Other Dymec programmable attenuators utilize a servomotor drive to provide continuous control of attenuator position. An average slewing rate of 20 db per second can be achieved. Programming is by remote potentiometer or analog voltage control. Transistor servo amplifiers are used for high efficiency and reliability.

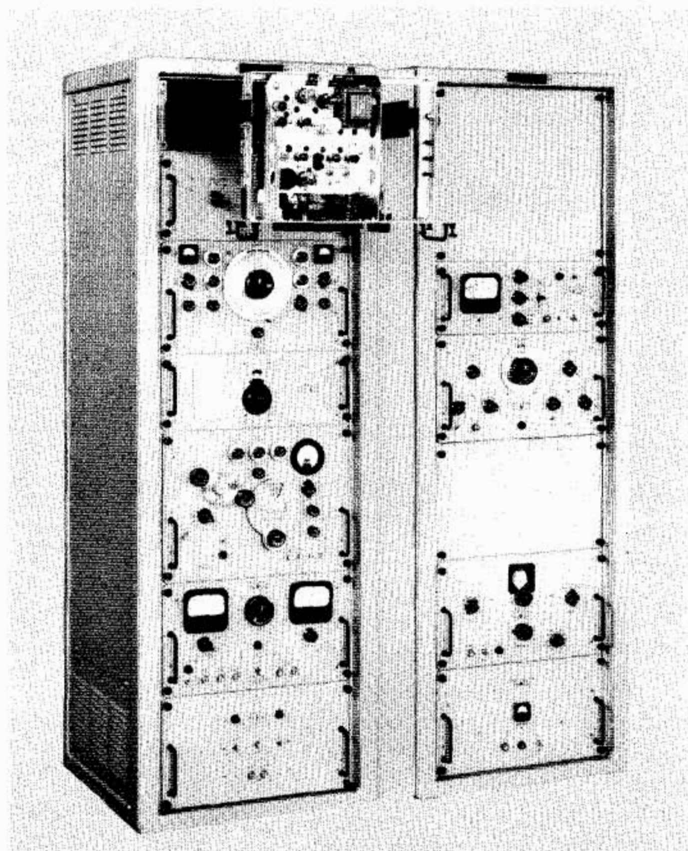


DY-5065, a typical Microwave Doppler Simulator, provides up to 1 watt CW output power, provides continuous output power monitoring, and has a very high degree of phase stability between two independent output signals generated to simulate doppler effect.

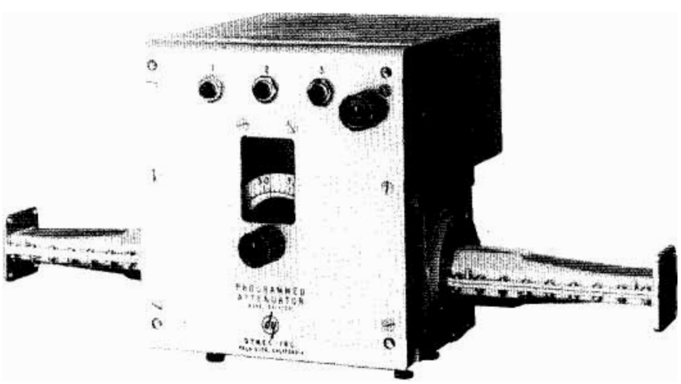
DYMEC RF SYSTEM TECHNIQUES

Constant Output Level from Microwave Signal Sources. For meaningful tests of many complex microwave systems, the output level from the test generator must be held constant over a wide range of frequencies and environmental conditions. To meet such requirements, Dymec provides power leveling devices which can maintain a constant output power level from any source providing a peak power output of 0 dbm or more in waveguide bands from 4 to 12 GC (KMC). A typical unit, the DY-5676, is simply inserted between the signal source and the load to provide constant power to the load, even through source variations of up to 40 db. Automatic level control can also be incorporated directly in Dymec signal generators.

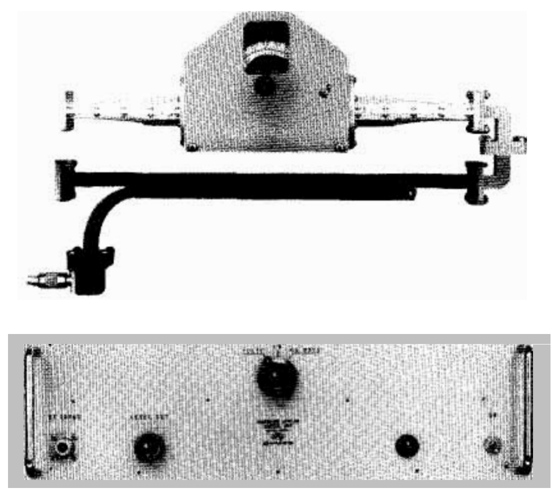
Constant Monitoring of Power Output. The techniques used for automatic control of output power level are also applicable to constant monitoring of output power. The attenuator in an automatic leveller rotates as a function of the peak pulse power input. Therefore, by calibrating the attenuator in terms of power level rather than attenuation, essentially the same device is a constant power monitor. With appropriate directional couplers and fixed attenuators to control the level of applied power, a 50 db range of power variation can be monitored for frequency modulated, amplitude modulated and square-wave modulated signals, as well as for pulse modulated signals with pulse widths as narrow as 0.25 microseconds. Frequency sensitivity is typically less than ± 1 db over X band, and even less at lower frequencies. Provision can be made for an analog voltage output proportional to the power level in order to operate an output meter, recorder, or other monitoring device.



DY-6190 Pulse-Doppler Radar Simulator is comprised of many standard Dymec rf system building blocks. System operates from 2 to 4 GC with output variable from 0 to −80 dbm. Amplitude, pulse, noise or phase modulation may be used. Similar systems have been built to meet specific needs of major radar systems.



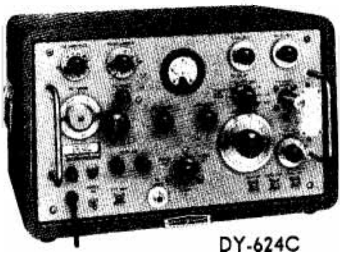
DY-2301 Programmable Waveguide Attenuator provides 3 preset values of attenuation at any points within 50 db overall range. Attenuator may be actuated by local or remote pushbuttons, or by remote contact closure. Unit provides SWR less than 1.15 and phase shift less than 3° over entire range. Units can be supplied in frequency range from 3.95 to 12.4 GC.



Constant power level is accurately maintained with DY-5676 Microwave Leveler. Servo-motor drive automatically inserts or removes attenuation as output level of source varies. Attenuator unit is mounted directly in waveguide transmission system between source and load. Control unit may be mounted at any convenient location.

MICROWAVE TEST SETS
SIGNAL GENERATORS

For Faster, More Convenient Test and Maintenance of Microwave Systems

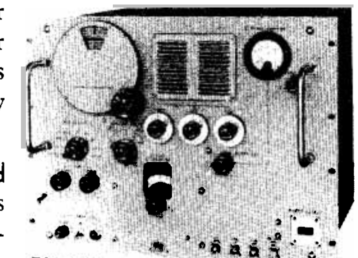


DY-624C

By combining several basic instruments into a single compact unit, Dymec Microwave Test Sets and Signal Generators provide faster and more economical test and maintenance for microwave systems. Each test set provides an efficient signal generator, accurate power and frequency meters, and a precision attenuator for maximum convenience in making receiver and transmitter measurements. The standard test sets and signal generator described here meet a wide range of test and measurement needs. Small or large quantities of comparable instruments can be provided to meet specialized or unusual requirements.

Model DY-623B SHF Test Set operates in the commercial and government communications bands between 5925 and 7725 MC. It is a compact unit for measuring receiver sensitivity and selectivity as well as transmitter frequency and power level. The DY-623B is particularly suitable for use with communications, control and video microwave systems.

Model DY-624C X-Band Test Set generates and monitors frequencies from 8,500 to 10,000 MC. It is particularly adapted to testing complete radar or fire control systems or radar beacon equipment. Circuitry is included to provide a variety of high quality rf pulses.



DY-5381

Model DY-5003 X-Band Test Set provides all features of the DY-624C, and in addition has a higher output power, making it particularly suited for testing radar transmitters and receivers where greater isolation between the equipment and the test set is required.

Model DY-5381 High Power X-Band Signal Generator for even more rigorous applications, provides power output of 250 milliwatts minimum over the range 8,500 to 10,000 MC, with output of approximately 400 mw toward the middle of the band. Internal and external pulse, FM and square-wave modulation is provided.

Model DY-5636 H-Band Test Set operates from 7125 to 8,400 MC to cover the important microwave relay communications band. Its provisions for transmitter power and frequency monitoring, along with received signal simulating facilities, make it particularly convenient for testing complete communications systems.

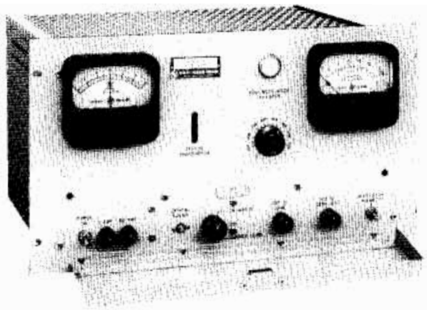
SPECIFICATIONS:*	DY-623B	DY-624C	DY-5003	DY-5381	DY-5636
Frequency Range:	5925-7725 MC (1)	8500-10,000 MC	8500-10,000 MC	8500-10,000 MC	7125-8400 MC
Frequency Meter Range:	5820-7780 MC	8500-10,000 MC	8500-10,000 MC	—	7125-8400 MC
Accuracy:	0.03% (2)	0.03%	0.03%	—	0.03% (2)
Output Power:	0 to —70 dbm	0 to —100 dbm	+15 to —85 dbm	+24 to —76 dbm	15 to —85 dbm
Output Connector:	Type N Jack	Type N Jack	UG-39/U Waveguide Cover Flange	UG-39/U Waveguide Cover Flange	UG-51/U Waveguide Cover Flange
Internal Modulation:	FM, 1 KC	Pulse, 35-3500 cps, FM, power line frequency	Pulse, 35-3500 cps FM, power line frequency	Pulse, Square Wave, 35-3500 cps. FM, power line freq.	FM, 1 KC
External Modulation:	FM, Pulse, Square Wave, 30 cps to 100 kc	FM, Pulse, Square Wave, 35-3500 cps	Pulse, FM, Square Wave, 35-3500 cps	Pulse, FM, Square Wave, 35-3500 cps	FM, Pulse, Square Wave, 30 cps to 100 KC
Power Meter: Range:	—6 to +3 dbm	—6 to + 3 dbm	—6 to + 3 dbm	—	—6 to + 3 dbm
Accuracy:	±1 db	±1 db	±1 db	—	±1 db
Input Attenuator Range:	—	0 to 25 db	0 to 25 db	—	0 to 25 db
Accuracy:	—	±0.2 db per 5 db attenuation	±0.2 db per 5 db attenuation	—	±1 db, meter + 2% attenuator setting
Dimensions: Cabinet:	20⅜" wide, 11½" high, 12½" deep	19" wide, 12¾" high, 16¼" deep	—	—	21¼" wide, 14" high, 17" deep
Rack:	—	19" wide, 10½" high, 10¼" deep	19" wide, 14" high, 14½" deep	19" wide, 14" high, 15" deep	—
Weight — Net:	57 lbs.	56 lbs. (cab.), 50 lbs. (rack)	64 lbs.	66 lbs.	75 lbs.
Shipping:	76 lbs.	80 lbs. (cab.), 73 lbs. (rack)	84 lbs.	91 lbs.	100 lbs.
Price:	$1,900.00 (transit case)	$2,265.00 (cab.) $2,250.00 (rack)	$3,600.00 (rack mount)	$4,835.00 (rack mount)	$4,475.00 (transit case)

*Please request Engineering Data Sheets for full specifications.
(1) 3 Klystrons needed for full range.
(2) .016% with temperature correction.

Prices F. O. B. Factory, Palo Alto, California.
All data subject to change without notice.

BROADCAST MONITORS

for TV, DY-335ER for FM, DY-335BR



For Continuous Monitoring of FM and TV Transmitters

Dymec broadcast monitors are compact packaged instruments specially designed to meet FCC requirements for monitoring FM and TV transmitters. Instruments are designed for continuous service at transmitter installations.

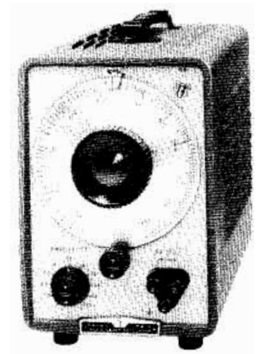
Model DY-335ER for vhf and uhf TV has three panel meters to show visual and aural carrier frequency, and percent modulation. A peak modulation indicator lamp is also mounted on the front panel. There is also provision for remote indicating meters, remote peak modulation indicating lamp, and a demodulated signal for measuring AM and FM noise levels, frequency response and distortion of the aural transmitter, and for continuous program monitoring. Price is $2,700.00.

Model DY-335BR for FM has two panel meters to show carrier deviation and percentage of modulation, with a lamp to indicate peak modulation. Provisions are made for operation of a remote modulation meter and a remote indicator lamp. Price is $1,550.00.

AUDIO SWEEP OSCILLATORS

DY-207A DY-2200AR

Speed, Simplify Full Range Frequency Response Tests



Models DY-207A and DY-2200AR Audio Sweep Oscillators cover their full frequency ranges in a single dial sweep to provide a convenient method for full range response tests.

Model DY-207A covers the 20 cps to 20 KC frequency range. It is particularly useful for testing response of audio circuits and devices such as amplifiers, transformers, and speakers. Amplitude variation is less than $\pm 3\%$ over the full range; sweep time can be as little as 20 seconds. The oscillator is available with a motor drive and/or accessory potentiometer to facilitate automatic testing with oscilloscope or X-Y recorder presentation of the test results. Price is $325.00 (Cabinet), $330.00 (Rack). Add $65.00 for accessory potentiometer; add $300.00 for motor drive and potentiometer.

Model DY-2200AR covers the 5 cps to 5 KC frequency range. Full range can be swept in as little as 10 seconds with output constant within ± 1 db. The DY-2200A is particularly suitable for rapid testing of servo and vibration systems. Price is $585.00 (Rack); add $65.00 for accessory potentiometer.

FOR ADDITIONAL INFORMATION

Engineering Data Sheets with descriptive information and complete technical specifications are available on all products listed in this catalog. Copies may be obtained from Dymec or your Dymec/ⓗⓟ Engineering Representative.

Your Dymec Representative will also be glad to discuss your needs for special instrumentation and instrumentation systems, and to forward your requirements to Dymec to obtain a quotation or engineering proposal.

How to order DYMEC Products:

All orders should be addressed to:

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395 Page Mill Road
Palo Alto, California.

Please do not include Dymec products on purchase orders for Hewlett-Packard instruments. Placement of separate purchase orders for ⓗⓟ and Dymec will assure faster handling and avoid unnecessary delay.

Prices F. O B. Factory, Palo Alto, California.
All data subject to change without notice.

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DARD WAVEGUIDE AND FLANGE SPECIFICATIONS

WAVEGUIDE		Material	Frequency Range for Dominant (TE_{10}) Mode GC (KMC)	INNER DIMENSIONS (In Inches)		OUTER DIMENSIONS (In Inches)			Cut - Off Frequency of TE_{10} Mode GC (KMC)	Theoretical Attenuation Lowest to Highest Frequency (db/100 Feet) (1)	WAVEGUIDE FLANGES	
EIA signation	JAN Type			Width	Height	Width	Height	Wall Thickness Nominal			Equivalent Cover Type JAN or EIA No.	Equivale Type an JAN or
VR284	RG-48/U RG-75/U	Brass Aluminum	2.60 - 3.95	2.840	1.340	3.000	1.500	0.080	2.078	1.478 - 1.008 0.940 - 0.641	UG- 53/U UG-584/U	UG- 5 UG-58
VR187	RG-49/U RG-95/U	Brass Aluminum	3.95 - 5.85	1.872	0.872	2.000	1.000	0.064	3.152	2.79 - 1.93 1.77 - 1.22	UG-149A/U UG-407/U	UG-1 UG-40
VR159		Brass Aluminum	4.9 - 7.05	1.590	0.795	1.718	0.923	0.064	3.711	2.89 - 2.24 1.84 - 1.42	CMR-159	
VR137	RG-50/U RG-106/U	Brass Aluminum	5.3 - 8.20	1.372	0.622	1.500	0.750	0.064	4.301	4.61 - 3.08 2.93 - 1.94	UG-344/U UG-441/U	UG-34 UG-44
VR112	RG-51/U RG-68/U	Brass Aluminum	7.05 - 10.00	1.122	0.497	1.250	0.625	0.064	5.259	5.51 - 4.31 3.50 - 2.74	UG- 51/U UG-138/U	UG- 5 UG-13
WR90	RG-52/U RG-67/U	Brass Aluminum	8.20 - 12.40	0.900	0.400	1.000	0.500	0.050	6.557	8.64 - 6.02 5.49 - 3.83	UG- 39/U UG-135/U	UG- 4 UG-13
WR75		Brass Aluminum	10.00 - 15.00	0.750	0.375	0.850	0.475	0.050	7.868	10.1 - 7.03 6.42 - 4.52	SPECIAL WRITE hp	
WR62	RG-91/U RF-107/U	Brass Silver	12.40 - 18.00	0.622	0.311	0.702	0.391	0.040	9.487	12.76 - 11.15 6.14 - 5.36	UG-419/U	UG-5
WR51		Brass Silver	15.00 - 22.00	0.510	0.255	0.590	0.335	0.040	11.571	17.3 - 12.6 8.43 - 6.12		
WR42	RG-53/U RG-66/U	Brass Silver	18.00 - 26.50	0.420	0.170	0.500	0.250	0.040	14.050	27.7 - 19.8 13.3 - 9.5	UG-595/U UG-425/U[3]	UG-5
WR28	RG-96/U	Silver	26.50 - 40.00	0.280	0.140	0.360	0.220	0.040	21.075	21.9 - 15.0	UG-599/U UG-381/U[3]	UG-6

ty of Brass—7.0 x 10^{-6} ohm - cm.
ty of Aluminum—2.83 x 10^{-6} ohm - cm.
ty of Silver—1.62 x 10^{-6} ohm - cm.

(2) All hp flanges are precision cover flanges. Where choke type connection is required, use hp 290A Cover to Choke Flange Adapter.

(3) Precision Circular flanges.

INDEX BY INSTRUMENT TITLE – hp and Dymec

Instrument	*Page*

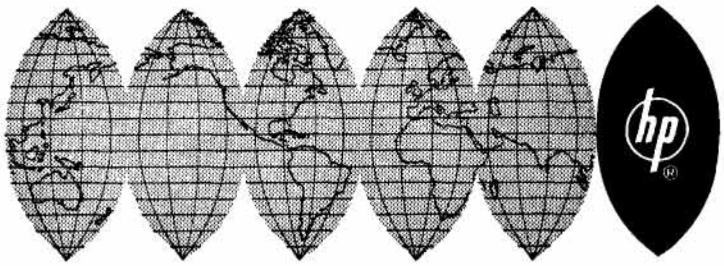
Hewlett-Packard Instruments (see third page of this index for Dymec Equipment)

Hewlett-Packard Instruments

Hewlett-Packard Instruments

Dymec Instruments

COMPLETE COVERAGE



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