CATALOG 23A 1957

electronic

measuring

instruments

HEWLETT PACKARD

COMPANY

INDEX BY INSTRUMENT TYPE AND FUNCTION

Oscilloscopes—DC to 10 MC

Intrument	Primary Uses	Characteristics	Price	Page
-*hp*- 130A	General laboratory and production testing	Dc to 300 KC—High sensitivity	$ 650.00	8, 9
-*hp*- 150A	General laboratory high frequency and TV work	Dc to 10 MC—Plug-in vertical amplifiers	1100.00	10, 11
-*hp*- 151A	High sensitivity—Plug-in for 150A	Dc to 10 MC—High sensitivity	200.00	10, 11
-*hp*- 152A	Dual Trace—Plug-in for 150A	Dc to 10 MC—Presents two phenomena for simultaneous viewing	250.00	10, 11

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	$130.00	16, 18
-*hp*- 200CD	Subsonic through supersonic audio and ultrasonic tests	5 cps to 600 KC	160 mw or 10 v/600 ohms; 20 v open circuit	160.00	16, 18
-*hp*- 200J	Interpolation, frequency measurements	6 cps to 6 KC	160 mw/10 v	275.00	17, 18
-*hp*- 200T	Telemetry, carrier current tests	250 cps to 100 KC	160 mw or 10 v/600 ohms; 20 v open circuit	350.00	18
-*hp*- 201C	High quality audio tests	20 cps to 20 KC	3 w or 42:5 v/600 ohms	225.00	17, 18
-*hp*- 202A	Low frequency measurements	0.008 to 1200 cps	28 mw or 30 v p-p/4000 ohms	465.00	20, 21
-*hp*- 202C	Servo equipment tests, measurements	1 cps to 100 KC	160 mw or 10 v/600 ohms	300.00	17, 18
-*hp*- 205AG	High power audio tests, gain measurements	20 cps to 20 KC	5 watts	440.00	26, 27
-*hp*- 206A	High quality, high accuracy audio tests	20 cps to 20 KC	+ 15 dbm	565.00	28, 29
-*hp*- 207A	Audio sweep generation	20 cps to 20 KC	160 mw or 10 v/600 ohms	275.00	19
-*hp*- 233A	Carrier oscillator—current tests	50 cps to 500 KC	3 w/600 ohms	475.00	24
-*hp*- 650A	Wide range video tests	10 cps to 10 MC	15 mw/3 v	490.00	22, 23

Vacuum Tube Voltmeters—10 cps to 700 MC

Instrument	Primary Uses	Frequency Range	Voltage Range	Input Impedance	Price	Page
-*hp*- 400AB	General purpose ac measurements	10 cps to 600 KC	0.003 to 300 v 11 ranges	10 megohms 25 $\mu\mu f$ shunt	$200.00	42
-*hp*- 400D	Wide range ac measurements High sensitivity	10 cps to 4 MC	0.001 to 300 v 12 ranges	10 megohms 15 $\mu\mu f$ shunt	225.00	40, 41
-*hp*- 400H	High accuracy wide range ac measurements	10 cps to 4 MC	0.001 to 300 v 12 ranges	10 megohms 15 $\mu\mu f$ shunt	325.00	43
-*hp*- 410B	Audio, rf, VHF measurements; dc voltages; resistances	Dc; ac—20 cps to 700 MC	0.1 to 300 v 7 ranges	Dc—122 megohms; ac—10 megohms/1.5 $\mu\mu f$	245.00	44, 45

Voltmeter Accessories

Extend usefulness of -*hp*- Models 400AB, D, H or 410B voltmeters

Instrument	Features	Price	Page
-*hp*-452A Capacitive Voltage Divider	For all -*hp*- ac VTVM. 25 cps to 20 MC. Division 1000:1	$100.00	46
-*hp*- 452-95A Adapter	Connects -*hp*- 452A to -*hp*- 410B VTVM probe	10.00	46
-*hp*- 453A Capacitive Voltage Divider	For -*hp*- 410B VTVM only. Division 100:1	25.00	46
-*hp*- 454A Capacitive Voltage Divider	For -*hp*- 400D and 400H only. Division 100:1	25.00	46
-*hp*- 455A Probe Coaxial "T" Connector	For -*hp*- 410B VTVM. Measures voltages between conductor and sheath of 50 ohm transmission line.	35.00	46
-*hp*- 458A Probe Coaxial "N" Connectors	For -*hp*- 410B VTVM. Measures volts at open end of 50 ohm transmission line.	25.00	46
-*hp*- 459A DC Resistive Voltage Multiplier	For -*hp*- 410B VTVM. For measuring high dc voltages safely. Multiplies 1:100	25.00	46
-*hp*-470 A-F Shunt Resistors	For -*hp*- 400 series VTVM. For measurement of current.	470A - 15.00 470B-F - 7.50	46

Frequency Measuring, Monitoring Equipment

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 100D Secondary Standard	Frequency, time measurements	100 KC, 10 KC, 1 KC, 100 cps, 10 cps	Stability 1/1,000,000 (short-time) Sine or rectangular output. Marker pips	$ 615.00△	56, 57
-hp- 335E TV Monitor	Aural and visual carrier monitoring; black and white or color	Channels 2 to 83	Aural deviation ±3 KC; video deviation ±3 KC; accuracy ±500 cps approx.	2,050.00	53
-hp- 500B Electronic Frequency Meter	Rapid frequency measurements	3 cps to 100 KC	9 ranges ±2% accuracy. Input 0.2 to 250 volts	285.00	58, 59
-hp- 500C Electronic Frequency Meter	Rpm measurements	180 to 6,000,000 rpm	Similar to 500B but calibrated in rpm	285.00	58, 59
-hp- 506A Optical Tachometer Pickup	Rps and rpm measurement	300 to 300,000 rpm	Phototube and light source; output 1 v rms	100.00	60
-hp- 508A Tachometer Generator	Shaft speed measurement	15 to 40,000 rpm	Output 60 cycles per revolution	100.00	60
-hp- 508B Tachometer Generator	Shaft speed measurement	15 to 40,000 rpm	Output 100 cycles per revolution	100.00	60
-hp- 508C Tachometer Generator	Shaft speed measurement	15 to 40,000 rpm	Output 120 cycles per revolution	100.00	60
-hp- 508D Tachometer Generator	Shaft speed measurement	15 to 5,000 rpm	Output 360 cycles per revolution	100.00	60
-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	615.00△	62
-hp- 521A Industrial Electronic Counter	Measure frequency, speed, time interval	1 cps to 120 KC	Direct reading, accurate within ±1 count ±0.1%, 4 place registration	475.00	63
-hp- 521C Industrial Electronic Counter	Measure frequency, speed, time interval	1 cps to 120 KC	Direct reading, accuracy within ±1 count ±0.01%, 5 place registration	650.00	63
-hp- 522B Electronic Counter	Frequency, period, time interval measurements	10 cps to 120 KC	Direct reading, accuracy ±1 count ±0.001%	915.00△	64, 65
-hp- 523B Electronic Counter	Frequency, period, time interval	10 cps to 1.1 MC	Direct reading, accuracy ±1 count ±2/1,000,000	1,175.00	66, 67
-hp- 524B Frequency Counter	Frequency, period measurements	10 cps to 10 MC (Freq.) 0 cps to 10 KC (Period)	Direct reading, no interpolation, accuracy about 2/1,000,000/week	2,150.00 ■	68, 69, 70
-hp- 525A Frequency Converter	Extends 524B's range to 100 MC; increases basic sensitivity	10 cps to 100 MC	Accuracy ±1 cps ± stability; 0.1 v rms min. input	250.00	69, 70
-hp- 525B Frequency Converter	Extend's 524B's range from 100 to 220 MC; high sensitivity	100 MC to 220 MC	Accuracy ±1 cps ± stability; 0.2 v rms min. input	250.00	69, 70
-hp- 526A Video Amplifier	Increases 524B's sensitivity to 10 millivolts	10 cps to 10 MC	Accuracy same as basic counter; 10 mv rms min. input	150.00	69, 70
-hp- 526B Time Interval Unit	Measures interval 1 μsec to 100 days	1 μsec to 10^7 sec	Accurate 0.1 μsec ±0.0001%	175.00	69, 70
-hp- 526C Period Multiplier	Period measurement	Extends range of 524B to measure 10,000 periods	Greater accuracy in period measurement	225.00	69, 70
-hp- 540A Transfer Oscillator	Frequency measurements	10 MC to 5 KMC	Extends range of 524B to 12.4 KMC	615.00△	72, 73
-hp- 560A Digital Recorder	Record counter measurements	Slave of counter	5 counts per second; 11 digit parallel entry; analog output	On request	74, 75

Distortion, Wave Form Analyzers — 20 cps to 20 KC

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 300A	Wave form analyzer	30 cps to 16 KC	Variable selectivity; measuring range 1 mv to 500 v	$775.00	34, 35
-hp- 330B	Measures total audio distortion	20 cps to 20 KC	Includes input amplifier, VTVM	410.00△	36, 37
-hp- 330C	For FM broadcast measurements	20 cps to 20 KC	Special VU meter to meet F.C.C. requirements	440.00△	37
-hp- 330D	For AM, FM broadcast measurements	20 cps to 20 KC	AM detector and VU meter to meet F.C.C. requirements	455.00△	37

Square Wave and Pulse Generators

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 211A	Square wave generator	1 cps to 1 MC	Output 7 v p-p across 75 ohms or 55 v p-p across 600 ohms	$265.00	32
-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	565.00△	30, 31

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

Signal Generators — 10 to 21,000 MC

Instrument	Frequency Range	Characteristics	Price	Page
-*hp*- 608C	10 to 480 MC	Output 0.1 μv to 1 v into 50 ohm load. AM, pulse, or CW modulation. Direct Calibration.	$ 950.00	80, 81
-*hp*- 608D	10 to 420 MC	Output 0.1 μv to 0.5 v. Incidental FM 0.002 entire range.	1,050.00	80, 81
-*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.	1,200.00	82, 83
-*hp*- 614A	800 to 2,100 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, CW or FM modulation. Direct calibration.	1,950.00	84, 85
-*hp*- 616A	1,800 to 4,000 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, CW or FM modulation. Direct calibration.	1,950.00	84, 85
-*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	86, 87
-*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	86, 87
-*hp*- 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.	1,750.00	88, 89
-*hp*- 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△	88, 89
-*hp*- 626A	10 to 15.5 KMC	Output 10 dbm to —90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,250.00	90, 91
-*hp*- 628A	15 to 21 KMC	Output 10 dbm to —90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,000.00	90, 91

Swept Frequency Oscillators

-*hp*- 670SM	2.6 to 4 KMC	Automatic adjustable motor-driven sweep, full frequency band coverage, output 10 mw full range, full modulation capabilities, direct-reading frequency dial.	1,175.00 with motor	92, 93
-*hp*- 670GM	4 to 6 KMC		1,175.00 with motor	92, 93
-*hp*- 670JM	5.85 to 8.2 KMC		1,175.00 with motor	92, 93
-*hp*- 670HM	7 to 10 KMC		1,175.00 with motor	92, 93
-*hp*- 686A	8.2 to 12.4 KMC	Electronically swept; variable sweep width and rate. Output 10 mw to 0. Pulse, square wave, FM and AM modulation.	2,250.00	94, 95

Other Instruments and Accessories

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-*hp*- 350A/B Attenuator	Measurement of attenuation, gain	0 to 100 KC	110 db in 1 db steps. A—500 ohm level; B—600 ohm level	$ 60.00	38
-*hp*- 360A-D Low Pass Filters	Eliminates harmonic voltages from uhf systems	Cutoff frequencies A- 700 MC C-2,200 MC B-1,200 MC D-4,100 MC	50 db rejection at 1.2 cutoff freq.	40.00	104
-*hp*- 450A Amplifier, Stabilized	General purpose lab amplifier	5 cps to 1,000,000 cps	20 and 40 db gain, free response ±½ db	140.00	52
-*hp*- 460A Amplifier, Wide Band	Wide band, pulse amplification	100 KC to 140 MC	20 db gain, rise time 0.0026 μsec	185.00	48, 49
-*hp*- 460B Amplifier, Fast Pulse	Pulse amplification, high output	100 KC to 140 MC	15 db gain, 125 peak volts	225.00	48, 49
-*hp* 46A Accessories	Apply and connect 460A/B amplifiers				49
-*hp*- 710B Power Supply	General purpose regulated plate and filament supply for lab and field use		100 to 360 volts @ 75 ma	100.00	96
-*hp*- 711A Laboratory Power Supply	Same as 710B		0 to 500 volts @ 100 ma	225.00	97
-*hp*- 712B Power Supply	Same as 710B		0 to 500 volts @ 200 ma	365.00△	98
-*hp*- 715A Klystron Power Supply	Regulated beam, reflector source for low power klystrons		250 to 400 volts @ 50 ma	300.00	99
-*hp*- 717A Klystron Power Supply	Powering Type 5721 klystrons		800 to 1,000 volts @ 25 ma	375.00	100
Binding Posts, Insulators, Support Pedestals					137
-*hp*- AC-2A/B Dual Rack Mount				25.00	136
-*hp*- AC-4A Decade Counter	Special setups or replacement in counters	120 KC counting rate	Drives following decade; staircase output	35.00*	71
-*hp*- AC-4B Decade Counter	Special setups or replacement in counters	220 KC counting rate	Same as AC-4A	70.00	71
-*hp*- AC-4D Decade Counter	Special setups or replacement in counters	1.1 MC counting rate	Same as AC-4A/B	150.00	71
-*hp*- AC-16 Cable Assemblies					138
-*hp*- AC-17 End Frames				7.50	136
-*hp*- AC-44 Cabinets					136
-*hp*- AC-60A Line Matching Transformers	Connect balanced system to VTVM, oscillators	5 to 600 KC	Max. level +22 dbm	25.00	137
-*hp*- AC-60B Bridging Transformer	Connect balanced line to -*hp*-330B	20 cps to 60 KC	Specifically designed for audio systems. Max. level +15 dbm	35.00	137
-*hp*- AC-60K Matching Transformer	Match barretters to -*hp*- 416A			45.00	119
-*hp*- AC-97A	Sweep motor for 670 series		Approximately 3 seconds to sweep full range of -*hp*- 670	75.00	92, 93
-*hp*- AC-97B	Same as AC-97A		Approximately 12 seconds to sweep full range of -*hp*- 670	100.00	92, 93

*f.o.b. Palo Alto, Calif. Quantity discount quotations available from the factory. △ Rack mounted instrument available for $15.00 less.

Microwave Equipment—2.6 to 40 KMC

Instrument	Coaxial Type N Conn.	"S" 3" x 1½" 2.6 - 3.95 KMC	"G" 2" x 1" 3.95 - 5.85 KMC	"J" 1½" x ¾" 5.2 - 8.2 KMC	"H" 1¼" x ⅝" 7.05 - 10.0 KMC	"X" 1" x ½" 8.2 - 12.4 KMC	"P" .702x.391" 12.4 - 18.0 KMC	"K" .500"x.250" 18.0 - 26.5 KMC	"R" .360x.220" 26.5 - 40.0 KMC	Page
Adapter, Waveguide to Coax		S281A $50	G281A $40	J281A $35	H281A $30	X281A $25				103
Cover to choke flange		S290A $65	G290A $50	J290A $35	H290A $25	X290A $15	P290A $20			103
Attenuators, Fixed 3, 6, 10, 20 db		S370A $75	G370A $65	J370A $65	H370A $60	X370A $55	P370A $60			106
Flap, 25 db max.		S375A $120	G375A $110	J375A $100	H375A $90	X375A $65	P375A $80	K375A $60	R375A $70	106
Calibrated, precision		S380A $260	G382A $500	J382A $350	H382A $350	X382A $250	P382A $275			107
Detector Mounts	420A $50				H421A $85	X421A $75	P421A $85			126
	420B $75									126
	440A† $85									126
		S485D° $145	G485D $140	J485D° $135						113
		S485A‡ $125	G485B† $95	J485B† $90	H485B† $85	X485B† $75	P485C■ $110			113
Isolators						X365A $225				105
Thermistor Mounts (Fixed tuned)■	477B $75		G487B $95	J487B $90	H487B $80	X487B $75		K487B $85		111, 112
Frequency Meters, Reaction				J530A/B**	H530A $120	X530A $120	P530A $150			127
Waveguide						X532A $150				127
Directional Couplers, Cross Guide: 20, 30 db		S750 $130	G750 $120	J750 $70	H750 $60	X750 $50				128
Directional Couplers, Multi Hole: 3, 10, 20 db		S752 $375	G752 $250	J752 $140	H752 $120	X752 $75	P752 $100	K752 $100	R752 $120	128
Slotted Sections, Waveguide		S810A* $450	G810B§ $110	J810B§ $110	H810B§ $110	X810B§ $90	P810B§ $110			124, 125
Slotted Sections, Waveguide							P815A $200	K815A $200	R815A $200	124, 125
Tuners, Slide Screw		S870A $225	G870A $185	J870A $150	H870A $130	X870A $125	P870A $130	K870A $140	R870A $140	131
E-H						X880A $130	P880A $135	K880A $155	R880A $170	131
Waveguide Phase Shifter				J885A $400		X885A $300	P885A $350			132
Terminations, Low Power		S910A $45	G910A $35	J910A $30	H910A $25	X910A $20	P910A $25	K910A $30	R910A $35	133
Terminations, High Power		S912A $160				X912A $50				133
Moving Load		S914A $100	G914A $75	J914A $70	H914A $60	X914A $50	P914A $55	K914A $65	R914A $75	134
Standard Reflections						X916A $100				134
Adjustable Shorts		S920A $90	G920A $70	J920A $60	H920A $50	X920A $40	P920A $55	K920A $75	R920A $85	135
Waveguide Shorting Switch						X930 $60				135
Broad Band Probe	442B§ $35	All frequencies								126
Broad Band Probe, Untuned		444A $35 2.6 to 12.4 KMC					446A $145 12.4 to 40 KMC			126
Waveguide Clamps, Stands										137

† For use with barretter or crystal. ‡ For use with barretter only. *Complete assembly including carriage. §Mounts in 809B Carriage.

■ Includes Thermistor, installed. **J530A, 5.85 to 8.2 KMC, $120; J530B, 5.20 to 7.05 KMC, $150 ° Includes barretter; checked for square law characteristics.

Microwave Test Instruments—for coaxial and waveguide systems

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 415B Standing Wave Indicator	SWR indicator or null indicator	300 to 3,000 cps. Normal freq. 1,000 cps	0 to 70 db attn. Max. sensitivity 0.3 μv	$200.00	123
-hp- 416A Ratio Meter	Reflection coefficient measurements	1,000 cps $\pm$40 cps	Continuous swept frequency presentation; accuracy $\pm$3%	450.00△	118, 119
-hp- 417A vhf Detector	vhf bridge detector (for *-hp-* 803A)	10 to 500 MC	Approx. 5 μv sensitivity	250.00	121
-hp- 430C Microwave Power Meter	Measurement of rf power	Depends on bolometer mount	0.02 to 10 mw $\pm$5% accuracy	250.00	110, 11
-hp- 475B Tunable Bolometer Mount	Measurement of rf power (with 430B/C)	1,000 to 4,000 MC	Matches 50 ohm line to 100 or 200 ohms	200.00	114
-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	114
-hp- 477B Coaxial Thermistor Mount	Measurement of rf power (with 430C)	10 MC to 10 KMC	No tuning required SWR less than 1.5	75.00	111
-hp- 490B Traveling-Wave Tube Amplifier	Amplification throughout "S" band	2 to 4 KMC	30 db gain; millimicrosec rise time; 10 mw output	1,100.00	50, 51
-hp- 491A Traveling-Wave Tube Amplifier	High power "S" band amplification	2 to 4 KMC	30 db gain; millimicrosec rise time; 1 watt output	1,100.00	50, 51
-hp- 492A Traveling-Wave Tube Amplifier	Amplification through most of "G" and "J" bands	4 to 8 KMC	30 db gain, millimicrosec rise time, 10 mw output	1,500.00	50, 51
-hp- 494A Traveling-Wave Tube Amplifier	Amplification throughout "X" band	7 to 12.4 KMC	25 db gain, millimicrosec rise time, 5 mw output	1,500.00	50, 51
-hp- 803A vhf Bridge	Measurement of vhf impedance, SWR	50 to 500 MC	2 to 2,000 ohms impedance —90° to +90° phase angle	495.00	120, 121
-hp- 805A Coaxial Slotted Section	Measurement of SWR	500 to 4,000 MC	For Type N Connectors flexible cables	475.00	122
-hp- 805B Coaxial Slotted Section	Same as above	Same as above	For rigid ⅞" RG44/U line	475.00	122
-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	125
-hp- 809B Universal Probe Carriage	G, J, H, X and P 810 Waveguide Sections Supports 806B section, also		Accepts 442B, 444A probes	160.00	124, 125
-hp- 814A Universal Probe Carriage	Supports P, K and R 815A Waveguide Slotted Sections		Accepts Untuned Probe 446A	225.00	124, 125

△ Rack mounted instrument available for $15.00 less.

Data subject to change without notice. Prices f.o.b. factory.

ELECTRONIC MEASURING INSTRUMENTS

SUGGESTIONS FOR ORDERING

Order by Model Number

Always order by catalog model number and name of instrument desired. For example, "Model 400D Vacuum Tube Voltmeter." Whenever possible mention frequency range or other significant specifications to prevent misunderstanding. Also mention features such as special color, non-standard power line voltage, etc., and whether cabinet or rack mounting style is desired.

Most Hewlett-Packard instruments are available in either cabinet or rack mounting. The letter "R" after the model number indicates rack mounting. For example, "400DR." An additional charge is made for most rack mounting style instruments.

Orders should be sent direct to the factory and addressed to Hewlett-Packard Company, 275 Page Mill Road, Palo Alto, California. All orders are subject to final acceptance by the Hewlett-Packard Company.

Shipments

Unless specifically requested otherwise, shipments are made by express or by truck, whichever is cheaper and more serviceable to the customer. Small items will be forwarded by parcel post. For expedited service, we will gladly ship by air freight, air express (more expensive), or air parcel post upon request.

Terms

30 days net. Unless credit has already been established, shipments will be made c.o.d. All prices are quoted f.o.b. Palo Alto.

Sales Representatives

Sales representatives are maintained in principal cities as a service to our customers. Customers are invited to contact the nearest representatives at any time. They will gladly supply technical information, help prepare your order and, if desired, forward order to the factory. Orders should be made out to the Hewlett-Packard Company and are subject to final acceptance by the Company in Palo Alto. Sales representatives and their addresses are shown in the back of this catalog.

Repairs

When returning instruments for repairs, recalibration, or any other reason, please contact the Hewlett-Packard Company for shipping instructions. Give model number, type number, and serial number and as much information as possible concerning reason for return.

Repairs are made by the Hewlett-Packard Company at cost of labor and materials plus a small service charge. Customers are invited to make full use of this service to insure maximum benefit from their instruments. In most cases instrument repairs can be made locally at field repair stations maintained by our representatives in Boston, Chicago, Dallas, Detroit, Los Angeles, New York, Philadelphia, Syracuse and Washington, D. C.

Repair Parts

When ordering repair parts please describe carefully parts required. Give model number, type number, serial number of the instrument and date of original purchase when known. Identify parts by schematic diagram circuit reference and by *-hp-* stock number, if possible.

ELECTRONIC MEASURING INSTRUMENTS

TO COMMUNICATE WITH HEWLETT-PACKARD

Mail: 275 Page Mill Road, Palo Alto, California, U. S. A.

Telephone: DAvenport 5-4451, Palo Alto.

TWX: Palo Alto, Cal. 02.

Cable: "HEWPACK".

TO COMMUNICATE WITH -hp- ENGINEER-SALESMEN

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

WHERE TO FIND THE -hp- INSTRUMENTS YOU NEED IN THIS CATALOG

By instrument type or function:

All *-hp-* instruments shown in this catalog are indexed by type or function in the tables at the beginning of the catalog. (Example—"Vacuum Tube Voltmeters.")

By instrument name or title:

All *-hp-* instruments shown in this catalog are indexed by name or title at the back of the catalog. (Examples—"Amplifier"; "Audio Oscillator.")

By instrument model number:

-hp- instruments are also listed numerically (by model number) at the back of this catalog. (Example—"*-hp-* 410B Vacuum Tube Voltmeter.")

Ordering information:

Essential ordering information, terms and shipping and repair data are listed on the previous page.

Prices:

Prices of major *-hp-* instruments (cabinet models) are listed on individual pages and also in the tables at the beginning of the catalog. Prices of certain small components and accessories are listed on pages where such equipment is catalogued. Prices are subject to change without notice, and are f.o.b. factory.

Warranty:

All *-hp-* instruments are warranted free from defects in materials and workmanship. For details see page 139.

ABOUT HEWLETT-PACKARD

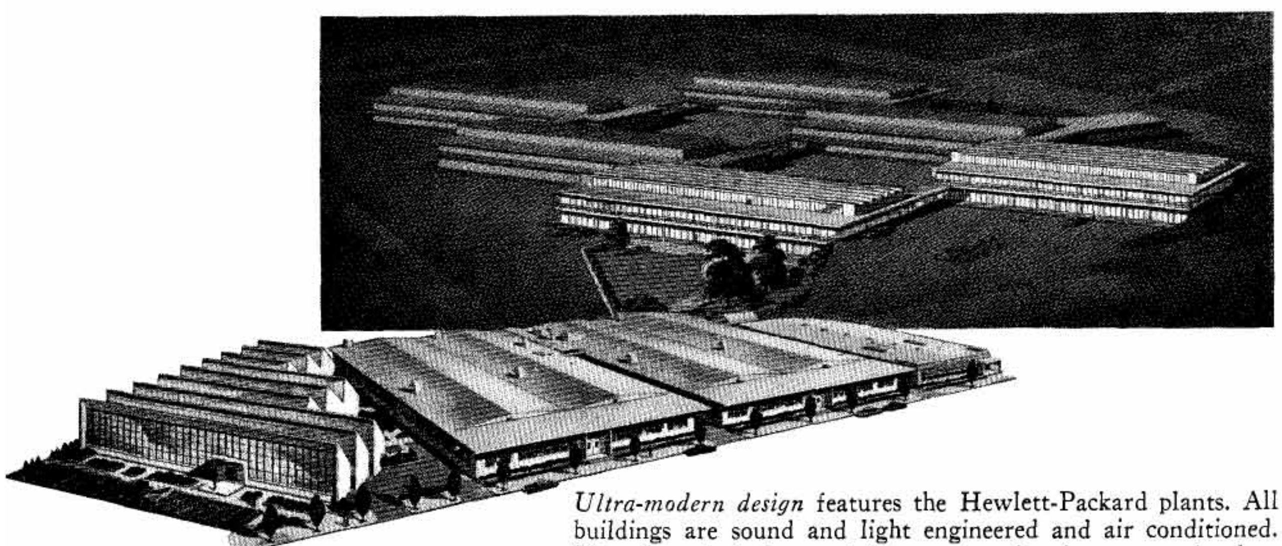
The Hewlett-Packard Company was founded in 1939 in Palo Alto, California. Here, in a suburban community 30 miles south of San Francisco, next door to Stanford University, Hewlett-Packard is squarely in the heart of the important northern California electronics center.

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 18 years, the Company has steadily broadened the instrument line, and now over 300 basic test instruments are manufactured. Among the more important types are oscilloscopes, audio oscillators, vacuum tube voltmeters, noise and distortion analyzers, signal generators, power meters, electronic counters and a complete array of waveguide and coaxial instrumentation for microwave work. The Company is now beginning construction of a totally new plant of six principal buildings on a 40-acre site just south of Palo Alto, California. These buildings will provide a laboratory, manufacturing and research area of over half a million square feet. Approximately 1,300 men and women are now regularly employed, and over 150 field representatives sell and service *-hp-* instruments in the United States, Canada and overseas.

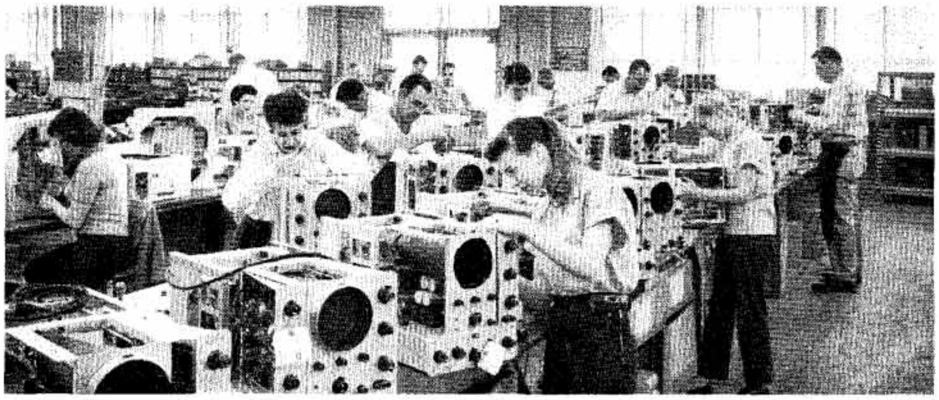
Behind every *-hp-* instrument is a basic philosophy governing equipment design, manufacture, sales and service. This philosophy specifies that there shall be built into each *-hp-* instrument the greatest possible usefulness, accuracy, convenience, dependability and dollar value.

Consistently, Hewlett-Packard has gone to lengths to insure that these standards are met. Every effort has been made to assemble the best engineering staff possible. The Company has sought not only men of skill and experience, but men with vision and daring and a desire to better the best.



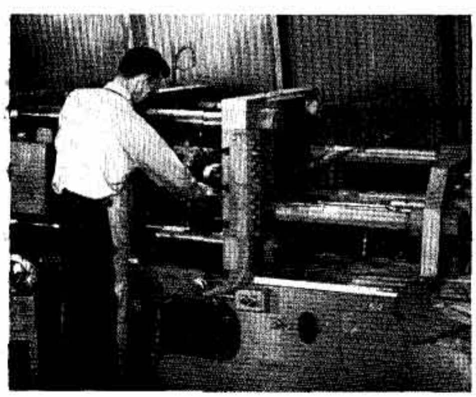
Ultra-modern design features the Hewlett-Packard plants. All buildings are sound and light engineered and air conditioned. The plants include one of the most complete instrument development laboratories in the world, as well as high-efficiency facilities for manufacture, quality control, service and administration.

Another cornerstone of the *-hp-* philosophy is insistence on 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 specialized turret

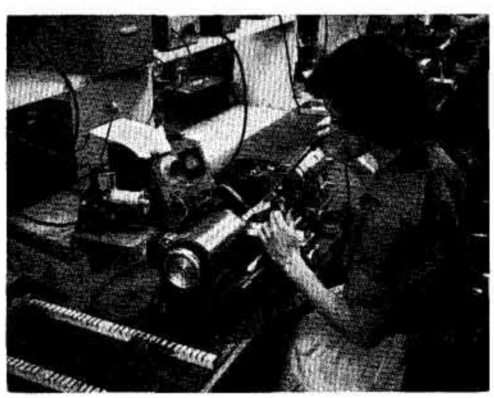


press which punches many sizes of perforations on instrument chassis with a single setup. Other examples include a heavy duty die casting machine for fast production of dial drive housings and other stationary parts, a fully-equipped machine shop for manufacture of precision mechanical parts, and a complete plastic molding department to fabricate special components which are either unobtainable elsewhere, or can be made more quickly and economically at *-hp-*.

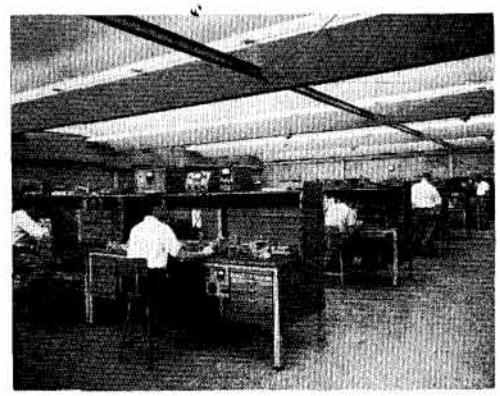
In addition to the different types of commercial machinery, a number of special devices developed by *-hp-* engineers are in daily use. Some of these were developed to meet unusual manufacturing problems; others were "imagineered" to make some special part better, faster, or at lower cost. They include such ingeniously simple units as the Lazy Susans, turntables mounting many resistor boards in a convenient position for assembly. And they include developments which are precision machines in their own right, such as the Kingman machine which stamps out terminal boards in gross quantities.



The -hp- plant is equipped with the most modern manufacturing machinery available for the job. Here is a heavy duty die casting machine for production of housings, shields, dials and other cast parts.

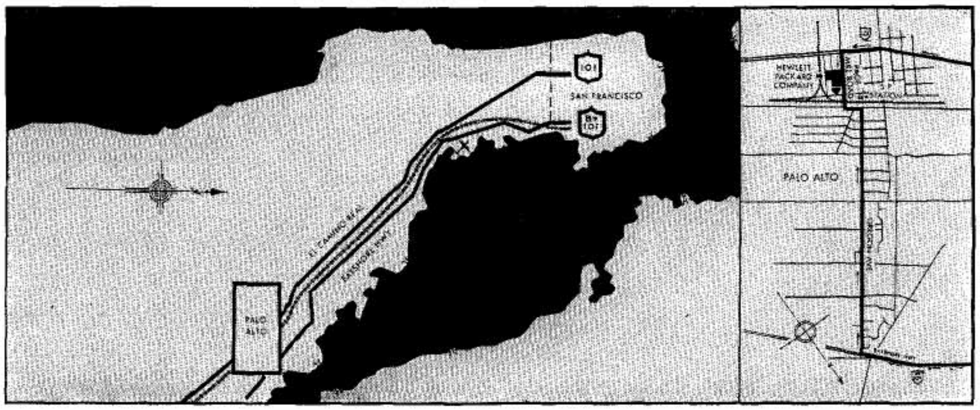


The ingenuity of -hp- engineers has produced many devices to speed and simplify manufacturing, produce better instruments at less cost. This precision lathe for winding resistors handles wire as fine as No. 42.



The new -hp- laboratory provides engineers with the most ideal working conditions possible. Note semi-private work benches, generous aisle space, large number of power outlets and individual power controls.

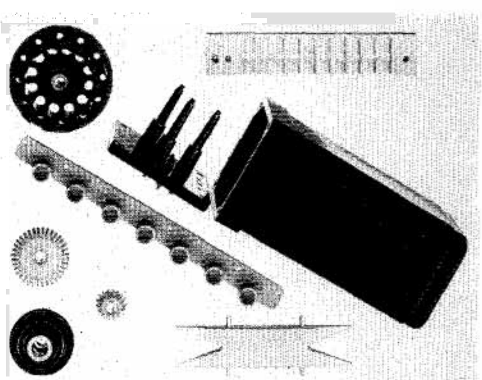
The Hewlett-Packard production policy is also somewhat different from that employed elsewhere. Instruments are manufactured in "runs," and actual fabrication is preceded by careful planning to insure that all parts are available and supplied as



At Palo Alto, home of Stanford University, *-hp-* is located in the heart of the nation's new electronics center on the San Francisco Peninsula. The *-hp-* plant may be reached by Southern Pacific commuter train (to South Palo Alto station), by Greyhound bus, or auto on U. S. 101. San Francisco's International Airport is just 30 minutes drive.

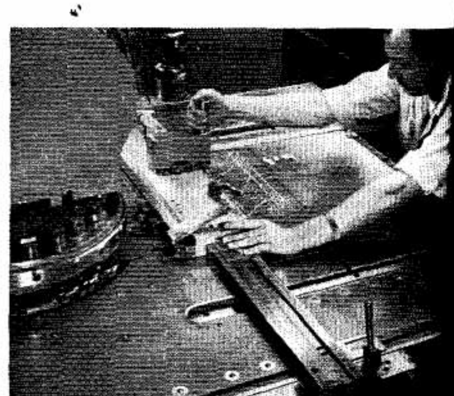
needed to keep the runs progressing smoothly. As many as thirty runs are normally in progress simultaneously, yet production schedules are kept flexible to permit meeting special orders or unusual delivery requirements involving substantial numbers of instruments.

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. For one week of each year, the entire sales organization meets at Palo Alto for an extensive new-information and re-training seminar which includes not only theory but actual "field problem" measuring with *-hp-* instruments and allied equipment. On many additional occasions, *-hp-* representatives return to the plant for special training or instruction on new instruments and measuring methods.



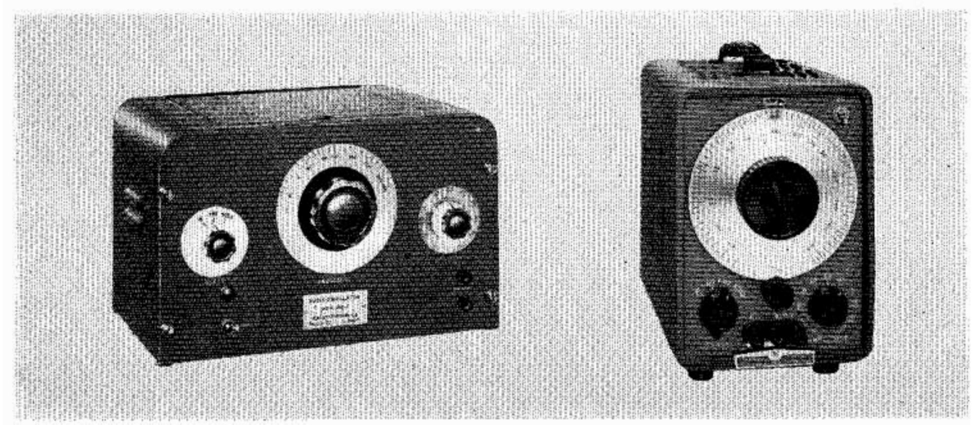
In electronics, special or unusual parts are often hard to find, or prohibitive in cost. To avoid this roadblock to progress, *-hp-* has its own plastics and molding shop, which turns out knobs, escutcheons, Nylon gears, etc.

The Kingman Machine, above, is another device born and built at *-hp-* to make possible faster manufacturing at lower cost. Named for the *-hp-* engineer who "imagineered" it, it mass-produces terminal boards.



Another unit typical of the modern machinery in daily use at *-hp-* is this turret press, a precision equipment which punches many sizes of perforations in instrument chassis with a single setup.

An equally significant part of the annual instruction given *-hp-* engineer representatives involves field servicing *-hp-* equipment. This is an important function of the modern *-hp-* service policy described on a preceding page of this catalog.

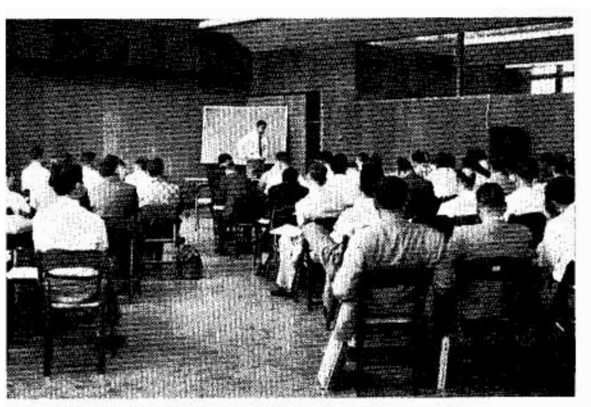


Old and new. Pictured at left are two *-hp-* audio oscillators—the very first instrument (left) and the brand-new Model 200AB oscillator. The *-hp-* line now includes 12 descendants of the original oscillator which was the first low cost oscillator employing the resistance capacity circuit.

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.



Frequently, members of the world-wide *-hp-* field organization return to Palo Alto to learn the newest developments in instruments and the latest in measuring technique. In addition, all return again to the *-hp-* plant for a week-long annual seminar devoted to the operation and application of *-hp-* instruments.

130A LOW FREQUENCY OSCILLOSCOPE

Most Dependable Oscilloscope Offered Commercially

Advantages:

Extreme operating dependability
Brilliant, high resolution trace
Automatic triggering system
Sensitivity 1 mv per centimeter
High gain, balanced input
21 calibrated sweeps; direct reading
Wide pass band, dc to 300 KC
Similar X and Y amplifiers
Twist-off bezel; easy CRT change
High stability, unique versatility
Etched, unitized circuits

Uses:

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

HERE at last is a new kind of oscilloscope—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. *-hp-* 130A provides each of these advantages, and sets new standards for oscilloscope usefulness, simplicity and reliability.

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

Simple operation is an outstanding characteristic of the new 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.

Automatic Triggering

Two novel 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 conditions. 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 X, Y 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 five 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-* 130A are highly stable, requiring virtually no adjustment during operation. Their gain may be standardized by an internal 1,000 cycle 120 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%.

Quick CRT Interchange

-hp- 130A is arranged physically for maximum convenience in use. In addition to concentric, color-coded controls, a tilt bail is provided to raise the instrument to a suitable viewing angle. The CRT bezel removes instantly with 15° rotation, simplifying changing of tubes and filters. The bezel also provides a firm mount for standard oscilloscope camera equipment. An alignment lever provides quick and direct orientation of the CRT trace with the graticule.

Etched Circuitry

Electrically and electronically, the design of Model 130A is highly conservative. Components are operated well below ratings. Etched circuitry is used extensively to stabilize capacities and increase operating dependability and accessibility. The entire instrument is broken down into several sub-assemblies, each functionally integral and readily reachable for servicing.

Specifications

Sweep

Range: 1 μsec/cm to approximately 15 sec/cm.

Calibrated: 21 calibrated sweeps in 1–2–5–10 sequence, 1 μsec/cm to 5 sec/cm. Accuracy within 5%.

Vernier: Permits continuous adjustment of sweep time.

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

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

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

Input Amplifiers

Vertical and horizontal amplifiers have same characteristics.

Sensitivity Range: 1 mv/cm to 50 v/cm.

Common Mode Rejection: Balanced input only. Rejection greater than 40 db. Common mode signal must not exceed 1.5 volts.

Input Attenuator: 14 calibrated ranges, in a 1–2–5–10 sequence, 1 mv/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.

Pass Band: dc to 300 KC, independent of attenuator setting.

Coupling: ac or dc.

Balanced Input: On 1, 2, 5, 10 and 20 mv/cm ranges. Input impedance 2 megohms shunted with 25 μμf.

Single Ended Input: On all ranges. Input impedance 1 megohm shunted with 50 μμf.

Undistorted Deflection: Three screen diameters.

Amplitude Calibrator: Fixed amplitude, accuracy within 5%. Approximately 1 KC square wave.

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.

CRT Bezel: CRT bezel readily removed by a 15° twist, providing rapid means of changing filters and replacing cathode ray tube if different phosphors are required. Bezel locks to provide firm mount for standard oscilloscope camera equipment.

CRT Plates: Direct connection to deflecting plates via terminals through rear access door.

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

Cathode Ray Tube: Five inch mono-accelerator flat face type 5AQP with 3,000 volt accelerating potential. Available with P1, P7, or P11 screen.

Size: Width—9¾"; Height—15"; Depth—21¼".

Weight: Net 39 lbs. Shipping 55 lbs.

Power Supply: 115/230 volts ±10%, 50/1000 cycles, approximately 175 watts.

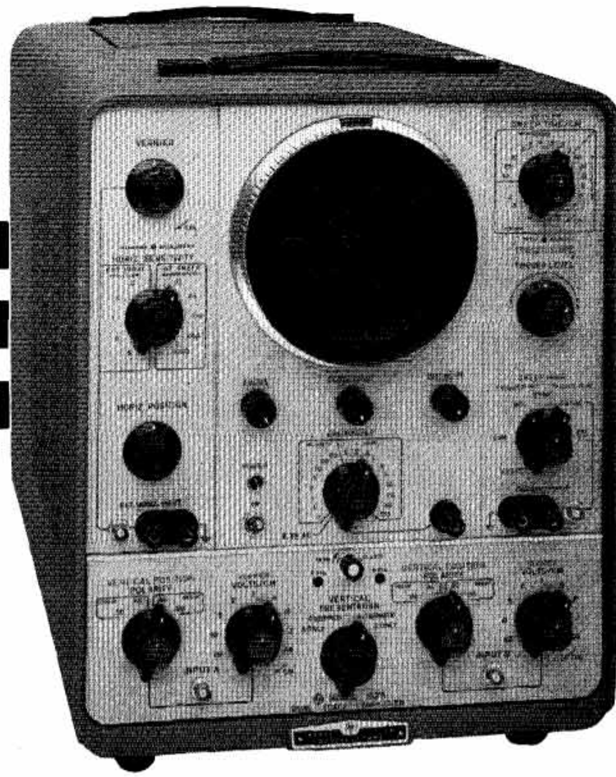
Filter: Color of filter compatible with screen phosphor.

Accessories Available: *-hp-* AC-83A Viewing Hood, $4.50; AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $650.00. (Normally supplied with P1 screen. When ordering with P7 screen, specify 130A-7. When ordering with P11 screen, specify 130A-11.)

Data subject to change without notice.

150A HIGH FREQUENCY OSCILLOSCOPE



Advantages:

- Maximum usefulness, reliability
- Brilliant, full screen high resolution trace
- No halo or bloom effect
- Leading edge of signal always visible
- 5-inch flat face CRT
- 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
- New pen-sized low capacity probe
- Sweep magnification of 5, 10, 50 and 100 x
- Single shot sweep with lock-out
- Twist-off bezel; CRT access door
- Quick CRT interchange
- Etched circuits, 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.

Setting New Standards of Oscilloscope Dependability!

MAXIMUM usefulness, convenience, and utmost electrical and mechanical dependability—these were the objectives in designing the new *-hp-* 150A Oscilloscope. The result is a high frequency instrument which answers more laboratory and production problems more conveniently than previous equipment, and is the industry's most outstanding oscilloscope value.

For maximum usefulness, *-hp-* 150A is designed for operation with plug-in vertical amplifiers. Currently, these include *-hp-* 151A, a high gain unit with 5.0 mv/cm maximum sensitivity and frequency response from dc to 10 MC; and *-hp-* 152A, a dual amplifier permitting two phenomena to be presented on the CRT simultaneously. Either of *-hp-* 152A'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.

0.25 Microsecond Delay Line

The oscilloscope's vertical amplifier provides excellent transient response and less than 0.035 μsec rise time; the pass band is dc to 10 MC. A distortionless 0.25 μsec delay line permits viewing the leading edge of the signal triggering the sweep, and requires no adjustment. A single, direct reading front panel control selects any of 24 calibrated sweep times. No calculation or interpolation is required. Sweep times are accurate within 3% and cover the range 0.02 μsec/cm to 5 sec/cm. The sweep may be triggered by internal or external voltage, or may be free running. Triggering may be accomplished on positive or negative slopes and at positive or negative voltages of +30 to −30 v.

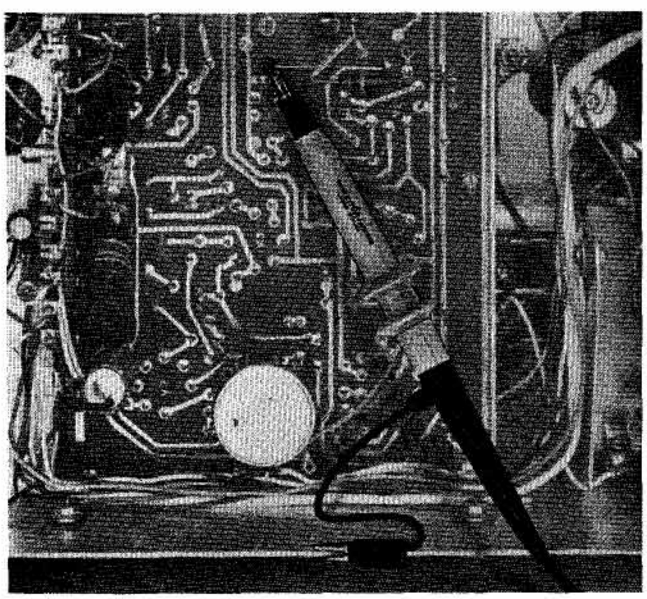
Sweep Magnification

Model 150A's horizontal amplifier provides sweep magnification of 5, 10, 50 and 100 times, and a multi-turn positioning control provides a fine degree of horizontal adjustment so that any 10 cm portion of the magnified scale may be examined. Indicating lamps show when the magnification circuit is in use, or when a combination of sweep time and magnification exceeds the fastest calibrated sweep time. The horizontal amplifier, which has a separate input, also includes a calibrated input attenuator, and has a maximum sensitivity of 200 mv/cm over a pass band from dc to more than 500 KC.

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. After firing, this circuit remains locked out until rearmed manually or electronically. A light indicates when the circuit is armed.

-hp- AC-21A Low Capacity Probe

Custom engineered for use with *-hp-* 150A High Frequency Oscilloscope, Model AC-21A pictured below is a highly convenient, pen-sized probe offering a 10:1 voltage division, 10 megohm impedance and only 10 μμf capacity. Compensating capacity is easily adjustable by rotating one portion of the nylon barrel. The probe is equipped with miniature alligator jaws and has a grounding clip with flexible lead, also fitted with alligator jaws. Model AC-21A is supplied as an accessory with *-hp-* 150A High Frequency Oscilloscope. The probe is also available separately at $25.00.

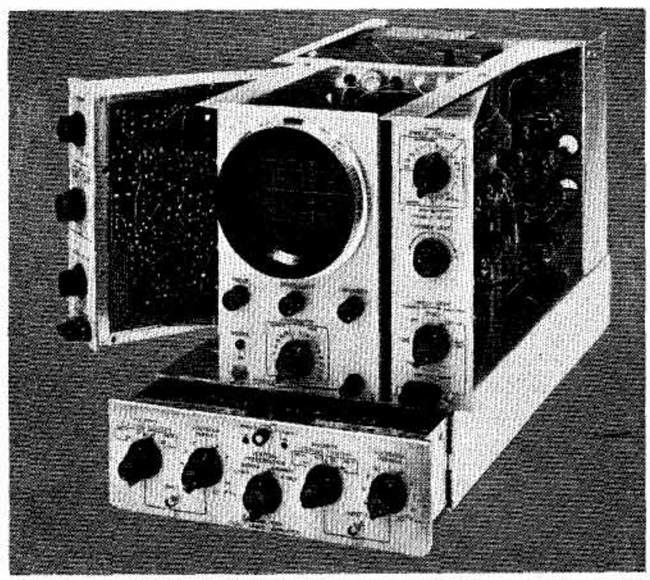


Etched Circuits

Every possible step has been taken to insure the mechanical and electrical convenience and reliability of *-hp-* 150A Oscilloscope. Controls are simplified, direct reading, concentric, color-coded and arranged logically by function. Tubes and circuits are grouped on hinged panels that swing out for simplified testing. Wherever possible, circuits are etched and unitized and may be isolated from the instrument by unplugging. Etched circuits are mounted on translucent plastic for "look-through" convenience. A 15° turn removes the bezel, facilitating filter and CRT interchange. A door on the cabinet top gives direct access to CRT terminals, and a lever inside permits the CRT trace to be aligned with the graticule. The instrument includes a large, high volume cooling fan with renewable air filter. All components are of highest quality obtainable. Model 150A is housed in a lightweight, streamlined metal cabinet equipped with leather carrying straps and a tilt bail for convenient viewing.

Unitized Circuits

The unitized construction illustrated below is a new concept in oscilloscope design. Basic circuit elements are etched or assembled as separate units; circuits may be disconnected without soldering, merely by unplugging. Tubes are instantly accessible on swing-out panels.



Specifications

-hp- 150A

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%.

Vernier: Permits continuous adjustment of sweep time.

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.

Preset Triggering: Switch position on sweep mode control automatically selects optimum setting for stable triggering for majority of conditions.

Single Sweep: Sweep circuits may be set for triggered single sweep operation. After being triggered, sweep remains locked out until reset. Indicator light glows when sweep is armed.

Horizontal Amplifier

Sweep Magnification: Sweep may be expanded 5, 10, 50 or 100 times. Multiturn horizontal positioning control provides a fine degree of adjustment, permits viewing any 10 cm portion of expanded sweep.

Indicators: "Reminder" lights glow when sweep magnifier is used, or when expanded sweep time exceeds fastest calibrated sweep time.

External Input: Pass band dc to over 500 KC. Sensitivity range 200 mv/cm to 25 v/cm. Five calibrated ranges plus vernier.

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.

Input: Through plug-in preamplifier.

General

Amplitude Calibrator: 18 Calibrating voltages in 2, 5, 10 sequence, 0.2 mv to 100 v peak-to-peak, are available at a binding post to provide maximum flexibility. Accuracy within 3%. Approximately 1 KC square wave with rise and decay times less than 1 μsec.

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

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: CRT bezel readily removable by a 15° twist, providing rapid means of changing filters and replacing CRT if different phosphors are required. Bezel locks to provide firm mount for standard oscilloscope camera equipment.

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 500 watts.

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

Size: Width—13½"; Height—17¼"; Depth—25".

Weight: Net 65 lbs. Shipping 105 lbs. (includes one plug-in unit).

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

Accessories Available: AC-21A Low Capacity Probes (specify grey or black lead), $25.00; AC-76A BNC Male to Binding Post Adapter, $5.00; AC-83A Viewing Hood, $4.50; AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25; AC-16K Cable Assembly, $5.00.

Price: $1,100.00. (Normally supplied with P2 screen. For P1 screen, specify 150A-1; for P7 screen, specify 150A-7; for P11 screen, specify 150A-11.)

-hp- 151A High Gain Amplifier

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

Input Attenuator: 12 calibrated ranges, in 0.5, 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 50 μμf.

Pass Band: dc to 10 MC, 0.035 μsec rise time.

Coupling: ac or dc.

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

Weight: Net 10 lbs.

Price: $200.00.

-hp- 152A 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 permits continuous adjustment between ranges.

Input Impedance: 1 megohm shunted with 50 μμf.

Pass Band: dc to 10 MC, 0.035 μsec rise time.

Coupling: ac or dc.

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

Vertical Positioning: Individually adjustable.

Polarity of Presentation: Input signal as applied or inverted.

Input Connectors: Type BNC both channels.

Weight: Net 10 lbs.

Price: $250.00.

Data subject to change without notice.

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 12 separate instruments which are essentially resistance-capacity oscillators. Collectively, they operate from 0.008 cps to 10 MC, covering the audio, sub-sonic, ultra-sonic and low rf regions. A number of these instruments are general-purpose types designed to operate over wide frequency ranges and to provide generous output voltages. Others are designed for particular applications.

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. 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. It also reduces distortion and limits amplitude of oscillations, insuring a constant and stable output over the entire range *(Figure 2)*.

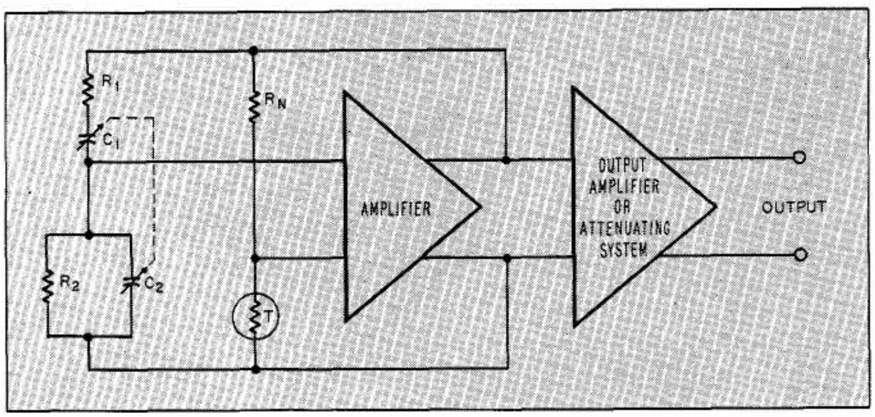


Figure 1. Basic Circuit, *-hp-* RC Oscillator.

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 effective isolation of the oscillator section.

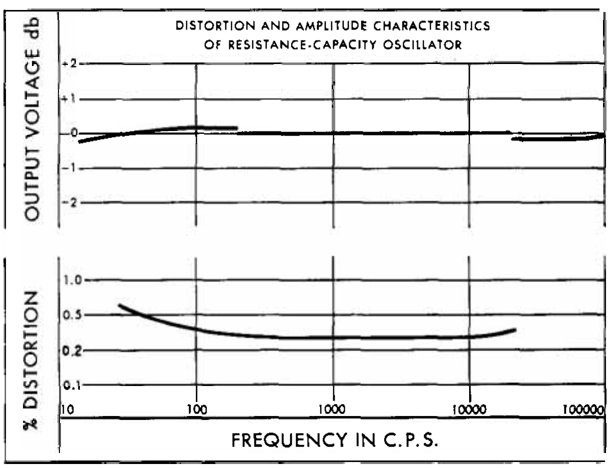


Figure 2. Distortion and Amplitude Characteristics, RC Oscillator.

There are, in general, two types of output circuitry used in *-hp-* 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 *-hp-* 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 satisfac-

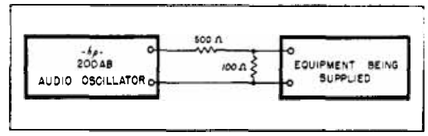


Figure 4. Voltage Divider Circuit.

tory for most applications. Other values of resistance may be used to obtain different voltage divisions but in all cases the sum of the divider resistance must equal the rated load in combination with the input impedance of the equipment under test.

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

Description of -hp- Oscillators

-hp- 200 series Oscillators (see page 16) 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

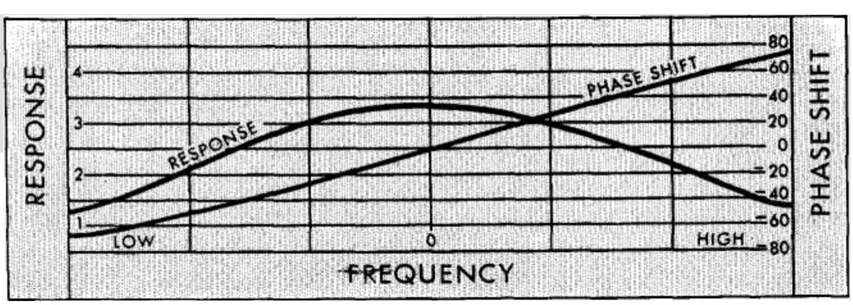


Figure 3. Characteristics of Frequency Determining Network.

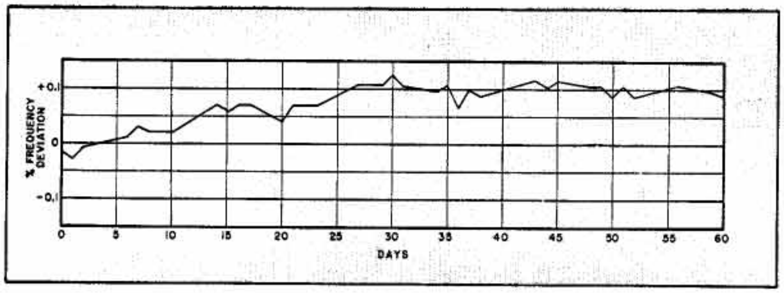


Figure 5. Long-time Stability Curve of circuit using wire-wound resistors and temperature compensation.

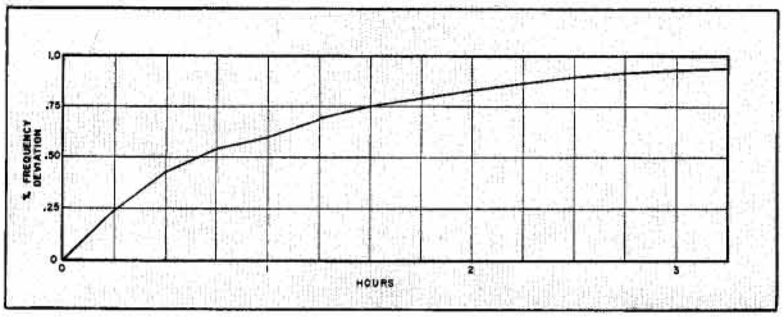


Figure 6. Short-time Stability Curve of RC Oscillator.

is greatly increased by their compact size, light weight and easy portability. *-hp-* 200J is especially suitable for interpolation work and for applications where the frequency of oscillation must be known very accurately.

-hp- 650A (page 22) 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.

-hp- 202A Low Frequency Function Generator (page 20) incorporates a circuit concept developed by *-hp-* and new to the low frequency oscillator field. The instrument's nominal low frequency 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 17) 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.

In audio work there are a number of applications that require test voltages with unusually low distortion. Although *-hp-* RC oscillators are inherently low-distortion generators (with usually less than 1% distortion) *-hp-* 201C Audio Oscillator (page 17) has less than 0.5% distortion at power levels up to 1 watt. Model 201C has an accurate and convenient method of frequency control and is particularly suited to high-fidelity audio work.

-hp- 233A Oscillator (page 24) is widely used in testing carrier-communications equipment. The output system of this instrument is balanced, thus permitting operation directly into balanced lines. Model 233A is a versatile unit and includes many features that make it suitable for testing and adjusting the most advanced types of carrier equipment. It uses 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. It also provides a single-ended output and includes a large tuning dial that gives a high resolution and a convenient arrangement for standardizing calibration.

-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 RDB spectrum for FM - FM telemetering is covered without splitting a single telemetering channel.

The latest *-hp-* RC oscillator is Model 207A Audio Sweep Oscillator. This instrument with its 1,000 to 1 range covers the complete audio frequency spectrum from 20 cps to 20 KC in a single band. It is specifically intended for operation as a swept frequency oscillator when the complete audio range must be covered smoothly and quickly. Output variation is less than ±1 db over the full range.

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 gain of 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. At higher frequency and higher 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 137.

200AB/CD 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:

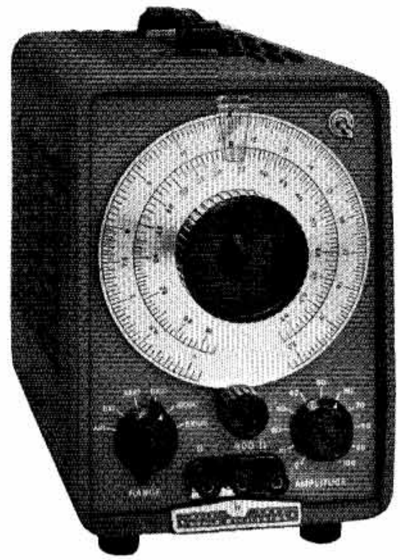
- Amplifier testing
- Transmitter audio response
- Voltage source for bridge measurements
- Modulating signal generators
- Supersonic voltage source
- Driving mechanical systems
- Synchronizing pulse generators
- Loudspeaker resonance tests

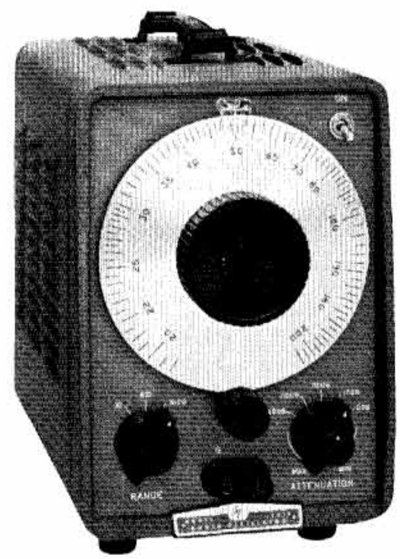
HEWLETT-PACKARD RC oscillators have long been basic tools for making electrical and electronic measurements of precise accuracy. Now these world-famous test instruments are redesigned to give you the most compact, dependable, accurate and easy-to-use commercial oscillators available.

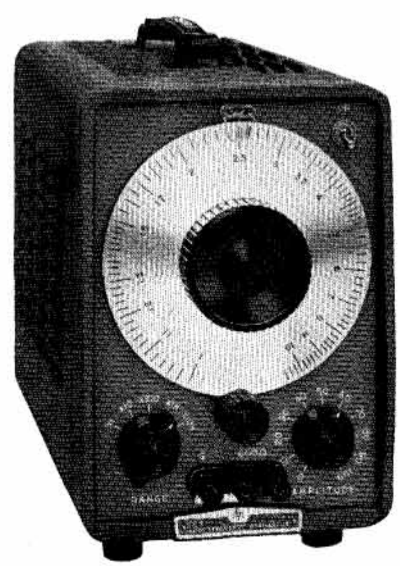
The *-hp-* 200 series oscillators have highest stability and precisely accurate, easily resettable tuning circuits. Low impedance operating levels together with superior insulation guarantee peak performance throughout years of trouble-free service. The instruments have wider frequency range and longer dial lengths than previous *-hp-* oscillators and feature an improved, vernier frequency control. Operation is simplified—just three controls are required. Size, too, is different—instruments are more compact, lighter in weight and enclosed in a convenient, smaller aluminum case with carrying handle. They occupy minimum bench space and are easily portable. (Rack mounting available on order.)

The total coverage of *-hp-* 200AB and 200CD oscillators is materially greater than that offered by four previous *-hp-* instruments. For example, Model 200AB, for general audio tests, offers a wider frequency range of 20 cps to 40 KC and a full watt output. *-hp-* 200CD, for wide range measurements at lower power, provides constant voltage output from 5 cps to 600 KC. *-hp-* 200AB, $130.00; *-hp-* 200CD, $160.00.

200J, 201C, 202C OSCILLATORS







-hp- 200J Interpolation Oscillator

THIS new ultra-precision instrument replaces the well-known *-hp-* 200I and is designed 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 10 volts into 600 ohms (160 mw), 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. $275.00.

-hp- 201C Audio Oscillator

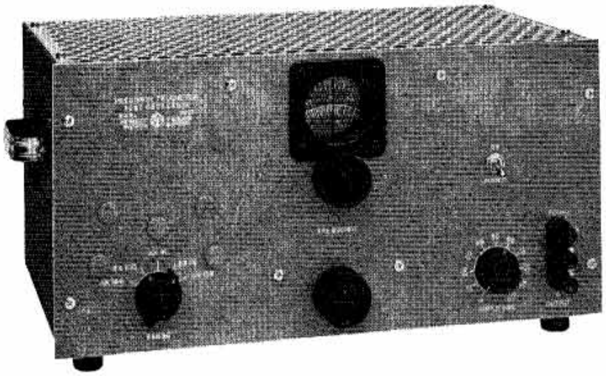
Particularly designed for amplifier testing, transmission line measurements, loud speaker testing, frequency comparison and other high fidelity tests, this new audio oscillator meets every requirement for speed, simplicity and pure wave form. It replaces the popular *-hp-* 201B, but has a more accurate attenuator, new compact cabinet, and lower price. The frequency range 20 cps to 20 KC is covered in 3 bands with calibration accuracy of 1.0% and frequency stability of ±2.0% or 0.2 cps. Frequency response is ±1 db full range. Output is 3 watts or 42.5 volts into 600 ohms; the output attenuator adjusts voltage 0 to 40 db and provides either low impedance or constant 600 ohm impedance. Distortion above 50 cps is less than 0.5%. $225.00.

-hp- 202C Low Frequency Oscillator

Replacing the established *-hp-* 202B, new model 202C brings to the low frequency spectrum the accuracy and stability you associate with audio measurements. It provides excellent wave form throughout its broad frequency range of 1 cps to 100 KC, and has unique usefulness in industrial, field or laboratory work. Offering an output of 160 mw or 10 volts into 600 ohms, or 20 volts open circuit, Model 202C is extremely convenient for vibration, stability, electro-cardiograph, electro-encephalograph and other measurements in the subsonic, audio and supersonic 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. $300.00.

Data subject to change without notice.

General specifications of these and other *-hp-* 200 series oscillators appear on the following page.



-hp- 200T Telemetry Oscillator

MODEL 200T is designed to provide 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 evaluation of telemetering circuits, determination of carrier current equipment operation, and measurement of characteristics of sharply tuned filters. *-hp-* 200T covers frequencies 250 cps to 100 KC with good overlap; output is 160 mw or 10 volts into 600 ohms, or 20 volts open circuit. The instrument is compact, versatile and moderately priced at $350.00.

Specifications

Model	Frequency Range	Calibration Accuracy	Output to 600 Ohms	Recommended Load	Maximum Distortion	Max. Hum & Noise ¶	Input Power	Weight—Lbs. Net	Weight—Lbs. Ship	Size (Inches) W H D	Price
200AB	20 cps to 40 KC (4 bands)	±2%	1 watt (24.5 v)	600 ohms	1.0%	0.05%	65 watts	15	22	7½ x 11½ x 12¼	$130.00
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%	110 watts	23	29	7½ x 11½ x 14¼	$160.00
200J	6 cps to 6 KC (6 bands)	±1%†	160 mw 10 volts	600 ohms*	0.5%	0.1%	110 watts	23	29	7½ x 11½ x 14¼	$275.00
200T	250 cps to 100 KC (5 bands)	±1%†	160 mw 10 volts	600 ohms*	0.5%	0.03%	170 watts	27	42	18¾ x 9¼ x 11¾	$350.00
201C	20 cps to 20 KC (3 bands)	±1%†	3 watts (42.5 v)	600 ohms**	0.5%‡	0.05%	75 watts	16	23	7½ x 11½ x 12½	$225.00
202C	1 cps to 100 KC (5 bands)	±2%	160 mw 10 volts	600 ohms*	0.5%§	0.1%	110 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 5000 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. §0.5%, 10 cps to 100 KC. 1.0%, 5 to 10 cps. 2.0% at 2 cps. 3.0% at 1 cps. ¶Measured with respect to full rated output.

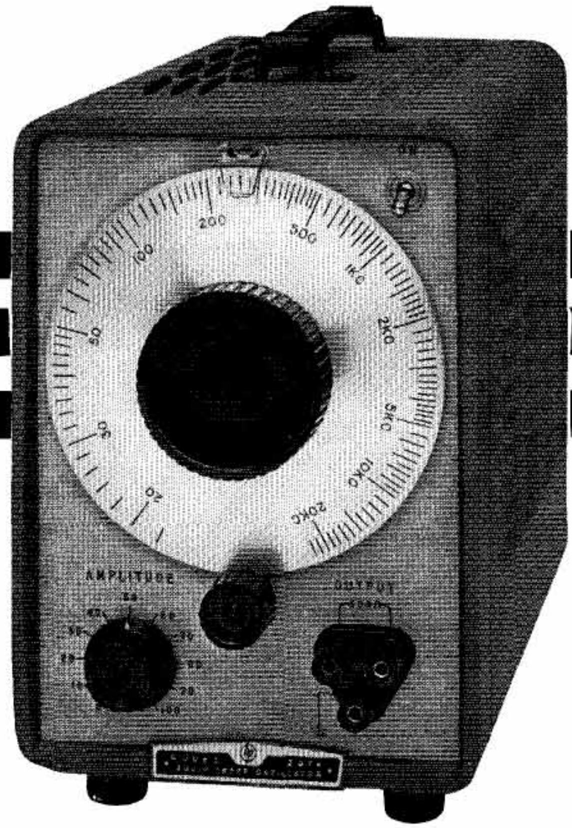
Frequency Response: Flat ±1 db over instrument range. Reference level at 1 KC except *-hp-* 200T at 5 KC.

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, $4.00; AC-16B Cable Assembly, $4.25; AC-60A Line Matching Transformer (200CD and 200T), $25.00.

Data subject to change without notice.



Continuous Coverage 20 cps to 20 KC For Swept Audio Tests

NEW -*hp*- 207A Audio Sweep Oscillator provides the unique convenience of continuous frequency coverage 20 cps to 20 KC without tedious band switching. Accuracy is ±4% including error induced by component aging, tube changes or warm-up variations. The instrument also offers an unusually flexible 10 volt into 600 ohm output which may be used whether balanced or with one side grounded. Frequency response over the full frequency range is within ±1.0 db, distortion is less than 1.0%, and hum voltage is less than 0.1% of rated output.

In operation, the instrument's output frequency may be controlled by a convenient, direct reading 6″ frequency dial (calibrated through 300° of arc). Or, the oscillator may be swept mechanically or tuned with a shaft which projects from the rear of the equipment. This mechanical drive (which can be motor driven) sweeps the instrument through its full frequency range with 150° of rotation.

Since -*hp*- 207A provides continuous one-band audio frequency coverage as well as flexible output, it is a most useful signal source for rapid audio testing.

Specifications

Frequency Range: 20 cps to 20 KC, covered in one range.

Accuracy: ±4% including changes due to warm-up, aging components, tubes, etc.

Dial: Six-inch diameter dial calibrated over 300° of arc.

Frequency Response: ±1 db entire frequency range.

External Frequency Control: ¼-inch shaft, extending from rear of instrument, rotation approximately 150° for full frequency coverage.

Output: 10 volts into 600 ohm rated load, balanced or 1 terminal at ground.

Output Control: Decreases level continuously by more than 40 db.

Distortion: Less than 1% over entire frequency range.

Hum Voltage: Less than 0.1% of rated output. Decreases as output is attenuated.

Power: 115/230 volts ±10%, 50/1,000 cps, 75 watts.

Dimensions: Cabinet Mount: 7½″ wide, 11½″ high, 15¼″ deep. Rack Mount: 19″ wide, 7″ high, 12½″ deep.

Weight: Approximately 25 lbs.

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $275.00.

Data subject to change without notice.

202A LOW FREQUENCY FUNCTION GENERATOR

Advantages:

- No transients
- Range 0.008 to 1,200 cps
- Continuously variable
- High stability
- Flat frequency response
- Distortion less than 1%
- Sine, square, triangular waves
- Versatile, multi-purpose

Use It For:

- Vibration studies
- Servo applications
- Medical research
- Geophysical problems
- Subsonic, audio testing

Transient-Free Voltages Down to 0.008 cps

THE *-hp-* Model 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 wave forms—sine, square or triangular—may be instantly selected by a front panel switch. Output is high—30 volts peak-to-peak—for all three wave forms and is essentially constant over the entire frequency range.

New Circuit Concept

-*hp*- 202A differs from conventional low-frequency oscillators in that the sine wave is electronically synthesized. A controlled bi-stable circuit generates a rectangular wave. This wave is passed through a special integrator providing a true triangular wave. *(See Figure 2A.)*

The triangular wave then enters a shaping circuit designed by -*hp*- exclusively for this equipment. In this circuit, 6 duodiode tubes modify or "shape" the peaks of the wave and provide a true sine wave. *(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 -*hp*- 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.

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 warm-up 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.

Distortion: Less than 1%, 0.008 to 100 cps; 2%, 100 to 1,200 cps.

Output System: Can be operated either balanced or single-ended. Output system is direct-coupled; dc level of output voltage remains stable over long periods of time. DC adjustment available on front panel.

Frequency Response: Constant within 0.2 db.

Hum Level: Less than .01% 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 $\pm$10%, 50/1,000 cps, 175 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¼" deep. Rack Mount: 19" wide, 10½" high, 13" deep. Also can be used with -*hp*- AC-17 End Frames.

Weight: Net 43 lbs. Shipping 63 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $465.00.

Data subject to change without notice.

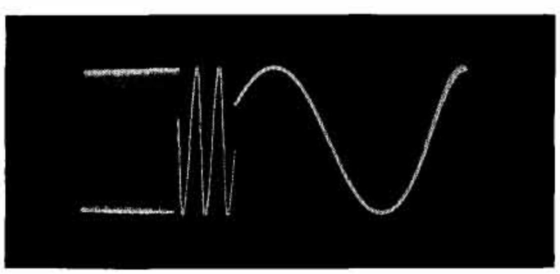


Figure 1. Oscillogram shows freedom from transients as output frequency is rapidly changed.

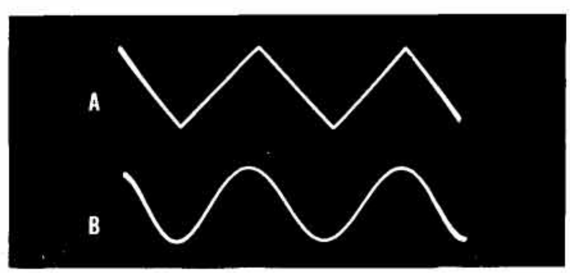


Figure 2. Oscillogram of (A) triangular wave applied to special -*hp*- developed shaping circuit and (B) resulting true sine wave.

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

Fast, Accurate Tests 10 cps to 10 MC

THE *-hp-* Model 650A Oscillator is another of the famous *-hp-* resistance-tuned oscillators. It 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, supersonic, 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 tuned 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 micro-drive for hair-line 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 attenuator system. The VTVM is calibrated in volts and decibels and reads actual output voltage when the attenuators are set for zero attenuation. For other attenuator settings true output voltage is obtained by subtracting the attenuator reading from the output voltmeter reading. The output attenuator is adjustable in 10 db steps and maximum attenuation is 50 db. 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-hundreth 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.

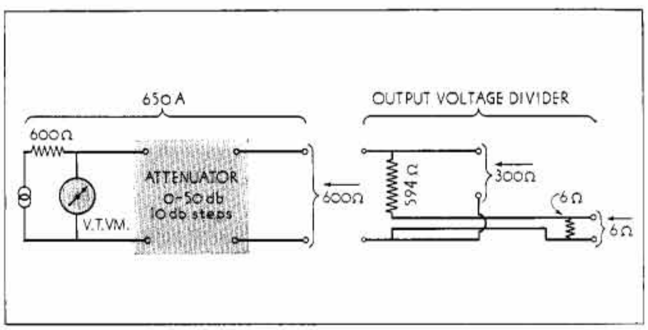


Figure 1

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-tuned circuit as -*hp*- audio oscillators (see pages 13, 14, 15 for description of -*hp*- resistance-tuned 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 bands.

Frequency Calibrations: 1 to 10.

Multiplying Factor	*Frequency Range*
x10 cps	10 to 100 cps
x100 cps	100 to 1000 cps
x1 KC	1000 to 10,000 cps
x10 KC	10 to 100 KC
x100 KC	100 to 1000 KC
x1 MC	1 to 10 MC

Stability: ±2%, 10 cps to 100 KC, ±3%, 100 KC to 10 MC including warm-up, line voltage variations, and tube changes.

Output: 15 milliwatts or 3 volts into 600 ohm resistive load. Open circuit voltage is at least 6 volts. 600 ohm source impedance. Source impedance of 6 ohms is available when voltage divider is used.

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. Approximately 5% from 100 KC to 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 maximum attenuated signal level.

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

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13" deep. Also can be used with -*hp*- AC-17 End Frames.

Weight: Net 46 lbs. Shipping 66 lbs. (cabinet mount).

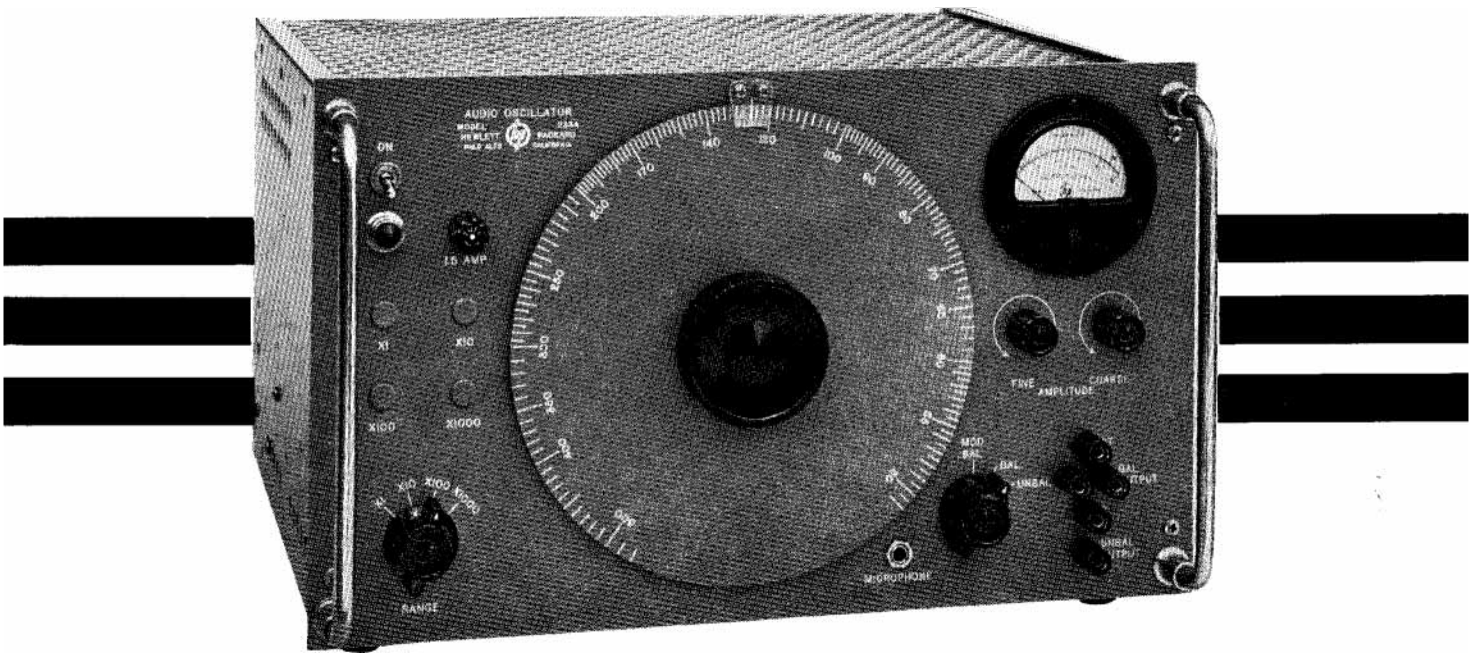
Accessories Furnished: 1 65A-16D Voltage Divider.

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $490.00.

Data subject to change without notice.

233A CARRIER TEST OSCILLATOR



Specifications

Frequency Range: 50 cps to 500 KC. 4 decade bands.

Frequency Dial: 3:1 vernier control knob. 9" in diameter, 270° arc. Effective scale 85". Effective calibration points approximately 520.

Frequency Stability: ±2% under normal room temperatures including initial warmup. ±10% line voltage variations result in negligible change in output frequency.

Frequency Adjustment: May be standardized periodically for maxi mum calibration accuracy. (Approx. 1%.) Each band trimmed by panel screwdriver control.

Output No. 1. 3 watts into 600 ohm balanced load (42.5 volts), 5 KC to 500 KC. Internal impedance 100 ohms, 5 KC to 100 KC, approx. 200 ohms at 500 KC. To match 600 ohms load impedance, approx. 200 ohms resistor pad required in each side of line.

Output No. 2. Approx. 6 volts into a 600 ohm load, 50 cps to 500 KC, one terminal at ground. Internal impedance approx. 6 ohms.

Frequency Response: Output No. 1 — ±1 db, 5 KC to 500 KC.
Output No. 2 — ±1 db, 50 cps to 500 KC.

Distortion: Output No. 1—1%, 10 KC to 100 KC at 2 watts; 3% 10 KC to 100 KC at 3 watts; 4%, 5 KC to 500 KC at 3 watts. Output No. 2—Less than 1% distortion operating into 600 ohm load, 50 cps to 100 KC.

Modulation: No. 1 output modulated at voice frequencies from 5 KC to 500 KC. Modulation by means of telephone test set.

Hum Voltage: Less than 0.1% of full output.

Amplitude Control: Adjusts level on both No. 1 and No. 2 output terminals.

Voltmeter: Monitors output No. 1 in volts and db (reference 1 mw in 600 ohms).

Power: 115/230 v ±10%, 50/1,000 cps, 160 watts.

Dimensions: Cabinet Mount—17¼" wide, 11" high, 15⅛" deep.

Weight: Net 39 lbs. Shipping 73 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $475.00.

Data subject to change without notice.

Fast, Accurate Checking of Carrier Systems Up to 500 KC

THIS *-hp-* oscillator was designed specifically for checking carrier current systems operating at frequencies up to 500 KC. 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 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.

For maximum readability and accuracy in setting frequency, the instrument has a large, 9" diameter dial calibrated to give an effective scale length of 85" with 520 calibration points. Panel controls adjust the frequency of each band to maintain maximum oscillator accuracy.

AUDIO SIGNAL GENERATORS

ONE of the basic instruments 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 combination of readings of voltmeter indication and attenuator setting.

-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, 10 microvolts to 150 volts. (5 watts), with less than 1% distortion. *-hp-* 205AG includes an additional

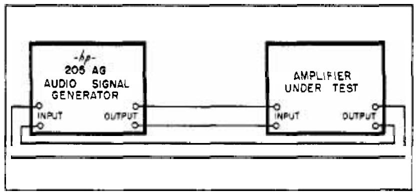


Figure 2. Typical test set-up.

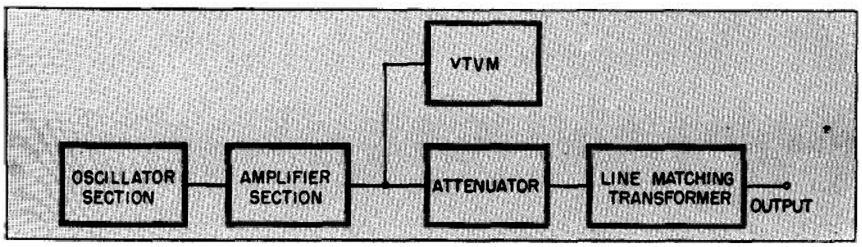


Figure 1. Elements of a signal generator.

signal sources for distortion measurements, in production testing or general laboratory work and in other applications where an accurate, quickly-obtainable 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. This is accomplished by switching taps on the output transformer. The frequency is determined by proper setting of the oscillator. The voltmeter indicates voltage at attenuator input terminals, while attenuator setting controls voltage delivered at output terminals. The output voltage level is determined by a 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. The frequency response of this model is flat within ±0.2 db from 30 cps to 15 KC when the VTVM reading is held constant. *-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, 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.

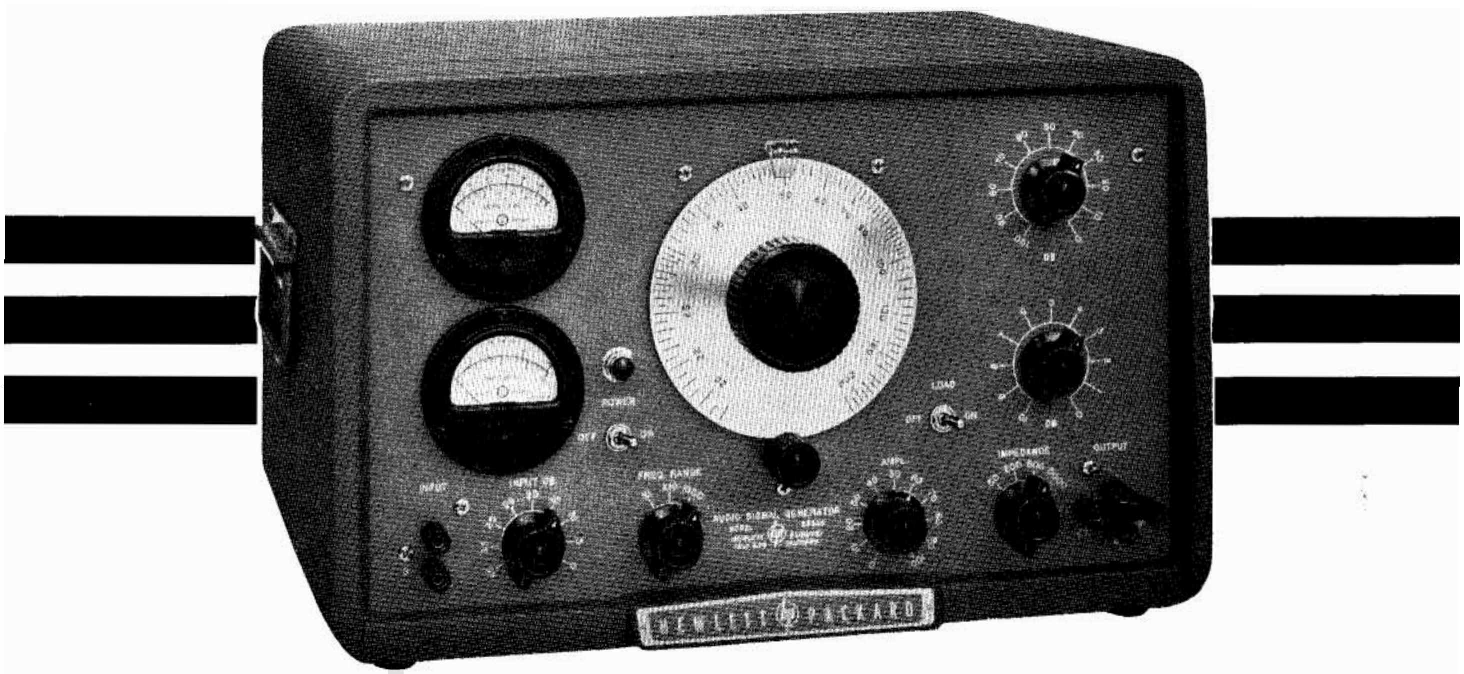
With an attenuator setting of zero, the source impedance of *-hp-* 205AG is very low in order to permit maximum power transfer to the load. In applications where a matched source impedance is required one of two procedures should be employed.

(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. The impedance is constant at 600 ohms under all conditions.

205AG AUDIO SIGNAL GENERATOR



Advantages:

- No auxiliary equipment needed
- Range—20 to 20,000 cps
- 5 watts output, less than 1% distortion
- No zero setting
- Supplies known voltage
- Output meter calibrated in volts and decibels
- Standardized frequencies instantly available
- Separate input meter for gain measurements
- Wide range of output impedances

Use It For:

- Amplifier gain measurements
- Network frequency response
- Source of voltage for distortion measurements
- Broadcast transmitter audio response
- Loudspeaker response
- General laboratory applications
- Production testing

Six Basic Instruments Combined to Speed Gain Measurements

ALL THE necessary instruments for accurate gain or frequency response measurements have been assembled by *-hp-* engineers in one compact unit. No auxiliary equipment is required.

This Audio Signal Generator brings new speed and ease to testing jobs. Any desired frequency within the range of 20 to 20,000 cps is made available by the resistance-tuned audio oscillator. These frequencies are developed at any desired voltage between 150 volts and 50 microvolts.

To make amplifier or network gain measurements with the *-hp-* Model 205AG Audio Signal Generator, the operator simply connects input and output leads to the binding posts.

Two vacuum tube voltmeters are provided, one to measure input and the second to measure output of the device under test. The input VTVM has a range of —5 dbm to + 48 dbm, (0 dbm is 1 mw in 600 ohms). The output level is adjusted by means of the step attenuators. The output impedance can be instantly changed by means of a selector switch to the commonly used impedances of 50, 200, 600, and 5,000 ohms, a convenience in matching various types of networks. The *-hp-* 205AG will supply 5 watts output with less than 1% distortion, and thus is useful where sizeable amounts of power are required.

The *-hp-* Model 205AG is well adapted to measuring frequency response and gain or loss of any network. The frequency remains accurate, without the necessity of zero setting. *-hp-* Audio Signal Generators are built for heavy duty and long, hard service.

Specifications

Frequency Range: The frequency coverage is 20 cps to 20,000 cps in three ranges:

X1	20 cps to 200 cps
X10	200 cps to 2,000 cps
X100	2,000 cps to 20,000 cps

Calibration: The dial is calibrated directly in cycles for the lowest range, 20 cps to 200 cps. A switch selects the desired range and indicates the proper multiplying factor. Each range covers approximately 270 degrees on the 6½" main dial.

Stability: Under normal temperature conditions the frequency will drift less than 2% over long periods of time.

Output: Five watts output will be delivered to a matched resistance load.

Load Impedances: A switch selects transformer taps for use with loads of 50, 200, 600 and 5,000 ohms. The output circuit is balanced and center tapped and any terminal may be grounded. The internal impedance is approximately 1/5 of the load impedance with zero attenuator setting at frequencies up to 5 KC. (Increases above 5 KC.) The internal impedance approaches the load impedance with attenuator settings of 20 db or more.

Frequency Response: The frequency response of the system beyond output meter is flat within ±1 db at all frequencies and all output levels.

Distortion: The distortion is less than 1% at rated output at all frequencies above 30 cps.

Hum Level: The hum level is 60 db below the output voltage or 90 db below zero level, whichever is the larger.

Output Meter: Output VTVM: 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: Input VTVM: range from −5 dbm to +48 dbm (0 dbm is 1 mw in 600 ohms). Meter scale is calibrated from −5 to +8 dbm. Multiplier switch adds from 0 to 40 db in 5 db steps. Input frequency response: ±0.2 db, 20 to 20,000 cps. Impedance is 5,000 ohms.

Output Attenuator: 110 db in 1 db steps. Consists of 100 db in 10 db steps and 10 db in 1 db steps.

Power: 115/230 v ±10%, 50/1,000 cps, 125 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13" deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 55 lbs. Shipping 77 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $440.00.

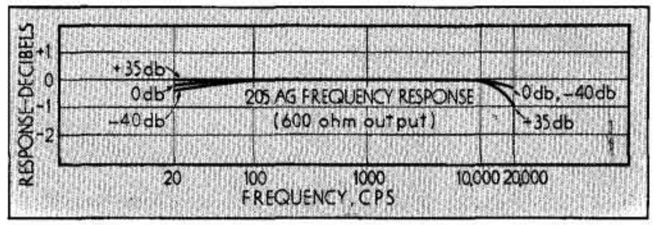


Figure 1. Typical frequency response of *-hp-* 205AG output section. (Response of attenuator and line matching transformer.)

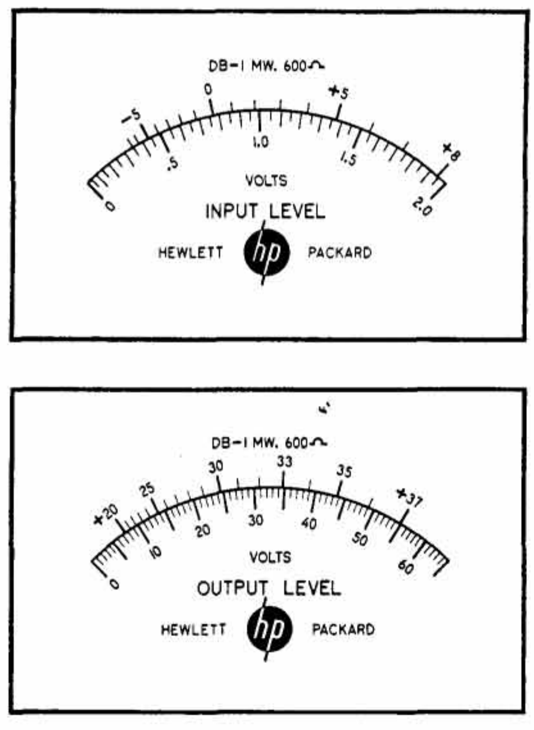


Figure 2. Input and Output Meters, *-hp-* 205AG. Input meter (top) is directly calibrated in dbm based on level in a 600 ohm circuit. Attenuator extends range by 40 db in 5 db steps. Output meter is directly calibrated in volts and dbm for operating into 600 ohm circuits.

Data subject to change without notice.

206A AUDIO SIGNAL GENERATOR

Continuously Variable Audio Signals Less Than 0.1% Distortion

Advantages:

- Continuously variable af voltage
- Accuracy 0.2 db, any level
- High stability
- Harmonic distortion less than 0.1%
- 111 db attenuator, 0.1 db steps

Use It For:

- Audio voltage source
- Checking FM transmitter response and distortion
- Checking broadcast studio performance
- High-quality amplifier testing
- Transmission measurements

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.

Circuit Description

The circuit arrangement of the Model 206A is shown in the block diagram, Figure 1. 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. This serves to reduce the percentage of harmonic distortion in the voltage reaching the instrument's output terminals.

The selective amplifier is followed by an output amplifier, a vacuum tube voltmeter, an attenuator and finally an output matching transformer. An electronic voltage regulator supplies plate voltage for the complete circuit.

Frequency Determining Network

The frequency determining network in the instrument's oscillator section is composed of low temperature coefficient elements, so that the instrument will have good stability over long periods of time. The frequency calibration of the instrument is accurate within 1%. Frequencies from 20 cps to 20 KC are continuously available. Three decade frequency ranges provide an effective scale length of 47″. The tuning dial is controlled directly or with a 6 to 1 vernier micro drive for hairline adjustments. The dial is read through a no-parallax illuminated window.

The output of the amplifier is measured by a vacuum tube 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.

Output System

The *-hp-* 206A generator includes an output matching transformer which allows it to be matched to resistive

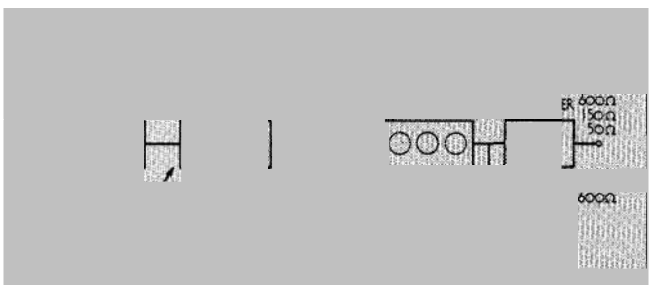


Figure 1

loads of 50, 150 and 600 ohms. This output system is balanced to ground and each winding is center-tapped. The internal impedance matches the load impedance.

A single ended 600 ohm output is provided which bypasses the line-matching transformer. This output connection results in superior distortion and frequency response characteristics.

Uses

This instrument is specifically designed for testing high quality audio circuits. It is suitable for FM transmitter maintenance, studio amplifier and console testing, as a low distortion source for bridge measurements, for use as a transmission measuring set, and for any application requiring a low-distortion, accurately-known audio test signal.

Specifications

Frequency Range: The frequency coverage is 20 cps to 20,000 cps in three ranges:

X1	20 cps to 200 cps
X10	200 cps to 2,000 cps
X100	2,000 cps to 20,000 cps

Calibration: The dial is calibrated directly in cycles for the lowest range, from 20 to 200 cps. Each range covers approximately 270 degrees of the 6″ dial. The dial is located behind the panel and is illuminated. A six to one rim drive enables the equipment to be easily and quickly set to any desired frequency.

Stability: The frequency is calibrated to within better than 1% when the instrument leaves the factory. The circuit elements in the frequency determining network have low temperature coefficients and good stability so that better than 2% accuracy will be maintained over long periods of time.

Output: The equipment will deliver an output level of +15 db above 1 mw 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: The frequency response of the system is better than 0.2 db at all levels, 30 cps to 15 KC, when the output meter reading is held constant.

Distortion: The total harmonic distortion in the output voltage is less than 0.1% at frequencies above 50 cps and less than 0.25% from 20 cps to 50 cps.

Hum Level: The residual hum and noise in the output signal is at least 70 db below the output signal or more than 100 db below zero level, whichever is the larger.

Output Meter: The output voltage is measured ahead of the attenuators by a 4″ square meter calibrated in dbm and also in volts. The meter has a scale which can be read to at least 0.2 db at all points above a 50% scale reading. (Zero dbm equals 1 mw in 600 ohms.)

Output Attenuators: Output attenuators provide a range of 111 db in 0.1 db steps. The accuracy of the attenuator is ±0.5 db at attenuations up to 80 db and ±1 db above 80 db.

Power: 115/230 v ±10%, 50/1,000 cps, 145 watts.

Dimensions: Cabinet Mount: 20½″ wide, 12½″ high, 14¾″ deep. Rack Mount: 19″ wide, 10½″ high, 13″ deep. Also can be used with *-hp-* AC-17 End Frames.

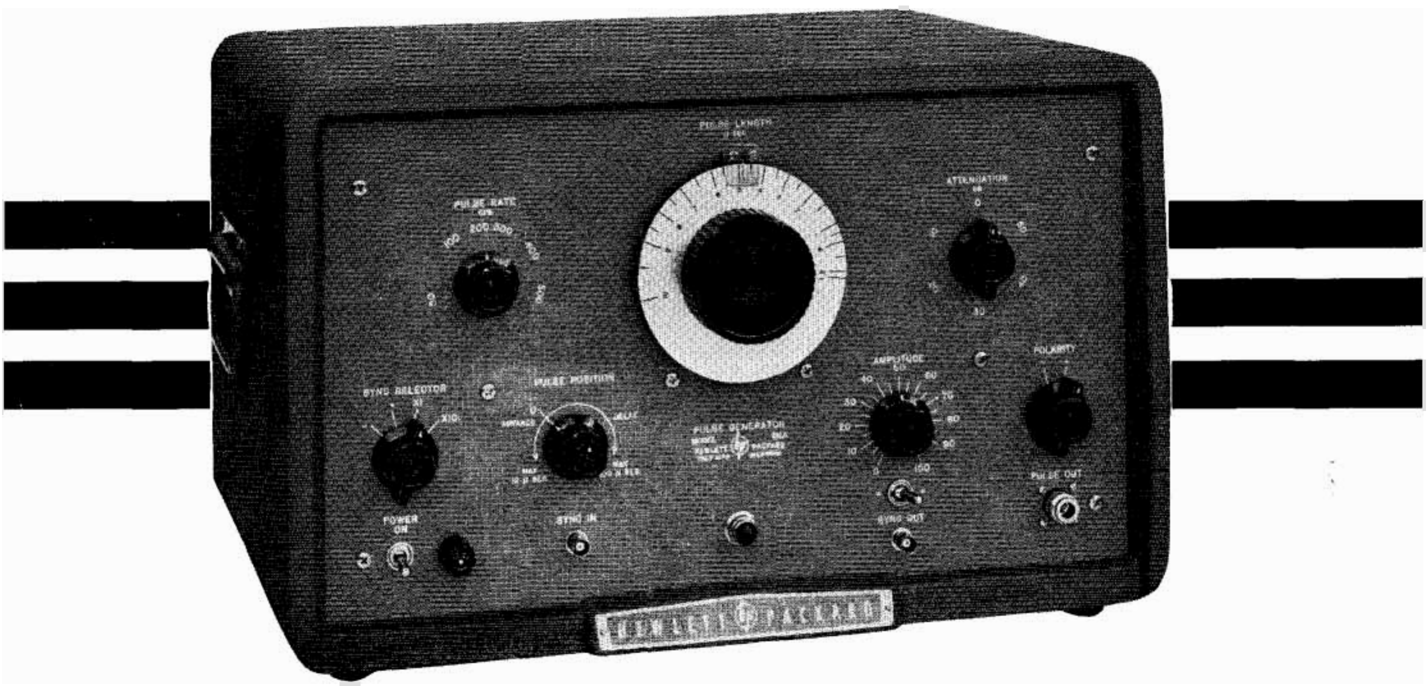
Weight: Net 56 lbs. Shipping 77 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $565.00.

Data subject to change without notice.

212A PULSE GENERATOR



Advantages:

- Broadest usefulness
- 50 watt peak pulses
- 0.02 μsec rise and decay
- Positive or negative pulses
- Complete synchronization
- Freedom from jitter

Uses:

- Radar, TV and nuclear work
- Testing rf amplifiers, filters, band pass circuits, oscilloscopes
- Checking peak measuring equipment
- Pulse-modulating uhf signal generators

Basic Test Instrument for Radar, TV and Other "Fast" Circuits

THE MODEL 212A Pulse Generator is designed for versatility and time-saving convenience. It offers positive or negative pulses, and may be synchronized to other equipment through built-in delay and advance sync out circuits. It offers continuously variable pulses from 0.07 to 10 microseconds. It has a direct-reading pulse length control, and 50 watts of pulse power. It offers high quality pulses with very fast rise and decay time, "flat" top, and minimum overshoot. (See Figures 1 and 2.) 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.

In addition to radar, TV and nuclear work the generator is useful for testing response of rf amplifiers, filters, band pass circuits, oscilloscopes; to check peak measuring equipment, modulate rf carriers, or pulse modulate uhf signal generators.

Double Pulses

Double pulses, useful for checking resolution time of pulse counters, can be obtained by connecting a stub line across the output of the generator. (See Figure 3.) In this application, pulse spacing is determined by the length of the stub line. When multiple pulses are required (for checking pulse position modulated equipment, as an example), *-hp-* 212A Pulse Generators can be connected in parallel. Pulse shape is well maintained, and a generous output voltage is available even when a number of units are paralleled to make a pulse train. In this application, the position, lengths and heights of the various pulses are fully variable. (For further information see *-hp-* Journal, Volume 5, Number 10.)

Output System

In the 212A, the major output pulse is applied to the output terminals through a step attenuator providing 50

Figure 1. 0.07 microsecond pulse delivered by *-hp-* Model 212A.

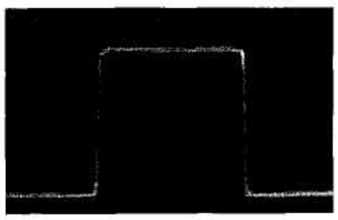


Figure 2. 1.0 microsecond pulse delivered by *-hp-* Model 212A.

db of attenuation in 10 db steps. Use of this attenuation does not cause deterioration of pulse shapes, even when small pulse voltages are desired. A continuously-variable amplitude control is also provided for making fine adjustments of output voltage. Maximum amplitude of the major output pulse is at least 50 volts into a 50 ohm load.

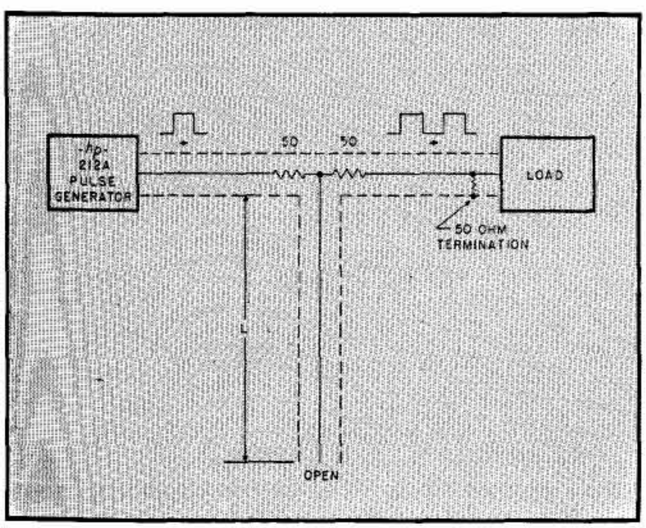


Figure 3. Circuit for generating double pulses.

Specifications

Pulse Length: At least 0.07 to 10 microseconds, continuously variable.

Pulse Amplitude: At least 50 volts peak into 50 ohm load (50 watts peak).

Pulse Polarity: Positive or negative.

Amplitude Control: (a) 50 db attenuator, variable in 10 db steps.

(b) Continuously variable control with range of at least 10 db.

Pulse Shape: (a) Rise and decay time approximately 0.02 microseconds (10% to 90%).

(b) Crest variation less than ±5% of average peak amplitude.

Jitter: Less than 0.01 microseconds.

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

Repetition Rate: (a) Internal synchronization, 50 to 5,000 pps.

(b) External synchronization, 0 to 5,000 pps.

Sync In: Positive or negative, 5 volts peak minimum.

Sync Out: (a) 40 volts positive or 25 volts negative into 2,000 ohm load.

(b) Duration, approximately 1 microsecond at half voltage points.

(c) Rise time, approximately 0.25 microseconds.

Pulse Position: (a) Delay, 0 to 100 microseconds after sync out pulse.

(b) Advance, 0 to 10 microseconds before sync out pulse.

Connectors: (a) Main pulse, Type N.

(b) Sync in, sync out, Type BNC.

Power: 115/230 v ±10%, 50/60 cps, 325 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¼" deep. Rack Mount: 19" wide, 10½" high, 13" deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 57 lbs. Shipping 78 lbs. (cabinet mount).

Accessories Available: AC-16K Video Cable Assembly, $5.00; AC-16F rf Cable Assembly, $7.50.

Price: $565.00.

Data subject to change without notice.

211A SQUARE WAVE GENERATOR

Specifications

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

Low Impedance Output: 7.0 v peak-to-peak across 75 ohm internal impedance. Rise time less than 0.02 μsec. BNC connector.

High Impedance Output: 55 v peak-to-peak across 600 ohm internal impedance. Rise time less than 0.1 μsec. Dual banana jacks—¾″ 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 ±10%, 50/60 cps, 195 watts.

Dimensions: Cabinet: 9¾″ wide, 15″ high, 14⅜″ deep.

Weight: Net 25 lbs. Shipping 40 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25; AC-16D Cable Assembly, $2.65.

Price: $265.00.

Data subject to change without notice.

Convenient Audio, Video Testing 1 cps to 1 MC

THE -*hp*- Model 211A Square Wave Generator is a versatile, wide range instrument particularly designed for testing video and audio amplifier performance, 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 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. 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 3 volts minimum amplitude.

Uses

Model 211A is ideal for testing amplifiers and networks and modulating signal generators. It will measure time constants, check cathode ray sweep circuits, and generate harmonics for frequency multiplication. It offers a simple means of controlling an electronic switcher. The generator is also a convenient instrument for indicating phase shift, frequency response or transient effects.

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:

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

(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 per cent 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 per cent is the distortion in the circuit.

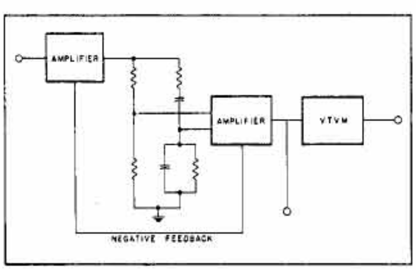


Figure 1
Block diagram of *-hp-* 330B Distortion Analyzer.

-hp- Wave Analyzer

For measuring distortion by the "fundamental" method, *-hp-* Model 300A Harmonic Wave Analyzer (page 34) is well suited. This instrument is of the selective-voltmeter type, and is ideal for measuring individual components of a wave. For example, the exact value of second harmonic voltage can be measured in the presence of hum and other extraneous voltages. Applications of this versatile equipment include determination of harmonic components in ac machinery and power systems, study of induced voltage in telephone lines, analysis of hum and noise in electronic systems. The instrument also makes possible convenient determination of intermodulation or cross modulation generated by simultaneous transmission of two frequencies in an audio system. And, it provides a simple means of measuring the demodulation which occurs when an audio modulated wave is amplified.

-hp- Distortion Analyzers

-hp- 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 modulated AM and FM broadcast carriers.

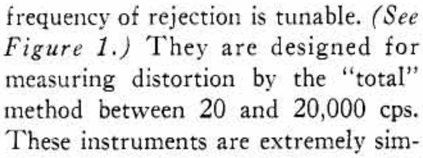


Figure 2
Recommended setup for distortion measurement using *-hp-* 330 Analyzers.

A typical setup utilizing *-hp-* 330 series analyzers for measuring by the "total" distortion method is shown in Figure 2. 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 in Figure 3B, 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 nondetectable unless an oscilloscope is used.

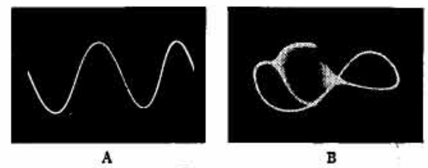


Figure 3
Oscillograms showing (A) sine wave with 1.5% distortion, (B) second harmonic distortion with superimposed transient oscillations.

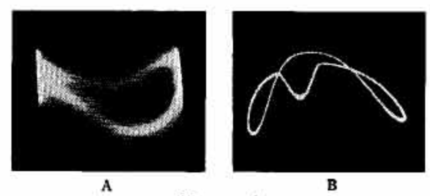
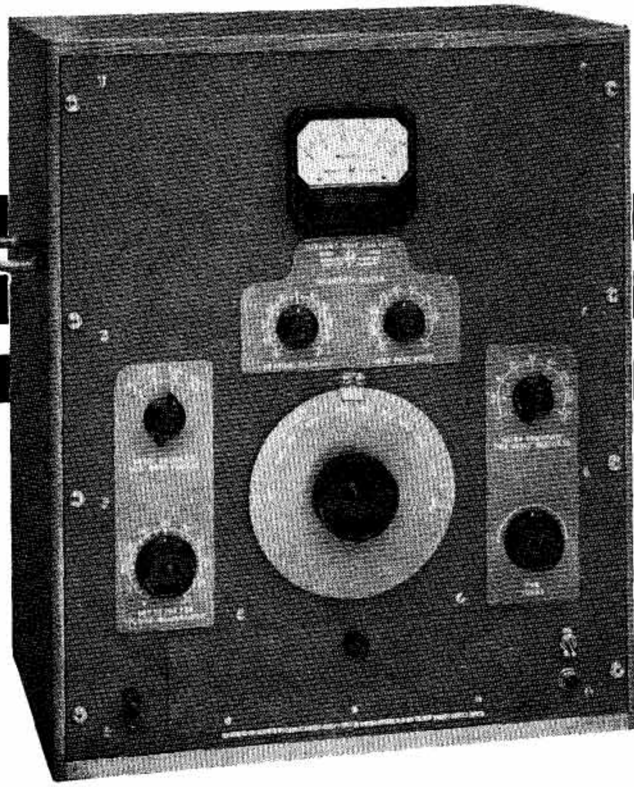


Figure 4
Oscillogram showing distortion in amplifiers when (A) distortion level is of same order of magnitude as hum, (B) amplifier is driven at point of overload; notch in pattern is caused by small grid current.

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 4A and 4B.)*

300A HARMONIC WAVE ANALYZER



Advantages:

- Direct reading
- Simplified operation
- Variable selectivity
- Wide voltage range
- Linear meter scale

Use It To Analyze:

- Noise characteristics
- Broadcast amplifier characteristics
- Modulating amplifier distortion
- Recording devices
- Film sound track distortion
- Recording distortion
- Hum
- Network characteristics

Variable Selectivity Provides Rapid, Accurate Wave Analysis

THIS *-hp-* Model 300A Harmonic Wave Analyzer is a selective voltmeter designed to measure the individual components of complex waves. The selectivity can be varied by means of a unique selective amplifier. Where the harmonics are close together the high selectivity easily separates the wave components. Yet, where the components are spaced far apart, the selectivity may be widened to increase the speed of operation without sacrificing essential accuracy. This feature is also valuable where it is necessary to measure distortion of waves containing a small amount of frequency modulation, such as in sound tracks, and may be used conveniently to integrate a small portion of the audio spectrum in noise measurements and the like. Maximum selectivity is sufficient to separate harmonic components spaced 30 cycles apart. *(See Figure 1.)*

Direct Reading

The -*hp*- Model 300A Harmonic Wave Analyzer covers the audio spectrum from 30 cps to 16,000 cps. The wide voltage range covers the values encountered in nearly every application. Full scale voltmeter readings may be obtained with inputs of 0.001 to 500 volts so that the instrument may be used with equal success with low output transducers and high power modulating amplifiers. Other features which make it unexcelled for both laboratory and production testing are the linear meter scales fully protected against overloads, and the built-in calibrating system to standardize voltage measurements.

Theory

The circuit of the Model 300A consists of a variable local oscillator, a balanced modulator, a selective amplifier, and an indicating meter. The variable local oscillator modulates the unknown frequency to produce a constant difference frequency. This difference frequency is applied to the selective amplifier, the output of which is then proportional to the magnitude of the unknown voltage. A meter in the output of the selective amplifier indicates the magnitude of the voltage.

The local oscillator is of the resistance-tuned type, providing a very stable, accurate voltage. A balanced modulator is used to eliminate the local oscillator frequency and to keep cross-modulation products very low. The selective amplifier consists of four tuned circuits in which the effective Q is controlled by positive feedback. Negative feedback is also used to stabilize the amplifier.

This amplifier has the unique characteristic that its selectivity may be varied over a wide range without appreciably affecting the gain of the amplifier.

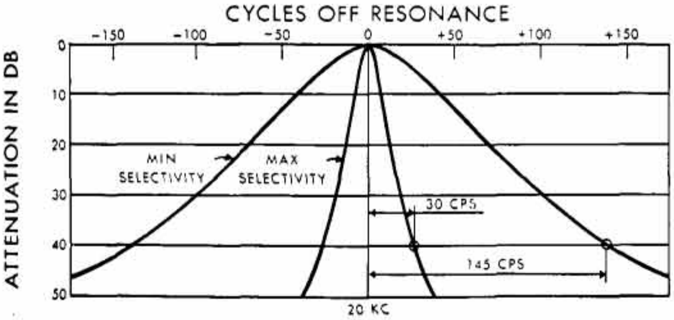


Figure 1

Uses

The Model 300A is well adapted to the measurement of the harmonic distortion in audio frequency equipment of all kinds, broadcast receivers, transmitters; to determine the harmonic components in ac machinery and power systems; to the study of induced voltages on telephone lines; to measurement of hum components in rectifier circuits.

Other uses include the study of noise by integrating portions of the spectrum with the selectivity control adjusted for a wide pass band and the checking of wave filter characteristics with maximum selectivity.

The -*hp*- 300A is also useful as a device to measure the amount of cross- or inter-modulation products generated by the simultaneous transmission of two frequencies by an audio system or to measure demodulation of a modulated wave applied through an audio system.

Specifications

Frequency Range: 30 to 16,000 cps.

Frequency Calibration: Above 100 cps, ±3%. 100 cps and below, ±5%.

Voltage Range: 0.1 millivolt to 500 volts, with full-scale readings of:

500 volts	5 volts	50 millivolts
250	2.5	25
100	1	10
50	0.5	5
25	0.25	2.5
10	0.1	1

Ranges provided by an input switch which selects maximum voltage values of 500, 50, 5 or 0.5 volts, and a meter multiplier to select finer divisions.

Voltage Accuracy: ±5% of full-scale value. Adjacent harmonics must be spaced so as to be suppressed by the selectivity of the instrument.

Residual Modulation Products: Suppressed at least 65 db.

Hum Voltage: At least 75 db below 0.5, 5, 50, or 500 volts, depending on input range selected.

Selectivity: Variable from 30 to 145 cps at the 40 db points *(Figure 1)*.

Input Impedance: 200,000 ohms. Potentiometer included for setting external voltage reference (set to maximum for voltage measurements).

Power: 115/230 v ±10%, 50/60 cps, 105 watts.

Dimensions: Cabinet Mount: 23¼″ wide, 24¼″ high, 14″ deep. Rack Mount: 19″ wide, 22¾″ high, 12½″ deep.

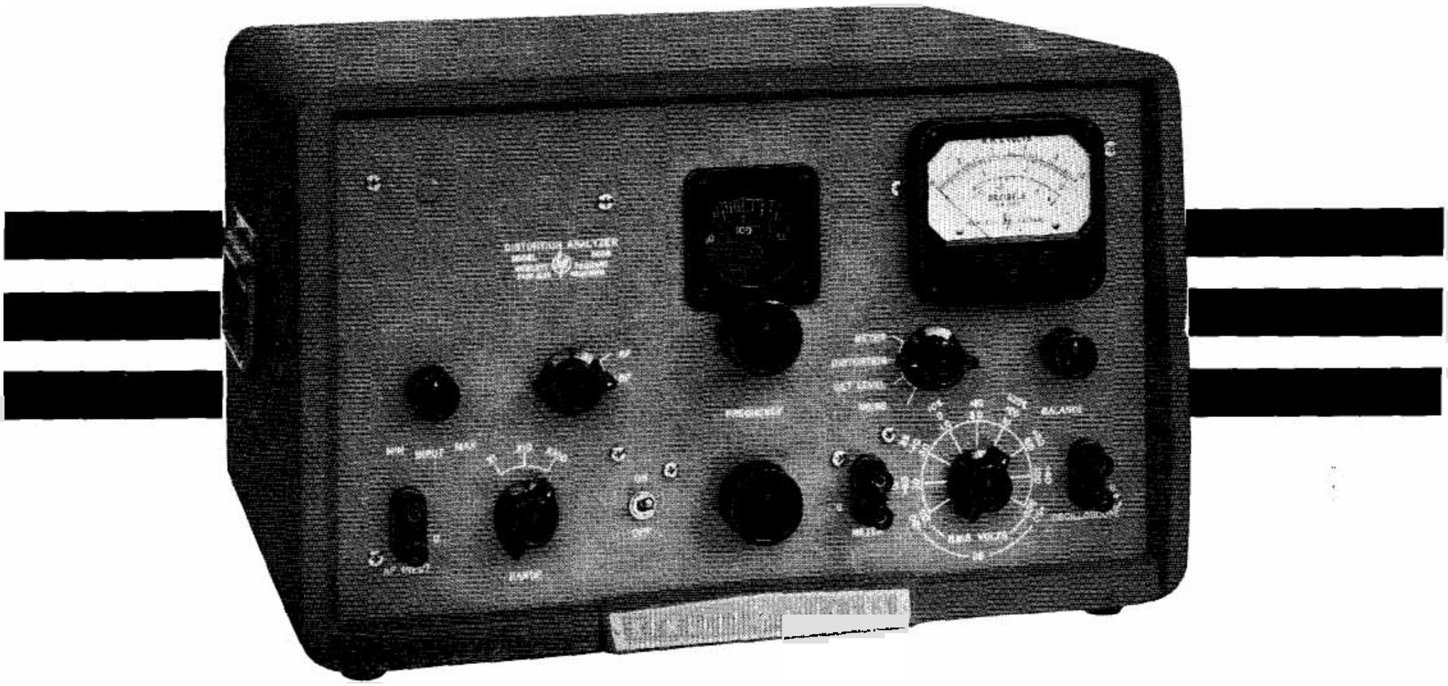
Weight: Net 80 lbs. Shipping 150 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25. AC-60B Transformer (for bridging input), $35.00.

Price: $775.00.

Data subject to change without notice.

330B/C/D DISTORTION ANALYZER



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

Accurate Distortion Readings 20 cps to 20,000 cps

THE *-hp-* Model 330B Distortion Analyzer will give you quick, accurate measurements of distortions 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 frequency-selective amplifier, a regulated power supply and a vacuum tube voltmeter.

The 20 db amplifier operates in conjunction with the *-hp-* resistance-tuned circuit to provide nearly infinite attenuation at one frequency while allowing all other frequencies 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 gain of the noise amplifier is 40 db ±1 db from 20 cps to 15 KC.

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 *-hp-* 330C Distortion Analyzer is offered. It is identical in all respects with *-hp-* 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.

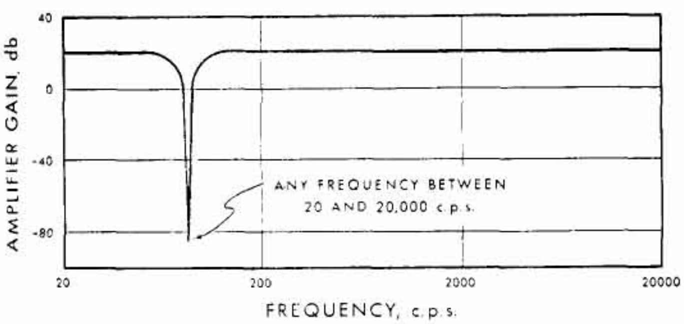


Figure 1

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 99.9% (60 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 $\mu\mu$f 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$\mu\mu$f 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 with full-scale meter deflection.

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 v, 50/1,000 cps, 95 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13" deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 37 lbs. Shipping 60 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25. AC-60B Transformer (for bridging input), $35.00.

Price: *-hp-* 330B, $410.00; *-hp-* 330C, $440.00; *-hp-* 330D, $455.00.

Data subject to change without notice.

Specifications

Two models are available. The *-hp-* 350A matches a 500 ohm impedance and the *-hp-* 350B matches a 600 ohm impedance (one side grounded).

Attenuation: The attenuation is 110 db in 1 db steps.

Accuracy: From 0 - 100 KC.
10 db Attenuator Section: Error less than 0.125 db at any step.
100 db Attenuator Section: Error less than 0.25 db any step up to 80 db attenuation, less than 0.5 db on 90-100 db steps.

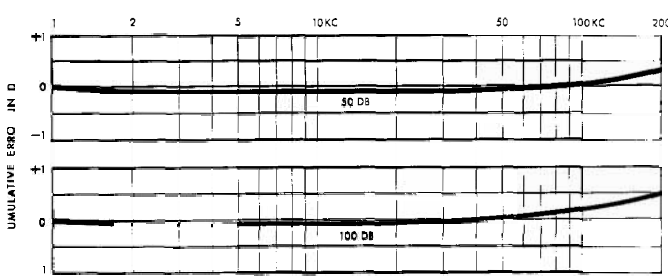
Dimensions: Cabinet Mount: 8¼″ wide, 5½″ high, 5¾″ deep. Rack Mount: 19″ wide, 5¼″ high, 4½″ deep.

Weight: Net 3 lbs. Shipping 7 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly $4.00; AC-16B Cable Assembly $4.25.

Price: $60.00.

Data subject to change without notice.



A Basic Bridged-T Instrument With Many Laboratory Uses

WHEN a high order of accuracy, wide-frequency response, large-power handling capacity or other special features are required, *-hp-* 350 series Attenuators are of great value and convenience. They are particularly useful in attenuating output of audio and supersonic oscillators, measuring gain and frequency response of amplifiers, measuring transmission loss and increasing the scope and usefulness of other laboratory equipment.

Two basic bridged-T circuits make up the *-hp-* 350 Attenuators. One circuit is a 100 db attenuator, adjusted in 10 db steps. The other is a 10 db attenuator, adjusted in 1 db steps. Frequency response is flat to 100 KC *(See Figure 1)*. The attenuators are available in two standard impedance levels—500 and 600 ohms. Resistors are adjusted to ±0.5% for maximum calibration accuracy. The instruments have large-power handling capacity—5 watts—and are ideal for supersonic and other work involving measurements above the range of conventional audio-frequency attenuators.

For power gain measurements or to form a signal generator, use *-hp-* 350 Attenuator with an *-hp-* oscillator and a voltmeter.

VACUUM TUBE VOLTMETERS

THE measurement of voltage is a basic electrical function which is required almost daily in the research laboratory, on the production line and in the operation of electrical, electronic and mechanical equipment.

For maximum speed and convenience in making measurements from 10 cps to 700 MC, Hewlett-Packard offers four stable, accurate vacuum tube voltmeters. Each gives you familiar *-hp-* characteristics of wide range, compact size, sturdy dependability and time-saving ease of operation.

High-Sensitivity Voltmeters

-hp- Models 400AB, 400D and 400H are high-sensitivity average-reading instruments calibrated in the rms value of a sine wave. In these voltmeters the dc current through the indicating meter is proportional to the average value of the ac voltage under measurement. Circuits include an input voltage divider, a stabilized amplifier with generous feedback, rectifier and meter circuits and a power supply. *(Figure 1.)* Operation is independent of the tube characteristics and line voltage changes.

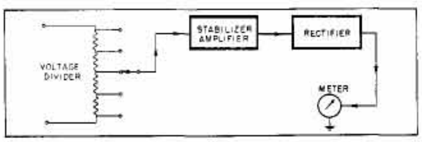


Figure 1. Block diagram, *-hp-* 400 series voltmeters.

-hp- Model 400D Voltmeter is particularly useful in measuring very small voltages down to 1 mv full scale and can also be used as a high-gain broadband amplifier to increase sensitivity of oscilloscopes, bridges, etc. It measures voltages throughout the audio, supersonic and low rf regions and is also excellent for geophysical and telemetering work, and the measuring of power circuits and high frequency voltages in broadcast equipment.

-hp- Model 400H, developed from the 400D, measures voltages of 1 mv (full scale) to 300 volts with an accuracy of at least ±1% from 50 cps to 500 KC. The *-hp-* 400H uses an indicating meter which has a 5-inch scale for maximum readability, a knife edge pointer and mirror to minimize parallax errors.

Wide-Range Voltmeters

-hp- Model 410B (page 44) is a wide-range peak-reading voltmeter designed especially for high-frequency work (20 cps to 700 MC). It has a high input resistance with minimum shunt capacity and can be connected into a circuit without introducing stray capacity. This instrument employs a special probe with a custom-designed diode tube. The cathode of this probe diode has solid grounding, and the anode lead is brought out with a minimum of inductance. Model 410B is independent of line voltage changes and offers highly stable performance ideal for audio, supersonic, rf or uhf measurements.

Voltmeter Accessories

To increase the useful range of *-hp-* voltmeters, a complete line of voltmeter accessories is offered (page 46). These include Probe Connectors, Capacitive Voltage Dividers, dc Resistive Voltage Multipliers, Shunt Resistors, etc.

Voltmeter Operating Techniques

In average-reading voltmeters such as *-hp-* 400AB, 400D and 400H, the meter indicates rms value of a true sine wave. When the waveform of the voltage under study contains appreciable harmonic or other spurious voltages, measurement errors will be encountered. The magnitude of the error will depend on the magnitude and phase relationship between harmonic and fundamental frequencies. Average reading voltmeters give superior accuracy to peak-reading voltmeters when complex waves are measured. Table 1 gives an indication of the limits of possible error due to the presence of harmonics in the waveforms to be measured. This table is universal in its application since these errors are inherent in all voltage measuring equipment of the average reading or peak reading variety.

% 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.

Voltmeter readings can be affected by hum pick-up when the circuit under study has a high impedance. Ordinary shielded leads reduce such pick-up, but are often not practical. In such cases, *-hp-* 454A Capacitive Voltage Divider is recommended (page 46). This instrument is a capacitive probe which presents a very high impedance to the point of measurement and provides a thoroughly shielded lead to the VTVM. This results in a sensitivity loss of 100:1 in the voltmeter.

In measuring voltage at very high frequencies, even very short leads can introduce reactance which results in meter error. When using the probe of *-hp-* 410B voltmeter for high frequency work, it is advisable to ground the outer shell of the probe with heavy copper strapping and keep the distance from the probe to the point of measurement as short as possible. The nose of the probe is removable when the ultimate in short leads is desired.

To facilitate measurement in coaxial transmission lines with *-hp-* 410B voltmeter, *-hp-* 455A Probe Coaxial "T" Connector is offered (page 46). This instrument is a specially designed "T" joint which connects the probe into the line without disturbing conditions in the line.

400D VACUUM TUBE VOLTMETER

Advantages:

Extremely wide voltage range
Accurate within 2% to 1 MC
Broadest frequency coverage
10 megohm input impedance
No switching transients
High sensitivity, stability
Reads direct in dbm
Light, small, portable

Use It To Measure:

Audio, supersonic, rf voltages
Amplifier gain. Network response
Output level. Hum level
Power circuit voltages
Video or carrier current voltages
Capacity. Coil figure of merit

10 cps to 4 MC! High Quality, High Sensitivity

THE *-hp-* 400D Vacuum Tube Voltmeter combines broad frequency coverage with high stability, accuracy and sensitivity.

Frequency coverage is 10 cps to 4 MC. The 400D has an amplifier providing approximately 56 db of feedback in mid-range. This assures highest stability and freedom from calibration change due to external conditions. A special switching arrangement in the cathode circuit minimizes switching transients while ranges are being changed. Input impedance is 10 megohms, assuring that circuits under test are not disturbed by loading. Output circuitry makes possible the use of the instrument as a broad band, high gain amplifier over its full frequency range.

Highest Quality Construction

Input voltages up to 600 volts peak will not damage Model 400D. Its indicating meter is a special 1%, 1 milliampere instrument with a large 4" scale and knife-edge pointer. All coupling and bypass condensers are sealed, and electrolytic condensers are long-life types designed for more than 10 years of trouble-free service. Circuitry and mechanical layout are clean and permit easy access to all parts. A rugged streamlined metal case insures handling ease and portability, and occupies minimum bench space. Fold-out front legs tilt the instrument for more convenient reading angle when desired.

This instrument includes the tested features of the reliable *-hp-* 400C Vacuum Tube Voltmeter, over 10,000 of which are in use in laboratories, service and production organizations today. The 400D provides a wider frequency range, improved accuracy, and even greater stability for line voltage variation and tube aging than was available with the popular Model 400C. *-hp-* Model 400D is also available with a special meter face having the db scale uppermost. This scale permits greater resolution in db readings. (Please order as Model 400D-DB at $12.50 extra.)

Simple Operation

-hp- instruments are noted for their simple, straightforward operation; Model 400D is particularly easy to use. Ranges are quickly selected on a front panel switch which changes sensitivity in precise 10 db steps. This, plus calibration of the meter in db, means direct readings are available without calculation or conversion between -72 and $+52$ dbm. (0 dbm = 1 mw in 600 ohms.) Meter voltage scales are arranged in multiples of 1, 3, 10, 30, etc., so that readings are always in the upper two-thirds of the scale where maximum accuracy is obtained.

Typical variations in accuracy resulting from line voltage changes and tube aging are shown in Figure 1. The exceptional stability of the 400D amplifier section is clearly shown by these graphs.

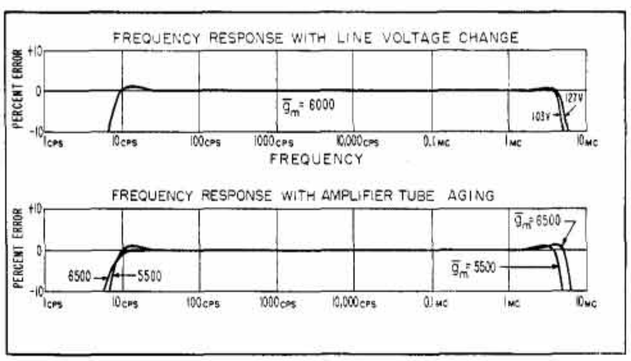


Figure 1. Typical variation in accuracy with line voltage changes and mutual conductance changes (geometric mean value of amplifier tubes).

New Broad Usefulness

In speed, accuracy and versatility the 400D is unmatched. It may be used for measuring amplifier gain, network response, output level, and almost all audio and rf voltages as well as video and TV voltages. In many instances, the voltmeter will also measure hum and noise directly besides determining power circuit and broadcast high frequency voltages. It further serves as an audio level meter, a high gain broad band amplifier; it detects nulls, monitors waveforms (in conjunction with an oscilloscope).

In conjunction with an oscillator, the 400D can be used to measure wide ranges of L and C as well as moderate ranges of R and Z. The 400D can also be used as the indicating device in measuring coil Q.

Specifications

Voltage Range: 0.1 millivolt to 300 volts. 12 ranges, front panel switch. Full scale readings from 0.001 to 300 volts.

0.001	0.03	1	30
0.003	0.1	3	100
0.01	0.3	10	300 volts

Frequency Range: 10 cps to 4 megacycles.

Accuracy: With line voltages of $\pm 10\%$ (103 volts to 127 volts), overall accuracy is $\pm 2\%$ of full scale, 20 cps to 1 MC; $\pm 3\%$ of full scale, 20 cps to 2 MC; $\pm 5\%$ of full scale, 10 cps to 4 MC.

Long Term Stability: Reduction in G_m of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 20 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 1 and 0 to 3; db scale, -12 db to $+2$ db, based on 0 dbm = 1 mw in 600 ohms, 10 db intervals between ranges.

Input Impedance: 10 megohms shunted by 15 $\mu\mu$f on ranges 1 to 300 volts; 25 $\mu\mu$f on ranges 0.001 to 0.3 volts.

Amplifier: Output terminals are provided so voltmeter can be used to amplify small signals or to monitor waveforms under test with an oscilloscope. Output approximately 0.15 volts rms corresponding to full-scale meter deflection. Internal impedance, 50 ohms. Gain approximately 150 for 0.001 volt range.

Power: 115/230 v $\pm 10\%$, 50/1,000 cps, 70 watts.

Dimensions: Cabinet Mount: 7½″ wide, 11½″ high, 12″ deep. Rack Mount: 19″ wide, 7″ high, 10¾″ deep.

Weight: Net 18 lbs. Shipping 25 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly $4.00; AC-16B Cable Assembly $4.25. *-hp-* 470A Shunt Resistor $15.00; *-hp-* 470B-F Shunt Resistors $7.50. *-hp-* 452A Capacitive Voltage Divider $100.00. *-hp-* 454A Capacitive Voltage Divider $25.00. *-hp-* AC-60A Line Matching Transformer $25.00; AC-60B Bridging Transformer $35.00.

Price: $225.00.

Data subject to change without notice.

400AB VACUUM TUBE VOLTMETER

Specifications

Voltage Range: 0.3 mv to 300 volts. 12 ranges, selected with front panel switch. Full scale readings of:

0.003 volts	0.1	3	100
0.01	0.3	10	300
0.03	1	30	

Frequency Range: 10 cps to 600 KC.

Accuracy: With nominal line voltage ±10% (103 volts to 127 volts), overall accuracy is within ±2% of full scale, 20 cps to 100 KC, ±3% 10 cps to 600 KC.

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 1.0; db scale, −12 db to +2 db, based on 0 dbm = 1 mw in 600 ohms, 10 db intervals between ranges.

Input Impedance: 10 megohms shunted by 25 $\mu\mu f$.

Amplifier: Output terminals are provided so voltmeter can be used to amplify small signals or monitor waveforms under test with an oscilloscope.

Power: 115/230 volts ±10%, 50/1,000 cps, approximately 70 watts.

Dimensions: 7½" wide, 11½" high, 8¼" deep (cabinet mount). Rack mounting available on 19" x 7" panel.

Weight: Net 13 lbs. Shipping 19 lbs. (cabinet mount).

Accessories Available: AC-60A Line Matching Transformer, $25.00. 452A Capacitive Voltage Divider, $100.00. 454A Capacitive Voltage Divider, $25.00. 470A Shunt Resistor, $15.00, 470B-470F Shunt Resistors, $7.50.

Price: $200.00.

Data subject to change without notice.

Precision Measurement 10 cps to 600 KC. Moderate Price

HERE is an *-hp-* precision voltmeter offering the utmost in utility, dependability and dollar value. Model 400AB replaces the famous Model 400A in the *-hp-* line; it retains the proven quality and convenience features of the earlier instrument yet embodies many important improvements. Frequency coverage is broad—10 cps to 600 KC. Measurements may be made from 0.3 millivolt to 300 volts. Stability and sensitivity are extremely high, and accuracy is ±2% full scale from 20 cps to 100 KC, ±3% down to 10 cps and up to 600 KC. Input impedance is high to prevent disturbance to circuits under test. The meter reads direct in voltage and dbm, and a generous overload capacity eliminates need for special operating precautions.

400H VACUUM TUBE VOLTMETER

New! Extreme Accuracy of 1% Covers 10 cps to 4 MC

NEW *-hp-* 400H has been adapted from the popular *-hp-* 400D voltmeter to make available an instrument combining general-purpose utility with extreme measuring accuracy.

Model 400H has a 5″ indicating meter with mirror scale and measures voltages from 0.1 mv to 300 volts. The high input resistance of 10 megohms effectively minimizes loading to circuits under test. A highly stabilized amplifier with 56 db feedback provides exceptional long term stability; even line voltage changes of ±10% cause negligible variations. Readings are direct in volts or db. Operation is extremely simple; input voltages up to 600 volts peak will not damage the instrument. The instrument is of highest quality construction throughout, and is available either in the lightweight, rugged *-hp-* portable cabinet or for rack mounting.

Model 400H is also available with a special meter face having the db scale uppermost. This scale permits greater resolution in db readings. (Please order as Model 400H-DB at $12.50 extra.)

Specifications

Voltage Range: 0.1 mv to 300 volts. 12 ranges, selected with front panel switch. Full scale readings of:

0.001	0.03	1	30
0.003	0.1	3	100
0.01	0.3	10	300 volts

Frequency Range: 10 cps to 4 MC.

Accuracy: With nominal line voltages from 103 to 127 volts, overall accuracy is:
within ±1% of full scale, 50 cps to 500 KC;
within ±2%, 20 cps to 1 MC;
within ±5%, 10 cps to 4 MC.

Long Term Stability: Reduction in G_m of amplifier tubes to 75% of nominal value results in less than 0.5% error from 20 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 1.0; db scale, −12 db to +2 db, based on 0 dbm = 1 MW in 600 ohms, 12 ranges in 10 db steps.

Input Impedance: 10 megohms shunted by 15 μμf, 1 to 300 v; 25 μμf, 0.001 to 0.3 v.

Amplifier: Output approx. 0.15 v max. Internal impedance 50 ohms. Max. gain approx. 150 on 0.001 v range.

Power: 115/230 volts ±10%, 50/1,000 cps. approx. 100 watts.

Dimensions: 7½″ wide, 11½″ high, 12″ deep. 19″ rack mount available.

Weight: Net 18 lbs. Shipping 25 lbs. (cabinet mount).

Price: $325.00.

Data subject to change without notice.

410B VACUUM TUBE VOLTMETER

Advantages:

- Range 20 cps to 700 MC
- Input capacity approximately 1.5 $\mu\mu f$
- High input impedance
- Few controls. High stability
- Rugged meter movement
- Excellent overload protection

Use It To Measure:

- Audio frequency, supersonic, rf, and vhf voltages
- Antenna voltage, current, and power
- Transmission line characteristics
- Standing waves
- Audio, video and vhf amplifiers
- Dc voltage in high impedance circuits

All-Purpose Test Instrument — Measures to 700 MC

BECAUSE of the tremendous number of tasks it will perform, the 410B High Frequency Vacuum Tube Voltmeter can play a uniquely valuable role in any laboratory, broadcast station, or production test department. It combines in one instrument an ac voltmeter covering the frequency range from audio to radar frequencies, a dc voltmeter with more than 100 megohms input impedance, and an ohmmeter capable of measuring resistance from 0.2 ohms to 500 megohms. In addition, it is easy to use, compact, portable, and light in weight.

A special probe, employing a radically different diode especially designed for Hewlett-Packard, is used for making ac measurements. The resonant frequency of the diode is approximately 1,250 MC, and the shunt capacity is extremely low. Mounted in the probe, it places a capacity of approximately 1.5 $\mu\mu f$ across the circuit under test. Total input impedance at low frequencies for ac measurements is 10 megohms shunted by this capacity.

The 410B employs a high impedance dc voltmeter having a special circuit developed by *-hp-* engineers. Its outstanding feature is low drift and maintenance of calibration over long periods of time. Only one zero adjustment is necessary for all voltage ranges, and once set it rarely needs adjustment. This circuit permits the use of a 1 ma meter movement which together with certain features of the circuit itself makes it impossible to damage the meter by overloads. Input impedance for dc measurements is more than 100 megohms for all ranges.

Uses

The versatility of the 410B is so great that the number of uses to which it may be put is almost endless. As an ohmmeter it will accurately measure resistance over a much wider range than is ever ordinarily encountered. As a dc voltmeter, its extremely high input impedance permits its use on almost any equipment without any appreciable loading of the circuit.

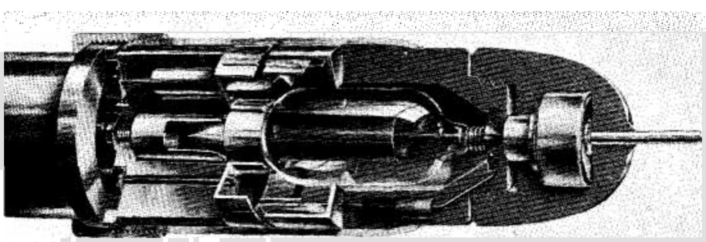


Figure 1. Construction details of *-hp-* diode probe.

As an ac voltmeter, its combination of high input impedance with great frequency range sets altogether new standards of performance. The probe can be inserted in almost any audio, supersonic, radio, or vhf amplifier without detectable loading of the circuit. It can be used to measure antenna and transmission-line voltage, current, and power with as much ease and convenience as if the circuits carried dc. Special adapters can be supplied for use with the probe to connect to standard transmission lines.

Finally, the fact that all these functions are combined in one instrument means that where previously a whole battery of equipment might be required to test a given piece of apparatus, the 410B, in one small, convenient, and highly portable instrument, does the whole job. Leads are provided for all functions so that it is necessary only to change the position of switch for selecting any particular operation. Storage space for leads and probes is provided at the rear of the instrument cabinet.

Specifications

Ranges: 0-300 v ac in 6 ranges; 0-1000 v dc in 7 ranges; 0.2 ohm to 500 megohms in 7 ranges. Midscale reading of 10, 100, 1,000, 10,000, 100,000 ohms, 1 megohm, and 10 megohms.

Frequency Range: 20 cps to 700 MC.

Accuracy: ±3% of full scale on all ranges on sinusoidal ac voltages and on dc voltages. The ac portion of the instrument is a peak-reading device, calibrated in rms volts.

Frequency Response: Frequency response is flat within ±1 db up to 700 MC and drops off less than 1 db at 20 cps; an indication can be obtained up to 3000 MC. *(See Figure 2.)*

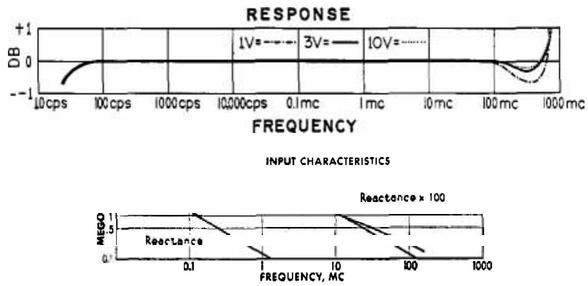


Figure 2

Input Impedance: Input capacity is 1.5 $\mu\mu f$; input resistance is 10 megohms at low frequencies. At high frequencies resistance drops off due to dielectric losses. *(See Figure 2.)* DC input resistance is more than 100 megohms for all ranges.

Probe: The probe is approximately 1″ diameter and 4½″ long. It is equipped with a ground clip. The center connector of the probe may be soldered to the point under test. Adapting connectors are available to measure voltages in coaxial transmission lines.

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.

Weight: Net 12 lbs. Shipping 19 lbs. (cabinet mount).

Accessories Available:

-hp- 452A Capacitive Voltage Divider, $100.00.
-hp- 453A Capacitive Voltage Divider, $25.00.
-hp- 455A Probe Coaxial "T" Connector, $35.00.
-hp- 458A Probe Coaxial "N" Connector, $25.00.
-hp- 459A dc Resistive Voltage Multiplier, $25.00.
-hp- AC-2B Dual Rack Panel, $25.00.

Price: $245.00.

Data subject to change without notice.

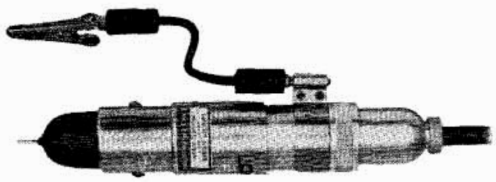
VOLTMETER ACCESSORIES

EXTEND the usefulness of your present *-hp-* voltmeters with these precision built *-hp-* accessories. Custom-designed for use with *-hp-* Models 400AB, 400D, 400H or 410B Vacuum Tube Voltmeters. Save time and work, simplify tedious jobs. Make fast, accurate measurements far beyond the original range of your instruments.

-hp- 452A Capacitive Voltage Divider

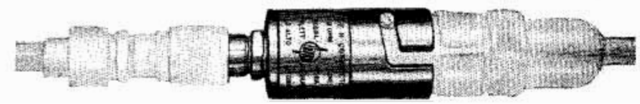
For *-hp-* 400 series and 410B. Safely measures power voltages to 25 kv. Accuracy ±3%. Division ratio 1000:1. Input capacity 15 μμf ±1. Maximum voltage ratings at 60 cps, 25 kv; 100 KC, 22 kv; 1 MC, 20 kv; 10 MC, 15 kv; 20 MC, 7 kv. Usable for dielectric heating, power and supersonic voltages. Price, $100.00.

452A-95A Adapter: Connects 410B to shielded connector. $10.00.



-hp- 453A Capacitive Voltage Divider

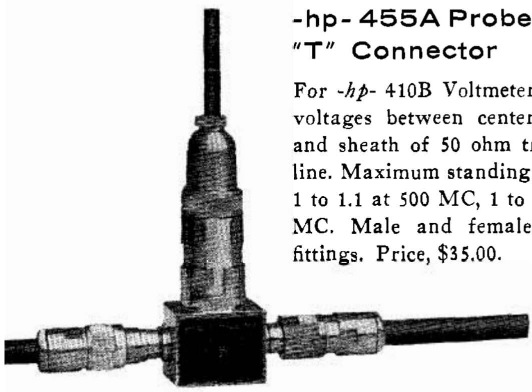
For *-hp-* 410B Voltmeter. Increases range so transmitter voltages can be measured quickly, easily. Accuracy ±1%. Division ratio, 100:1. Input capacity approximately 2 μμf. Maximum voltage 2,000 v. For frequencies 10 KC and above. $25.00.



-hp- 458A Probe Coaxial "N" Connector

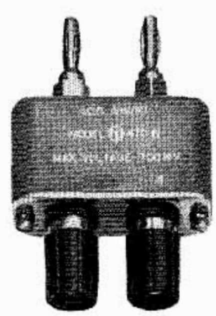
For *-hp-* 410B Voltmeter. Measures volts at open end of 50-ohm transmission line. (No terminating resistor.) Uses female type "N" fitting. Price, $25.00.

-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 to 1.1 at 500 MC, 1 to 1.2 at 1,000 MC. Male and female type "N" fittings. Price, $35.00.

-hp- 470A-470F Shunt Resistors



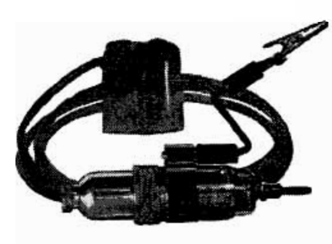
For *-hp-* 400 series Voltmeters, to measure currents as small as 1 μa full scale. Accuracy ±1% to 100 KC, ±5% to 4 MC (470A, ±5% to 1 MC). Maximum power dissipation 1 watt.

INSTRUMENT	VALUE	PRICE
-hp- 470A	0.1 Ω	$15.00
-hp- 470B	1 Ω	7.50
-hp- 470C	10 Ω	7.50
-hp- 470D	100 Ω	7.50
-hp- 470E	600 Ω	7.50
-hp- 470F	1,000 Ω	7.50

-hp- 459A DC Resistive Voltage Multiplier

For *-hp-* 410B Voltmeter. Gives maximum safety and convenience for measuring high voltages as in television receivers, etc. Accuracy ±5%. Multiplication ratio 100:1. Input impedance 12,000 megohms. Maximum voltage 30 kv. Maximum current drain 2.5 microamperes. Price, $25.00.

-hp- 454A Capacitive Voltage Divider



For *-hp-* 400 series Voltmeters. Safely measure power, audio, supersonic and rf voltages. Accuracy ±3%. Division ratio, 100:1. Input impedance 50 megohms, resistive shunted with 2.75 μμf capacity. Maximum voltage, 1,500 v. Price, $25.00.

Data subject to change without notice.

AMPLIFIERS

Hewlett-Packard offers seven amplifiers covering a wide variety of measuring requirements.

General-Purpose Amplifier

-hp- 450A Amplifier (page 52) 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.

Distributed Amplifiers

-hp- 460A and 460B Distributed Amplifiers (pages 48, 49), are wide-range amplifiers providing distortionless pulse amplification. They combine extremely short rise time with zero overshoot.

These instruments are employed to amplify pulses in the order of 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 200 MC. Response is substantially constant down to 100 KC.

Operating Techniques

-hp- 460A is a two stage voltage amplifier (which does not invert the input signal) having approximately 20 db gain with a maximum 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 the polarity as well as the amplitude of 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 to invert the input pulse to the final 460B whenever necessary.

The rise time of amplifiers in cascade is greater than that of a single amplifier by $T \times (n)^{1/2}$; where n is the number of 460 amplifiers in the system and T is the rise time of one 460 amplifier (2.6×10^{-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. The rise time of a type 5XP tube driven from a 200-ohm source is approximately 2×10^{-9} seconds. (A chain of five *-hp-* 460 amplifiers with a 5XP CRT will result in a rise time of 6.1×10^{-9} seconds.)

Traveling-Wave Tube Amplifiers

Hewlett-Packard 490B, 491A, 492A and 494A Traveling-Wave Tube Amplifiers (pages 50, 51) are high gain broad band linear devices covering the frequency range of 2 to 12.4 KMC. Besides amplifying any type rf signal in their pass band the *-hp-* Models 490B (2 to 4 KMC), 492A (4 to 8 KMC), 494A (7 to 12.4 KMC) may be used to modulate rf signals with pulses of millimicrosecond rise and decay time. They may also be used to frequency modulate and phase modulate rf signals. In addition they are suitable as broad band 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-* 616A) to provide a flexible 1 watt source in the 2 to 4 KMC band.

Noise Consideration in Amplifiers

The limit of minimum useful input signal level of an amplifier is determined by random varying voltages and currents present in the circuit and tubes.

In distributed amplifiers, the noise figure 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 due to their extreme band width 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.

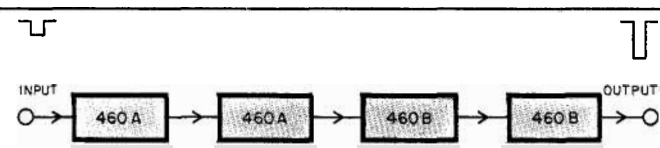
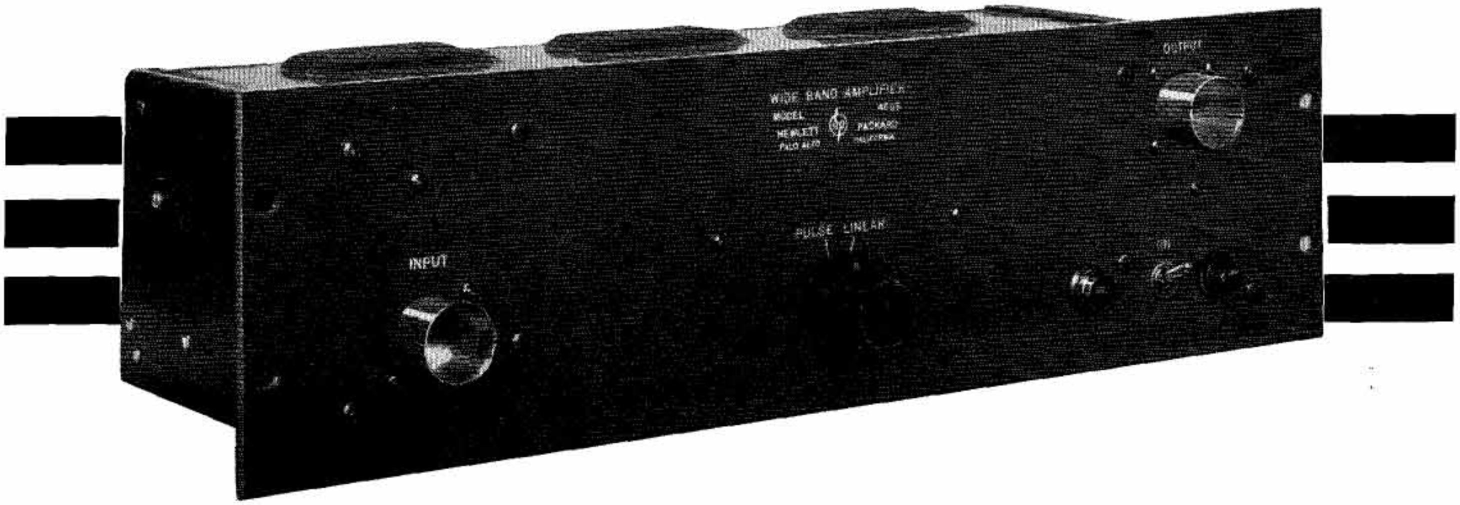


Figure 1. Typical cascading of 460A/B Amplifiers to give approximately 70 db gain and 125 volt pulse output.

460A/B WIDE-BAND AMPLIFIERS



Wide-Band Distortion-Free Fast-Pulse Amplifiers

Advantages:

- 20 db gain—up to 90 db in cascade
- True amplification of millimicrosecond pulses
- Rise time 0.0026 μsec
- 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 over 200 MC range
- 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.

-hp- 460A Wide-Band Amplifier is used fundamentally to provide voltage gain, (approximately 20 db). Its companion equipment, *-hp-* 460B, is designed as a terminal amplifier to give maximum voltage or power output. The amplifier's ultra-short rise time of 0.0026 μsec, combined with zero overshoot, insures distortion-free amplification of pulses faster than 0.01 μsec. *-hp-* 460B cascaded with 460A provides linear amplification of 16 volts peak output; and with two 460B, pulse amplification of 125 volts (open circuit limited duty cycle). This permits full deflection of 5XP cathode ray tubes. (Slight non-linearity, *see Figure 3.)* 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

-hp- 460A represents a new type of amplifier with a very wide transmission band—approximately 200 MC. The equipment has two stages of 5 and 7 tubes, respectively.

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 precise accuracy 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 pages 44, 45) 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.)

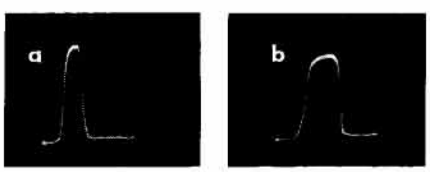


Figure 1. (a) 0.01 μsec pulse through *-hp-* 460B Amplifier. (b) 0.02 μsec pulse through 3 amplifiers in cascade.

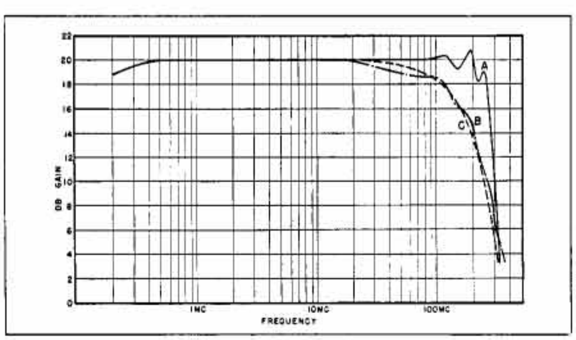


Figure 2. Typical response of 460A Amplifier working into (B) resistive load and (A) using *-hp-* 410B Vacuum Tube Voltmeter. (C) Gaussian curve.

Specifications

-hp- 460AR*

Frequency Response: *High Frequency*—closely matches Gaussian curve when operating into a 200-ohm resistive load. 3 db point is 140 MC. *Low frequency*—when operating from a 200-ohm source and 0.01 μf blocking condenser, frequency response off 3 db at 3 KC into an open circuit or succeeding amplifier. When operating into a 200-ohm load, off 3 db at 100 KC. With *-hp-* 410B VTVM: ±1 db, 200 KC to 200 MC.

Gain: Approximately 20 db into 200-ohm load. Gain control has range of 6 db. 5 amplifiers may be cascaded.

Output: Approx. 8 v peak open circuit. Internal impedance, 300 ohms.

Input Impedance: 200 ohms.

Noise Figure: Less than 10 db.

Delay Characteristics: Approx. 0.014 μsec.

Rise Time: Approx. 0.0026 μsec (10% to 90% amplitude). No appreciable overshoot.

Power: 115 v ±10 v, 50/1,000 cps, 35 watts.

Dimensions: Rack Mount: 19" wide, 5¼" high, 7" deep.

Weight: Net 11 lbs. Shipping 28 lbs.

Price: $185.00.

-hp- 460BR*

(Same as 460A except as follows):

Gain: Approximately 15 db into 200-ohm load.

Output: Linear Amplifier—Approximately 8 volts peak into a 200-ohm load or 16 volts peak into open circuit.
Pulse Amplifier—Approximately 125 volts negative peak into open circuit (unilateral pulse operation).

Input: Impedance 200 ohms (+8 volts input required for −125 volt output).

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: $225.00.

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*AR and BR designate rack mount. Cabinet mount not available.

-hp- 46A Accessories

***-hp-* 46A-16A Patch Cord**—200 ohms, 2' long. **$14.50.**

***-hp-* 46A-16B Patch Cord**—200 ohms, 6' long. $23.50.

***-hp-* 46A-95A Panel Jack**—For 200-ohm cables, low capacitance. $5.00.

***-hp-* 46A-95B Cable Plug**—For 200-ohm systems. $5.00.

***-hp-* 812-52 Cable**—200-ohm cable in length to specification. Per foot $2.25.

***-hp-* 46A-95C 50-Ohm Adapter**—Type N connector for coupling 50-ohm line into *-hp-* amplifiers. $10.00.

***-hp-* 46A-95D Adapter**—Bayonet sleeve for connecting *-hp-* 410B VTVM to output of 460A amplifiers. $10.00.

***-hp-* 46A-95E Connector Sleeve**—Joins two 46A-95B Cable Plugs. $7.50.

***-hp-* 46A-95F Adapter**—For connecting to 5XP CRT. $7.50.

Data subject to change without notice.

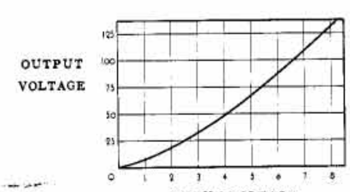
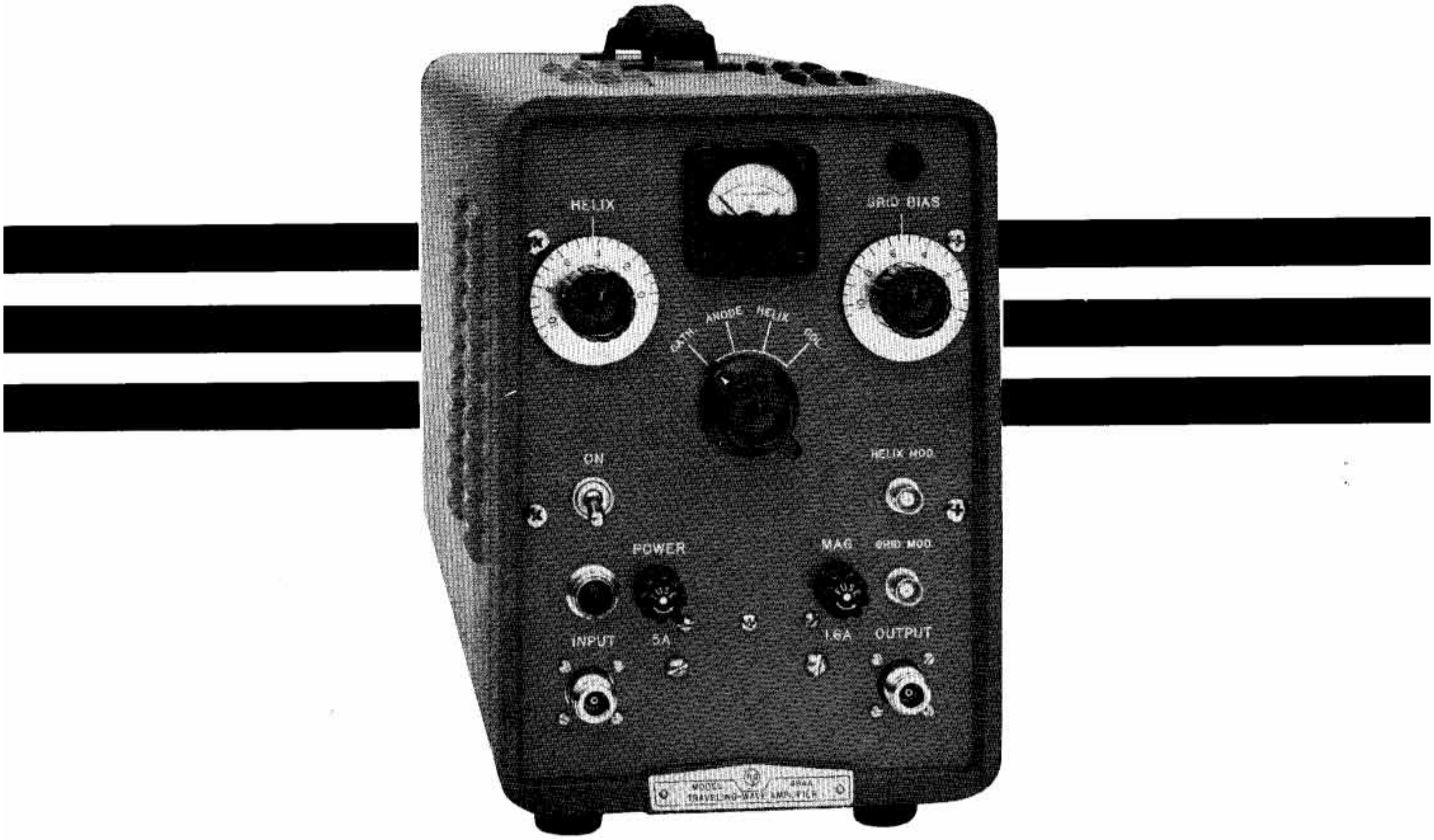


Figure 3. Linearity of *-hp-* 460B Amplifier.

490B/491A/492A/494A TRAVELING-WAVE TUBE AMPLIFIERS



Advantages:

- Radical coupled-helix design
- Frequency coverage 2 to 12.4 KMC
- High power output
- 25 to 30 db gain
- Millimicrosecond 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
- High power measurements
- Low level, low noise amplification
- High speed pulse generation

Broad Band, High Gain, Low Noise Amplification - 2 to 12.4 KMC

New Hewlett-Packard Traveling-Wave Tube Amplifiers are precision, broad band 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 in the past two years, the problem of coupling broad band signals into and out of the tube was not satisfactorily solved, and the industry had no practical, dependable equipment of this type.

Radical Design Approach

-hp- engineers developed a simple new broad band coupling method employing helices *(Figure 1)*. There is no mechanical connection to the inner helix, yet full energy transfer is effected. The difficulties in previous experimental amplifiers using multi-element networks, taper or vacuum leads have been overcome through use of matching helical couplers at both input and output ends of the tubes. A similar helix is used for a coupled attenuator which surrounds the central portion of the tube, preventing amplified energy causing regeneration.

Four Separate Instruments

For work at S band frequencies, *-hp-* offers two instruments, each providing high gain, good noise figure and complete coverage 2 to 4 KMC.

-hp- 490B (superseding *-hp-* 490A) provides at least 10 milliwatts output, 30 db gain with noise level 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 Generators in this catalog) provides a versatile full watt source for high power testing at 2 to 4 KMC. When modulated output is desired, the 616A Signal Generator may be modulated and the 491A will faithfully amplify the modulated signal.

New **-hp- 492A** (4 to 8 KMC) and **-hp- 494A** (7 to 12.4 KMC) are low level, high gain instruments with 30 and 25 db gain respectively. They offer the unique versatility of amplitude, pulse, phase or FM modulation, and are ideal for use as broad band amplifiers or isolating buffer stages.

Simple Operation

All *-hp-* Traveling-Wave Tube Amplifiers have simple front panel controls for adjusting helix and grid or anode voltages to best performance levels. The anode or grid voltage adjustment increases tube life by lowering dissipation when maximum output power is not needed. The helix adjustment provides maximum tube performance at any frequency; or a single setting will yield optimum broadband response.

All instruments also have front panel controls and metering for performance checks or continuous monitoring, and modulation connections brought out to the front.

Encapsulated Replacement Tubes

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.

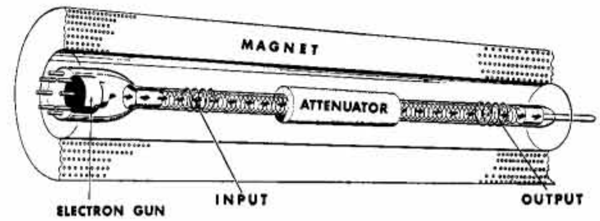


Figure 1. Construction of the *-hp-* Traveling-Wave Tube showing input and output coupling helices and attenuator helix.

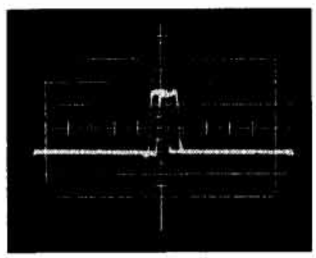


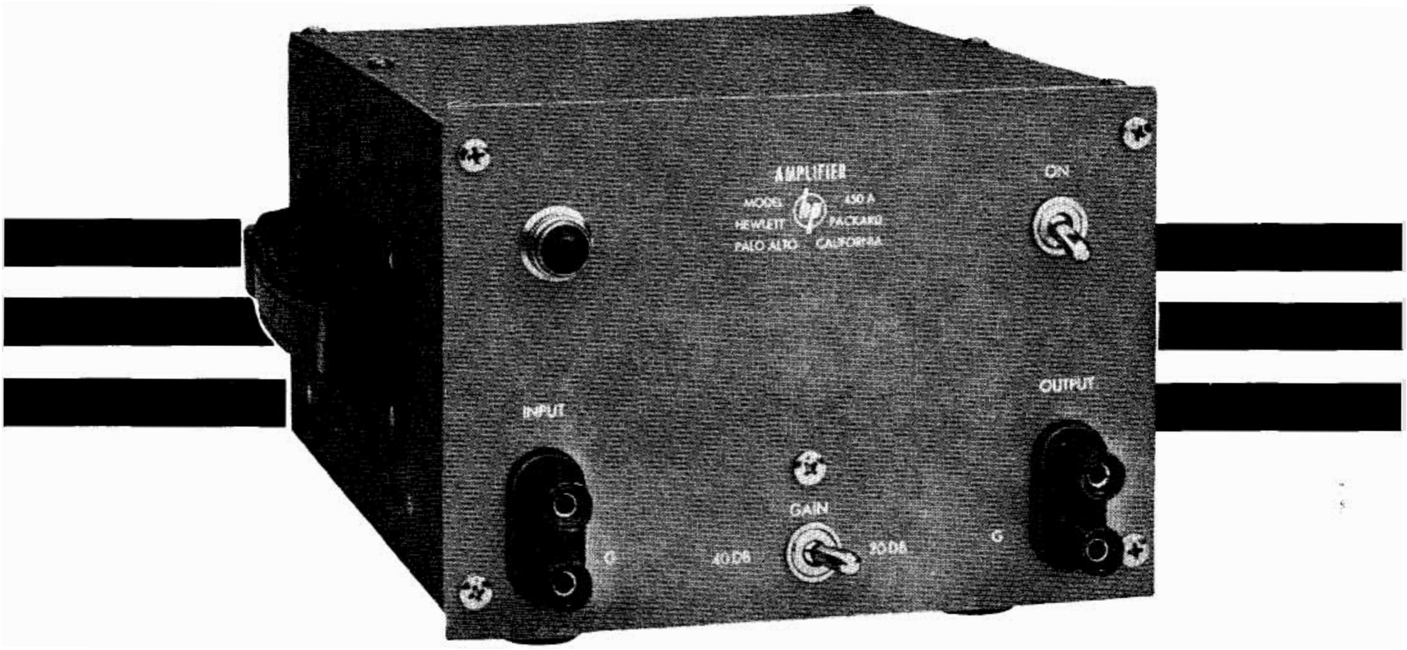
Figure 2. Unique modulating fidelity of *-hp-* 490B is shown in double-exposure oscillogram of 0.1 μsec pulses. First pulse (applied by *-hp-* 212 Pulse Generator) is modulating pulse with rise time of 0.02 μsec; delay through tube approximately 50 millimicroseconds. Second pulse is rf output. Note absence of deterioration.

Specifications

	-hp- 490B	-hp- 491A	-hp- 492A	-hp- 494A
Frequency Range:	2 KMC to 4 KMC.	2 KMC to 4 KMC.	4 KMC to 8 KMC.	7 KMC to 12.4 KMC.
Gain:	30 db minimum.	30 db minimum.	30 db minimum.	25 db minimum.
Output Power:	10 milliwatts minimum into 50-ohm load.	1 watt minimum into 50-ohm load.	10 milliwatts minimum into 50-ohm load.	5 milliwatts minimum into 50-ohm load.
Noise Figure:	Less than 25 db.	Less than 30 db.	Less than 25 db.	Less than 25 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 volt 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 1 megohm.	Approx. 50 volts peak to peak. Provides 360° phase shift. Input impedance 1 megohm.
Hum, Spurious Modulation:	At least 30 db below signal level.	At least 30 db below signal level.	At least 30 db below signal level.	At least 30 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. 65 lbs.	7½" wide, 11½" high, 20" deep. 55 lbs.	7½" wide, 11½" high, 20" deep. 55 lbs.
Power Supply:	115 volts ±10%, 50-1000 cps, approx. 125 w.	115 volts ±10%, 50-60 cps, approx. 250 w.	115 volts ±10%, 50-60 cps, approx. 175 watts.	115 volts ±10%, 50-60 cps, approx. 175 watts.
Traveling-Wave Tube:	Huggins Laboratories HA-1HP.	Huggins Laboratories HA-2HPA.	Huggins Laboratories HA-3HP.	Huggins Laboratories HA-4HP.
Price (including tube):	$1,100.00.	$1,100.00.	$1,500.00.	$1,500.00.

All instruments equipped with front panel metering for cathode, anode, helix and collector current. *Data subject to change without notice.*

450A AMPLIFIER



Specifications

Gain: 40 ±⅛ db or 20 ±⅛ db at 1,000 cps as selected by panel switch.

Frequency Response: At 40 db gain: within ±0.5 db between 10 and 1,000,000 cps; within ±1 db between 5 and 2,000,000 cps. At 20 db gain: within ±0.5 db between 5 and 1,000,000 cps; within ±1 db between 2 and 1,200,000 cps.

Stability: ±2% with line voltage of 115 v ±10 v and normal change in tube characteristics.

Input Impedance: 1 megohm shunted by approx. 15 $\mu\mu$f.

Output: 10 volts maximum to 3,000 ohms or higher resistive load.

Internal Impedance: Less than 150 ohms over entire range.

Distortion: Less than 1% at rated output from 2 cps to 100 KC; approximately 5% above 100 KC to 1 MC.

Equivalent Input Noise Level: 40 db gain, 40 microvolts approx.; 20 db gain, 250 microvolts approx.

Power: 115/230 v ±10%, 50/1,000 cps, 40 watts.

Dimensions: Cabinet Mount: 8¼" wide, 5½" high, 10½" deep. Rack Mount: 19" wide, 5¼" high, 10" deep.

Weight: Net 9 lbs. Shipping 22 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly $4.00; AC-16B Cable Assembly $4.25.

Price: $140.00.

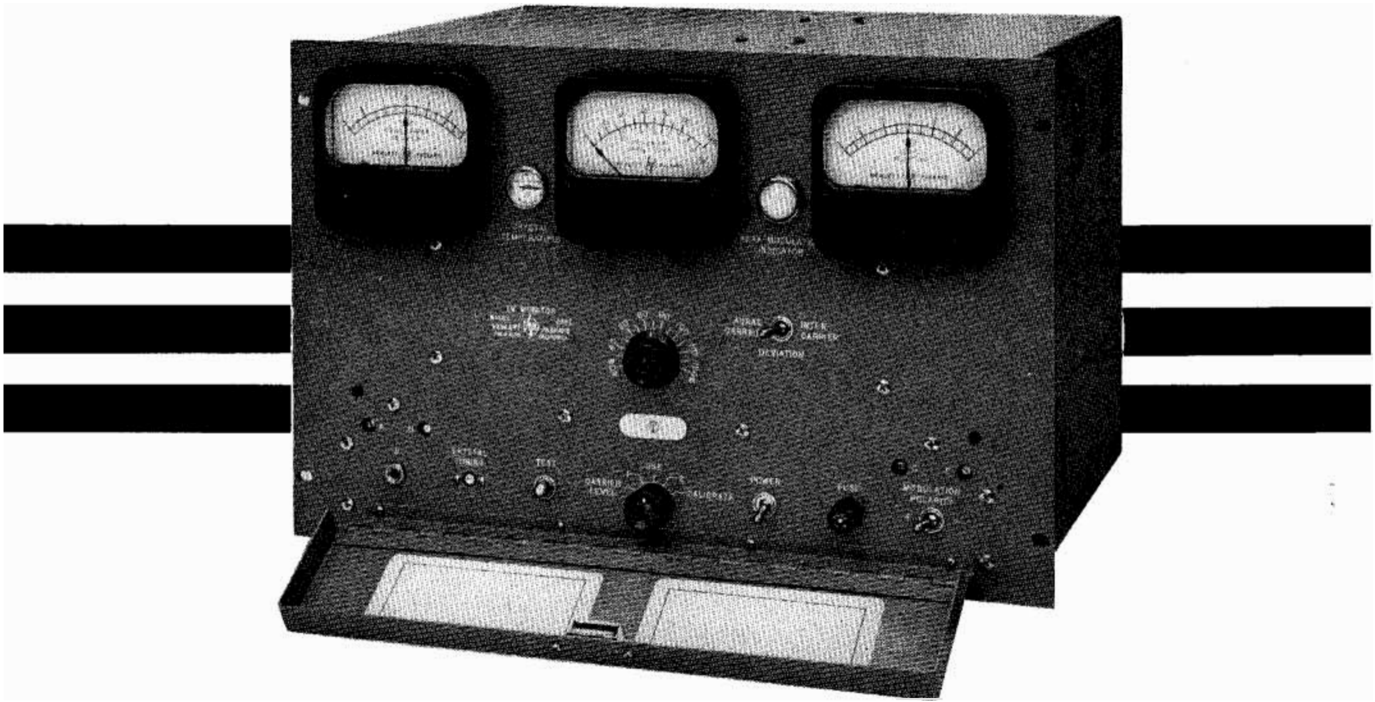
Data subject to change without notice.

General Purpose Amplifier
20 db or 40 db Gain

The *-hp-* Model 450A Amplifier is ideal as a general purpose instrument wherever wide frequency range and stable gain are essential. The instrument has an extremely stable 20 db or 40 db gain over a continuous frequency range of 10 cps to 1,000,000 cps. Either gain may be quickly selected with a toggle switch on the front panel.

The amplifier is resistance-coupled and does not use peaking or compensating networks. Optimum performance is obtained entirely from a straightforward amplifier design in combination with inverse feedback. Phase shift is negligible, and there are no spurious oscillations or resonances.

This amplifier consists of two stages followed by a cathode follower output stage. Hum is kept to a minimum by using direct current filament supply for the two amplifier tubes.



Low Cost, Channels 2 to 83; for Color or Black-and-White

Model 335E is the most compact and inexpensive quality TV monitor offered, yet it performs every important TV carrier monitoring function continuously and without adjustment.

The instrument gives continuous, precise indication of visual and aural frequency deviation and percentage, and shows intercarrier separation directly. No calculations are required, and no front panel adjustment is needed during operation. It is never necessary to reset carrier level or realign circuits. Proper operation can be checked easily with controls behind the hinged front panel cover. Instrumentation includes a crystal temperature indicator.

Model 335E is built of highest quality components for long years of trouble-free operation. Adroit chassis design assures easy accessibility and cool operation. The Monitor fits a standard relay rack, is adjusted for your specific channel and offset, and can be color finished to match your transmitter installation.

Model 335E slides out of the rack for easy servicing.

Specifications

Aural and Visual Frequency Monitors:

Deviation Range: +3 KC to −3 KC mean frequency deviation.

Accuracy: Channel 2– 6 ±500 cps for 90 days.
7–13 ±500 cps for 45 days.
14–83 ±500 cps for 14 days.

Aural Modulation Meter:

Modulation Range: Meter reads full scale on modulation swing of 33.3 KC. Scale calibrated to 100% at 25 KC swing; 133% at 33.3 KC swing. Also includes db scale (0 db = 100%).

Accuracy: Within 5% of indicated modulation percentage over entire scale.

Meter Characteristics: Meter damped in accordance F.C.C. requirements. Reads peak value of modulation peak of duration between 40 and 90 milliseconds. Meter returns from full reading to 10% of full value within 500 to 800 milliseconds.

Frequency Response: Flat within ±0.5 db from 50 to 15,000 cps.

Modulation Peak Indicator:

Peak Flash Range: From 50% to 120% modulation (25 KC = 100%).

Inter-Carrier Spacing: Directly measured, accuracy ±500 cps for 6 months.

Audio Output:

Frequency Range: 50 to 15,000 cps. Response flat within ±0.5 db. Equipped with standard 75 microsecond de-emphasis circuit.

High Impedance Output: 10 volts into 100,000 ohms at 100% modulation at low frequencies. Distortion less than 0.25% at 100% modulation. Residual noise at least 65 db below output level corresponding to 100% modulation at low frequencies.

Monitoring Output: 1 milliwatt into 600 ohms, balanced, at 100% modulation, at low frequencies.

Power: 115 v ±10 v, 50/60 cps, 180 watts.

Dimensions: Available only for rack mounting: 19″ wide, 12½″ high, 13″ deep.

Weight: Net 67 lbs. Shipping 107 lbs.

Accessories Furnished: 2 38-74 UG21B/U AN Connectors.

Accessories Available: 335E-95F External Aural Deviation Meter Assembly, $65.00; 335E-95H External Visual Carrier Deviation Meter Assembly, $65.00; 335E-95B External Aural Modulation Percentage Meter Assembly, $65.00.

Price: $2,050.00.

Data subject to change without notice.

By means of electronic circuits, frequencies can be added, subtracted, multiplied and divided with mathematical exactness. When such circuits are used in conjunction with a high-quality frequency standard, measurements can be made whose precision approaches that of the standard to any desired degree.

Since a standard of frequency is by definition also a standard of time, frequency standards and measuring instruments are used in every branch of science and engineering where these quantities are considered. The complexity and precision of a frequency measuring instrument depends largely upon its application.

Frequency Standard

Until recently, the problem of obtaining standardized precisely-known frequencies has been solved by the use of elaborate and expensive primary frequency standards whose frequency is established by constant checks against standard time. However, the reliability and convenience of standardizing with Bureau of Standards transmissions (Station WWV) have resulted in the recent widespread use of more economical secondary standards as a source of accurate frequency (Fig. 1).

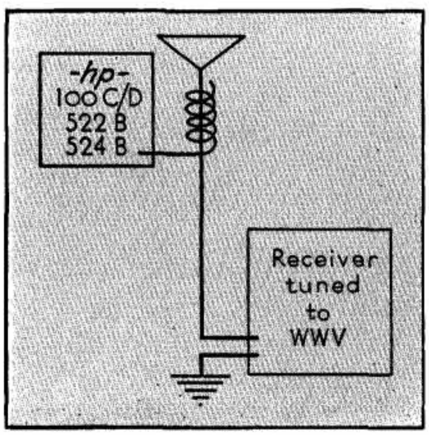


Figure 1. Method of checking *-hp-* frequency measuring equipment with station WWV.

Such an instrument is *-hp-* 100D Secondary Frequency Standard (page 56). This instrument contains a precision crystal oscillator which may easily be standardized against Station WWV. Five sinusoidal standard frequencies 100 KC, 10 KC, 1 KC, 100 cps, and 10 cps—are generated and the four lower frequencies are also available in rectangular waveshape. All of these frequencies are accurate to within a few parts in a million. A self-contained oscilloscope provides means of calibrating signal sources operating in the range of subsonic to radio frequencies by means of Lissajous figures. Harmonics as high as 5 MC can be obtained from the rectangular waves; and are useful in calibrating receivers or calibrating signal sources by zero-beat methods. This range can be extended by the use of multipliers.

TV and FM Monitors

-hp- offers Model 335E TV Monitor for the direct measurement and continuous display of visual carrier deviation, aural carrier deviation and per cent of aural modulation for both monochrome and color TV. This widely-used instrument employs frequency counting circuits based on the *-hp-* RC pulse integrating circuit.

-hp- Tachometry Instruments

Hewlett-Packard has drawn upon its experience with precision electronic counters to produce simplified and versatile tachometry units tailored for industrial use. The individual components are designed for accurate analysis of most kinds of mechanical motion.

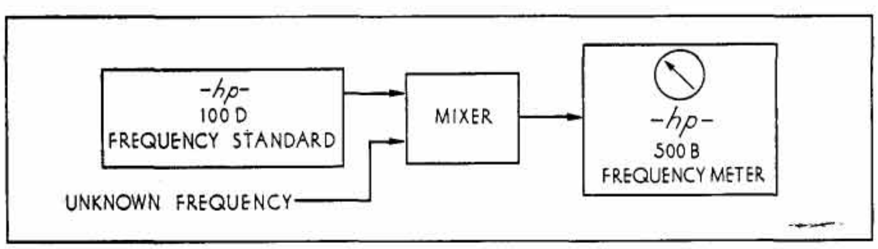


Figure 2. Typical setup for measuring deviation of unknown frequency from standard frequency.

The tachometry equipment falls naturally in two general classes.

A. Transducers which convert the mechanical motion to be measured into electrical pulses.

B. Tachometer indicators which measure the rate of these pulses.

These two general classes of instruments open the door to a wide variety of measurements with a degree of accuracy that has heretofore been unattainable.

Hewlett-Packard produces two general types of transducers and two general types of tachometer indicators.

Transducers

The two types of *-hp-* transducers are (1) Tachometer Generator, and (2) Optical Tachometer Pickup.

The Tachometer Generator is a low torque, compact generator which is used in the measurement of shaft revolutions. Or it can be used to determine the instantaneous rate of rotation for torsional vibration measurements. When the Tachometer Generator is connected to the rotating shaft it generates output pulses which can be counted in any of the *-hp-* counters. The Tachometer Generators are similar but generate a different number of pulses per shaft revolution. The *-hp-* 508A produces 60 pulses per shaft revolution, the 508B produces 100, the 508C produces 120, and the 508D produces 360. Shaft revolutions of from 15 rpm to 40,000 rpm can be measured accurately with these Tachometer Generators.

Hewlett-Packard's other transducer, *-hp-* 506A Optical Tachometer Pickup, uses a light source and phototube receiver to generate its electrical pulses for counting purposes. For making rpm measurements, the light is directed upon the rotating shaft, which is prepared with alternate reflecting and absorbing surfaces. The reflected light is picked up by the photo cell, thus generating electrical impulses. The Optical Tachometer Pickup has the advantage that it does not load the machinery under test. It can be used over a wide range of 300 rpm to 3,000,000 rpm.

Tachometer Indicators

Tachometer indicators measure the rate at which the transducers produce electrical pulses and display this information in terms of cycles per second (rps) or revolutions per minute. The tachometry accuracy largely depends upon these tachometer indicators.

Hewlett-Packard makes two general types of tachometer indicators, frequency meters and frequency counters. The principal difference is that the frequency meters respond in proportion to the rate of input pulses, whereas the frequency counters directly count each input pulse. This means in practice, that whereas the frequency meters have the necessary accuracy for most industrial applications, the frequency counters are able to give a high degree of precision and are suitable for not only ordinary measurements, but also the most exacting design applications.

Hewlett-Packard produces the following frequency meters: *-hp-* 500B, counting in cps or rps, *-hp-* 500C, counting in rpm.

These instruments will measure at a rate of 180 to 6,000,000 rpm, and will give accuracy of better than ±2%. For small differentials in readings or small changes in repetitive readings these instruments have even better accuracy.

-hp- 500B Electronic Frequency Meter (page 58) is a complete measuring instrument in its own right which can also be used to measure difference frequencies. This instrument provides direct meter indication of frequencies from 3 cps to 100 KC in nine convenient scale ranges. It is suitable for laboratory and production measurements at audio and supersonic frequencies.

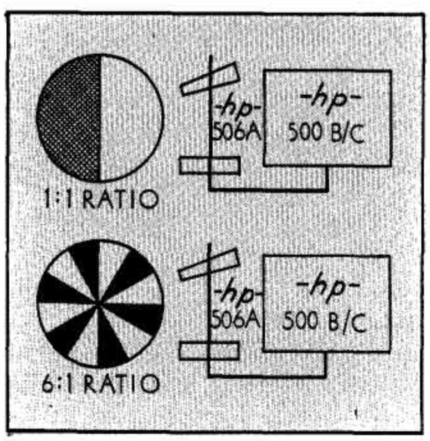


Figure 3. Typical set-up for extending low-frequency range of *-hp-* 500B/C Electronic Tachometer Indicators.

-hp- 500B is particularly suited to crystal grinding work, where it can be used to measure frequency deviation from standard quickly and accurately *(Figure 2)*.

-hp- 500C Electronic Tachometer Indicator is a natural development from the 500B. While the 500B is calibrated to read in cycles or revolutions per second, the 500C reads directly in revolutions per minute.

When used with *-hp-* 506A Optical Pickup it will indicate speeds from 300 rpm (5 rps) to 300,000 rpm (5,000 rps). Speeds lower than 300 rpm can be measured with the *-hp-* 500C Electronic Tachometer Indicator and 506A by dividing the rotating shaft or disc into more than two segments. For example, a 6-black, 6-white segmentation *(Figure 3)* will give a multiplication factor of 6. Actual speed of rotation in this set-up is the direct reading of *-hp-* 500C divided by the number of white or number of black segments—in this example 6. Speeds ranging from about 15 to 40,000 rpm can also be measured by the 500C in conjunction with the *-hp-* 508 series Tachometer Generators.

Frequency Counters

For the utmost precision and versatility in tachometry, as well as general frequency type measurements, Hewlett-Packard produces five electronic counters:

-hp- 521A Industrial Electronic Counter, which makes possible wide range frequency, speed and time interval measurements. It will count at the rate of 1 cps to 120 KC.

-hp- 521C Industrial Electronic Counter is the same as 521A except for these additional features: a crystal controlled time base, 5 decades, and a 10-second gate.

-hp- 522B Electronic Counter measures frequency and period from 0.00001 cps to 120 KC and time interval from 10 μsec to 10^5 seconds (27.8 hours).

-hp- 523B Electronic Counter is a frequency counter measuring period 0.00001 cps to 10 KC and time interval 3 μsec to 100,000 seconds (27.8 hours). Front panel controls adjust trigger slope and level for start and stop circuits. Pulse output coincident with start and stop is provided for intensity modulation of a CRT ~~to show~~ exact interval measured.

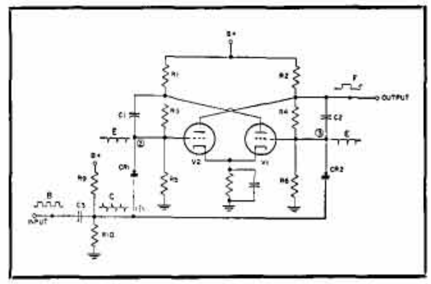


Figure 4. Basic binary scaler.

-hp- 524B Electronic Counter, although primarily a laboratory instrument, has tachometry applications when its supreme accuracy and frequency range are required. With plug-in units it will count at the rate of 0 cps to 220 MC.

In these instruments, frequency is measured by pulse counting techniques, with results being displayed automatically, instantly, and in direct-reading numerical form. The reading is complete even to an illuminated automatic decimal point.

The counting is performed with a bistable multivibrator or binary scaler *(Figure 4)*. The binary will produce one output pulse for each of two pulses at the input. Cascading four of these basic units results in one output pulse for sixteen input pulses.

But because of the greater convenience of decimal over binary scaling, special circuitry is added in the counters to enable the four binaries to put out one pulse for each ten input pulses. This is the decimal scaling approach used in all *-hp-* Electronic Counters.

Counter Details

-hp- 521C, 522B, 523B and 524B Electronic Counters contain a precision oscillator which may be readily standardized against transmissions from Station WWV *(Figure 1)*. For its time base the *-hp-* 521A Industrial Counter makes novel use of the standard 60-cycle line frequency which is universally available and normally accurate to 0.1%.

The simplicity of operation of Hewlett-Packard Electronic Counters in making frequency measurements is worthy of special mention. When an unknown is connected to the input terminals, the measured frequency is displayed instantly on illuminated scales and meters. This extreme simplicity of operation means the counters can be used by non-technical personnel with virtually no special instruction.

For further information on the capabilities and operation of *-hp-* Counters, please see page 61.

100D SECONDARY FREQUENCY STANDARD

Advantages:

- Sine or rectangular waves
- 100 μsec time markers
- Built-in oscilloscope
- Stability 1/1,000,000
- Low output impedance
- Controlled frequencies: 100 KC, 10 KC, 1 KC, 100 cps, 10 cps

Use It To:

- Perform most functions of expensive primary standards
- Establish standard frequencies
- Calibrate audio oscillators
- Calibrate supersonic or rf oscillators
- Check transmitter stability
- Check oscillator stability
- Measure short time intervals
- Provide time standard

Generates 5 Standard Frequencies for Swift, Sure Comparison

TODAY, nearly every electronics or communication establishment is confronted with the problem of obtaining standardized, precisely-known frequencies for use in determining unknown frequencies. Until recently, this problem has been solved by the use of elaborate and expensive primary frequency standards whose frequency is established by constant checks against standard time. However, the reliability and convenience of standardizing with Bureau of Standards transmissions (Station WWV) have resulted in the recent widespread use of more economical secondary standards as a source of accurate frequencies.

The Model 100D Secondary Frequency Standard has been developed with this trend in mind. The instrument may be standardized against Station WWV without the use of additional equipment other than a standard audio oscillator and a communications receiver. Thus the instrument provides most of the advantages of a primary standard, at much lower cost.

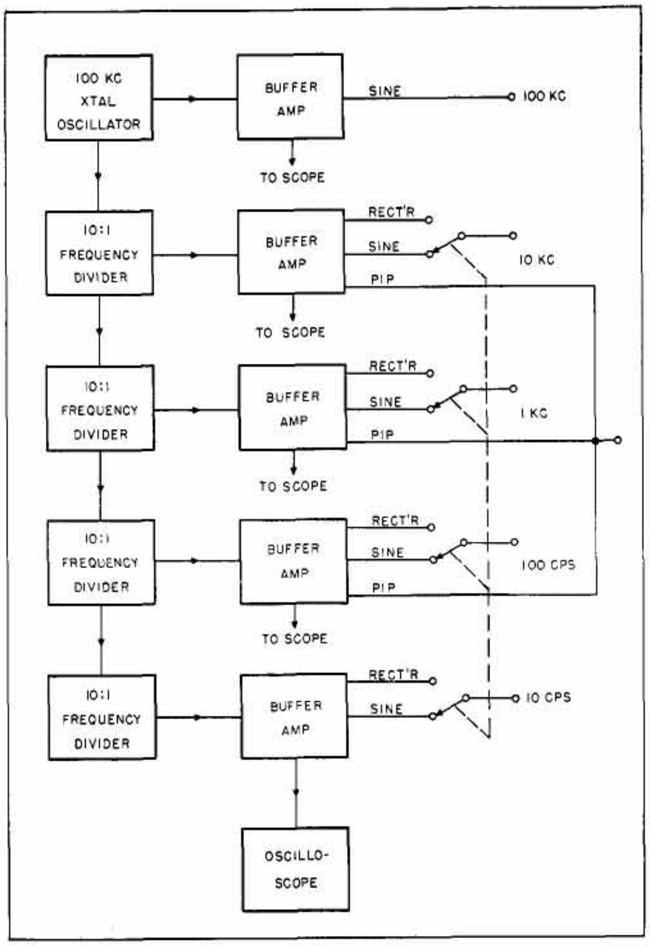


Figure 1. Block diagram of circuit, Model 100D.

Sine or Rectangular Frequencies

Five sinusoidal standard frequencies—100 KC, 10 KC, 1 KC, 100 cps and 10 cps—are generated by Model 100D. In addition, the equipment also generates rectangular waves at all the above frequencies except 100 KC. Harmonics as high as 5 MC can be obtained from these rectangular waves for measurement purposes.

In addition, the instrument also provides marker pips at 100, 1,000 and 10,000 microsecond intervals. *(See Figure 2.)* A self-contained oscilloscope further contributes to convenience in standardizing the instrument. It provides a visual check of the division ratio and is useful in calibrating audio oscillators and other supersonic or rf equipment by means of Lissajous figures.

Circuit Description

The block diagram in Figure 1 shows the circuit arrangement of this Secondary Frequency Standard. A crystal-controlled oscillator operating at 100 KC controls the stability of all frequencies generated by the instrument. The frequencies of 10 KC, 1 KC, 100 cps and 10 cps are obtained from four 10:1 cascaded frequency dividers driven by the 100 KC crystal-controlled oscillator. Each divider operates its own isolating amplifier so that all sine waves or rectangular waves generated are available for external use simultaneously.

Crystal Oscillator

The oscillator circuit employs a very low-temperature coefficient crystal. Housing for the crystal is a double-chamber oven, temperature controlled by a mercury thermostat having a differential of 0.1°C. Control of the oven and stability of the crystal are such that an over-all accuracy within approximately 2/1,000,000 is provided over an interval of one week.

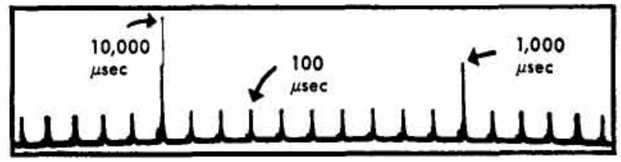


Figure 2. Timing comb, *-hp-* Model 100D.

Specifications

Accuracy: About 2 parts per million per week, at normal room temperatures.

Stability: About 1 part per million over short intervals.

Panel Control: Panel trimmer allows oscillator frequency to be varied over a range of approximately 0.5 cps for correction purposes.

Voltage Output: Sinusoidal output 5 volts into 5,000 ohms or higher load. Internal impedance approximately 200 ohms.

Distortion: Less than 4% when operating into 5,000 ohms or higher load.

Frequency Output: Controlled frequencies: 100 KC sine wave; 10 KC, 1 KC, 100 cps, 10 cps sine or rectangular waves.

Marker Pips: Generated at intervals of 100 µsec. A pip of double amplitude is generated every 1,000 µsec; and a pip of triple amplitude every 10,000 µsec.

Oscilloscope: Integral with circuit. Establishes 10:1 Lissajous figures to show division ratio. May be used independently of standard.

Frequency Shifting Circuit: Panel push-button lowers oscillator frequency by approximately 1 cps at 100 KC (50 cps at 5 MC) to aid in frequency measurements.

Rectangular Waves: 4 waves, generated corresponding to 10 KC, 1 KC, 100 cps and 10 cps. Harmonics up to 5 MC obtainable from 10 KC waves. Corresponding harmonics obtainable from other waves.

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

Dimensions: Cabinet Mount: 20½″ wide, 12½″ high, 14¾″ deep. Rack Mount: 19″ wide, 10½″ high, 13⅜″ deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 44 lbs. Shipping 66 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $4.25.

Price: $615.00.

Data subject to change without notice.

500B/C ELECTRONIC FREQUENCY METER

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

Measures Frequency of ac Voltages as High as 100 KC

THE *-hp-* 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 *-hp-* 506A or 508A/B/C/D. Use of *-hp-* 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, 500B is available as *-hp-* 500C with scale calibration in rpm. (See opposite page.)

The *-hp-* Models 500B/C are completely redesigned versions of the *-hp-* 500A and *-hp-* 505A/B so as to provide broader frequency coverage and increased versatility of use. To achieve these results an entire new circuit has been designed. 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 average value, making the meter reading proportional to the number of pulses per second, and hence proportional to the frequency of the input signal.

Independent of Signal Voltage

The reading is independent of the input voltage waveform. The regulated current source makes the reading independent of variations in input signal voltage, line voltage, and vacuum tube characteristics. 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. Provision is also made to operate a 1 ma recorder for a continuous frequency record.

Expanded Scale Feature

For extreme ease of readability the *-hp-* 500 Frequency Meter contains an expanded scale feature which permits any 10% or 30% portion of a selected range to 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 precise accuracy in the measurement of small frequency changes or differential frequencies.

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 checking for the presence of vibration or torsion.

Specifications -hp- 500B

Frequency Range: 3 cps to 100 KC. Nine ranges with full scale values of 10, 30, 100, and 300 cps; 1, 3, 10, 30, and 100 KC.

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 on front panel to reduce threshold sensitivity.

Input Impedance: Approximately 1 megohm shunted by 40 $\mu\mu$f. 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: Phone jack on panel for direct connection to 1 ma 1400 ohm ±100 ohm recorder or to a resistance voltage divider to operate other current or voltage sensitive recorders.

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, 9" high, 12½" deep.

Weight: Net 17 lbs. Shipping 35 lbs.

Accessories Available: *-hp-* 506A Optical Tachometer Pickup, $100.00. *-hp-* 508A/B/C/D Tachometer Generator, $100.00. Accessory meter 500B-95A, $32.50. *-hp-* AC-2A/B Dual Rack Panel, $25.00.

Price: $285.00.

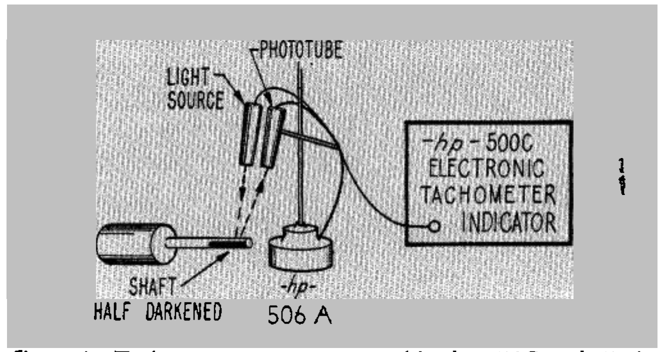


Figure 1. Tachometry measurements with *-hp-* 500C and 506A.

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. The range of direct measurement (one input pulse per shaft revolution) is 180 to 6,000,000 rpm. When used with *-hp-* 506A Optical Tachometer Pickup (see next page) rotational speeds from 180 to 300,000 rpm may be measured. The lower limit of speed measurement may be extended by dividing the rotating shaft into a greater number of light reflecting and absorbing surfaces (see Figure 1), and the upper limit may be extended by amplifying the signal from *-hp-* 506A. The 500C - 506A combination is particularly useful where mechanical tachometry connection to a rotating shaft is inconvenient or impossible.

Rotational speeds from 15 to 40,000 rpm may also be measured with *-hp-* 500C and an *-hp-* 508 series Tachometer Generator. This range may be extended above and below these limits by using an amplifier between the 500C and 508.

Rotational speed measurement using the systems described above has the advantage that fractional and multiple errors, inherent in stroboscopic systems, are eliminated.

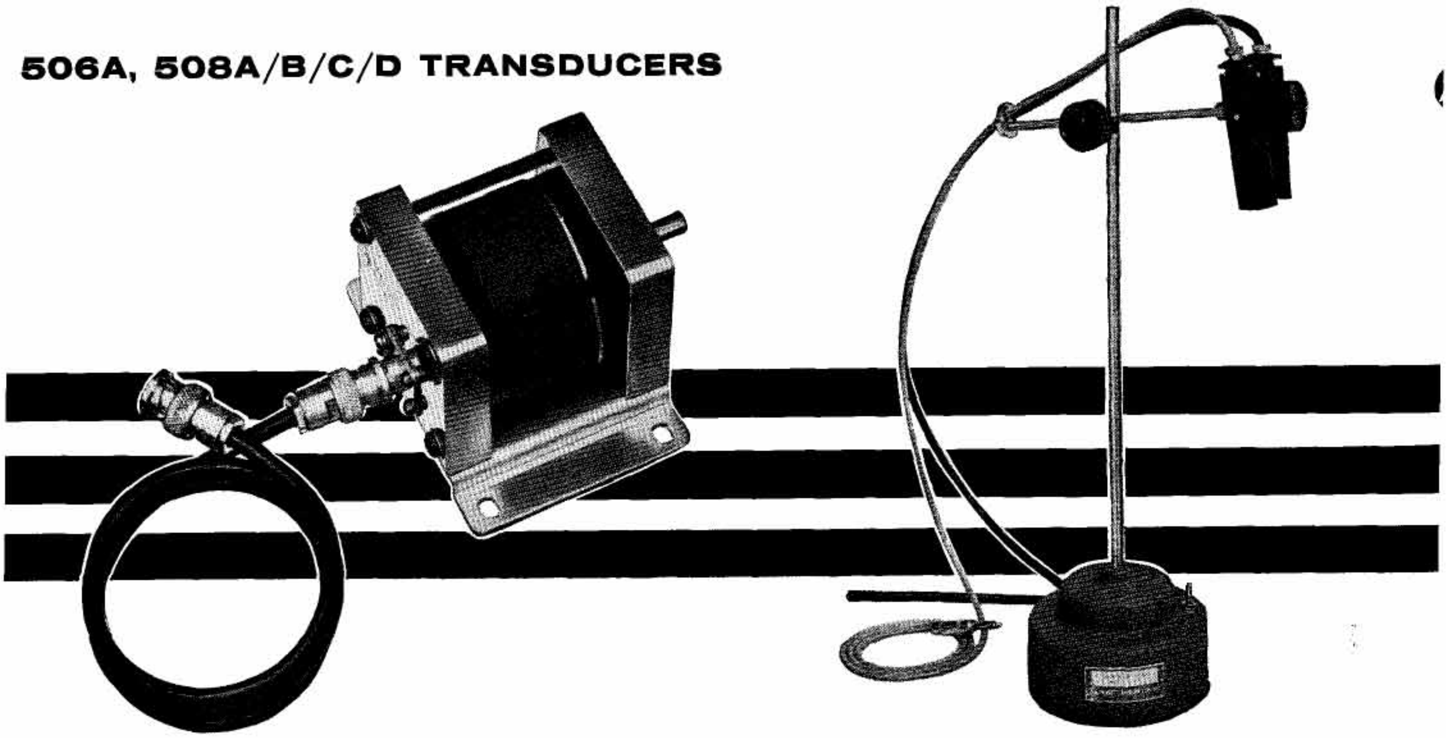
Specifications -hp- 500C

Circuit and Construction same as *-hp-* 500B except for meter calibration.

Speed Range: 180 rpm (15 rpm with transducers) to 6,000,000 rpm in nine ranges.

Price: $285.00.

Data subject to change without notice.



-hp- 508A/B/C/D 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.

Measurements of speeds above and below rated limits are possible through use of an amplifier.

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 pps, 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: 15 rpm to 40,000 rpm.

Output Frequency: 508A, 60 cycles/rev.; 508B, 100 cycles/rev.; 508C, 120 cycles/rev.; 508D, 360 cycles/rev.

Output Voltage: Increases approximately linearly with shaft speed from 15 pps to 5,000 pps. Decreases from 5,000 pps to 40,000 pps. Typical values: 0.2 volt rms at 15 pps, 1 volt rms at 100 pps.

Drive Shaft: 1/4″ diameter; projects 19/32″.

Running Torque: Approximately 1/4 in.-oz. at 200 rpm; 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: (all models) $100.00.

-hp- 506A Optical Tachometer Pickup

Model 506A is a versatile, flexible light source and pickup for use as a transducer with instruments such as *-hp-* 521A/C Industrial Electronic Counter, *-hp-* 500B Electronic Frequency Meter and *-hp-* 500C Electronic Tachometer Indicator. The instrument will measure very high speeds—from about 300 to 300,000 rpm—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

Nominal Shaft Speed Range: 300 to 300,000 rpm. (Measurements of higher and lower speeds are possible by providing increased gain with an amplifier such as *-hp-* 450A between the transducer and indicating instrument.)

Output Voltage: At least 1 v rms, 300 to 100,000 rpm (into 1 megohm or more impedance) with reflecting and absorbing surfaces 3/4″ square.

Light Source: 21 candlepower, 6 volt automotive bulb.

Phototube: Type 1P41.

Phototube Bias: +70 to +90 volts dc (supplied by *-hp-* 500B/C, 521A/C).

Accessories Available: *-hp-* 56A-16B Adapter Cable (connects *-hp-* 506A to *-hp-* 522B Counter), $15.00.

Price: $100.00.

Data subject to change without notice.

ELECTRONIC COUNTERS

THE development of pulse counter circuits has led to the manufacture of electronic counters capable of many measurements—particularly those involving frequency and time—that were not possible previously. Hewlett-Packard electronic counters such as Models 521A/C, 522B, 523B, and 524B offer the convenience of instantaneous, automatic reading, in direct numerical form, of unknown frequencies, time intervals or periods. They are engineered for utmost dependability and accuracy. Model 524B is perhaps the most broadly useful counter ever developed and incorporates the highest speed counting circuit ever used in a commercial instrument of this type. *-hp-* counters are designed for simple operation, and may be readily used by non-technical personnel.

A brief discussion of these counters in various types of measuring work appears below. Detailed descriptions appear on the following pages.

Frequency Measurements

The unknown frequency (fx) to be measured by the counter is applied to the signal gate (Figure 1). The gate is held open for the precise length of time selected by the operator. The time base generator is a crystal oscillator with high stability. The pulses passed to the counter circuits during this period of time are totalized and displayed on the instrument. The high frequency limit of *-hp-* 521A/C and 522B is 120 KC; 523B is 1.1 MC; 524B is 10 MC. With *-hp-* 525A/B Frequency Converters, the 524B is capable of measuring to 220 MC. The *-hp-* 540A Transfer Oscillator extends this range to 12.4 KMC. Accuracy is determined by the crystal oscillator and a possible error of ±1 count that is inherent with the gate and counter type of instrument.

Period Measurements

-hp- counters are arranged so that they can measure period ($1/f_x$) directly (Figure 2). This is particularly important in frequency measurements below 300 cycles. When counting frequency below 300 cycles (Figure 3) the ±1 count becomes a significant factor. In period measurement the unknown frequency (fx) opens and closes the signal gate for 1 period or 10 periods and a standard frequency from the time base generator is applied to the counter circuits. Accuracy is then increased to 0.3% for a one-period measurement and 0.03% for a 1 v rms signal over a ten-period average. Readings are displayed directly in microseconds, milliseconds or seconds.

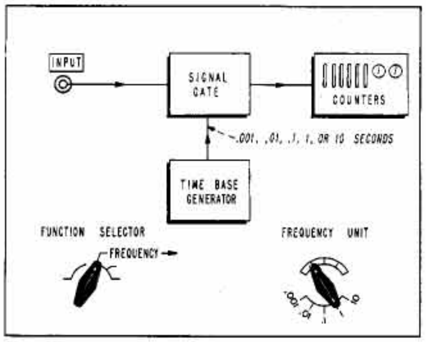


Figure 1. Frequency measurement circuitry in *-hp-* electronic counters (*-hp-* 524B illustrated).

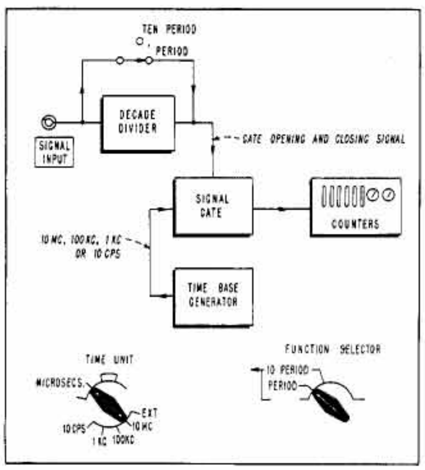


Figure 2. Period measurement circuitry in *-hp-* electronic counters (*-hp-* 524B illustrated).

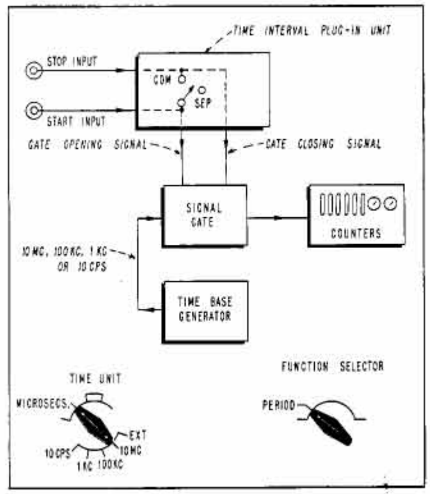


Figure 4. Time interval measurement circuitry in *-hp-* electronic counters (*-hp-* 524B, 526B illustrated).

Time Interval

Time interval measurements are similar to period measurements except that the point on the signal waveform or waveforms is adjustable. This adjustable threshold 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.

As in the case of period measurements, the input signal controls the opening and closing of the gate, while the standard frequencies are passed to the counters (Figure 4). Thus the accurate frequencies generated in the time base are used as units of time to measure the unknown interval in terms of microseconds, milliseconds, or seconds. Accuracy of this method is ±1 count of the standard frequency counted. Time interval measurement is incorporated in the 522B, 523B and is available for the 524B.

Instrument Self Check

The standard frequency (or frequencies) of *-hp-* counters can be counted for any selected gate time enabling the operator to determine if the counter is functioning properly.

Miscellaneous Measurements

-hp- electronic counters can also serve as a totalizer to indicate total number of random unit events. They will also measure time and frequency ratios, or serve as a secondary frequency standard. In conjunction with transducers such as *-hp-* 506A, 508A, B, C, and D, tachometry measurements can be made with a high degree of accuracy.

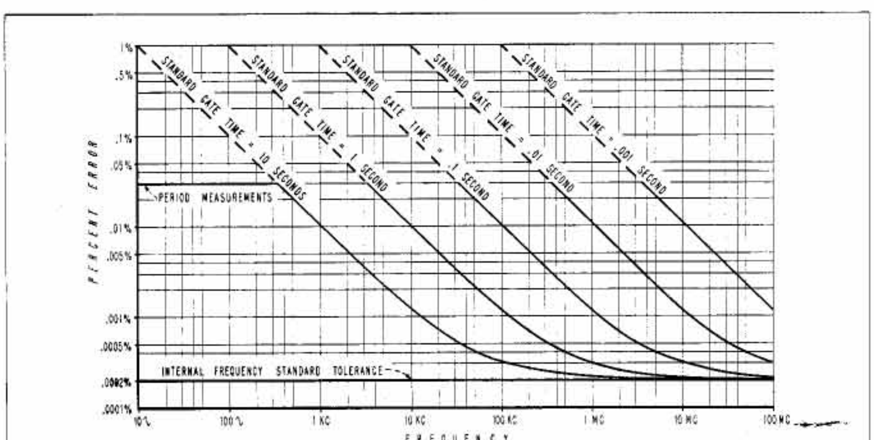
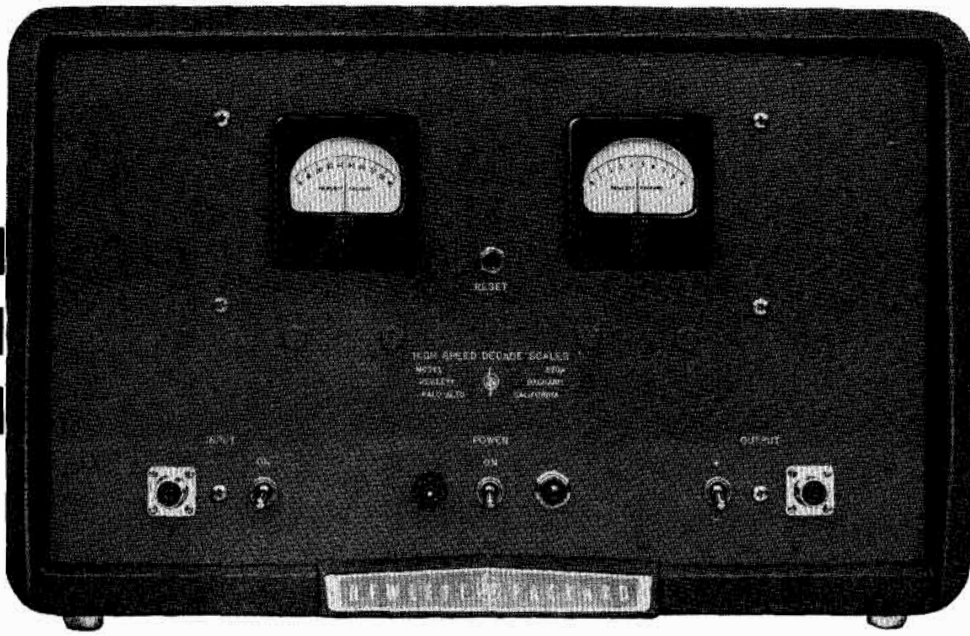


Figure 3. Possible error factor in frequency measurement (*-hp-* 524B, 525A).

520A HIGH SPEED DECADE SCALER



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.
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, 50 volts amplitude and approximately 5 μsec wide at base. Rise time approximately 1 μsec.
Output Impedance: Operates into 5,000 ohm load, or higher.
Connectors: Uhf type.
Power: 115/230 v $\pm$10%, 50/60 cps, 200 watts.
Dimensions: Cabinet Mount: 20½" wide, 12½" high, 13¾" deep. Rack Mount: 19" wide, 10½" high, 14" deep.
Weight: Net 51 lbs. Shipping 72 lbs. (cabinet mount).
Accessories Available: 125-UG273/U uhf-BNC Adapters, $2.50. AC-16K Video Cable Assembly, $5.00; AC-16D Video Cable Assembly, $2.65.
Price: $615.00.

Data subject to change without notice.

Quantitative Measurement of "Fast" Circuit Pulses

Model 520A makes possible quantitative measurement of extremely fast random or continuous occurrences. Its precise accuracy and high speed operation make possible easy measurement of "fast" circuit pulses or nuclear parameters. The instrument is an aperiodic counter which will record accurately continuous input rates of 10,000,000 counts per second, or will separate 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 100,000 pulse-per-second counter (such as *-hp-* 521A/C and 522B) to record large numbers of occurrences. This feature makes the *-hp-* 520A useful for measurement of frequencies up to 10 MC, in applications where the accuracy of the last two places is unimportant.

Versatile, Low Cost, Easy To Use — 1 cps to 120 KC

THIS new Hewlett-Packard counter fills the need for an easy to use, moderately priced instrument that will make specific industrial measurements heretofore possible only with much more elaborate equipment.

Model 521A measures frequency, speed, rpm and rps and counts events occurring at random within a selected period of time. With proper transducers converting mechanical into electrical phenomena, the instrument will also measure weight, pressure, temperature, acceleration and other quantities which can be related to frequency. The instrument is intended for use with such transducers as *-hp-* 506A Optical Tachometer Pickup and *-hp-* 508-A/B/C/D Tachometer Generators.

Model 521A reads in cycles per second, and also will indicate rpm and rps directly. Display of results is variable from 0.1 to 15 seconds or can be "held" indefinitely. Other useful features include a 60-cycle self check circuit to confirm accuracy of operation, three accessory power supplies of —150 v dc, +300 v dc, and 6.3 v ac, and a socket for connecting to a numerical printer.

Like other *-hp-* Counters, Model 521A uses *-hp-* AC-4A Decade Counters, the dependable, versatile units described on page 71.

Specifications

-hp- 521A Industrial Counter

Range: 1 cps to 120 KC.
Accuracy: ±1 count ± accuracy of 60 cycles timing frequency. (Usually 0.1% when timed by power line frequency.)
Registration: 4 places. Total count capacity 9,999.
Input Requirements: 0.2 volts rms.
Input Attenuator: Allows adjustment of sensitivity from 0.2 to 100 v rms to overcome noise.
Input Impedance: Approx. 1 megohm 50 μμf shunt.
Gate Time: 0.1 and 1 second.
Manual Gate: Controlled by "Open-Closed" switch or external contacts.
Display Time: Variable 0.1 to 15 seconds; or display can be held indefinitely.
Reads In: Cps or directly in rpm with proper pickup.
Self Check: Counts 60 cycles for any selected gate time.
Accessory Socket: Supplies —150 v dc, +300 v dc unregulated and 6.3 v ac.
Photocell Input: Jack in back.
Printer Output: Socket in back.
Power Requirements: 115 v ±10 v, 50/60 cps.
Dimensions: Cabinet Mount: 9¾" wide, 15¾" high, 14" deep. Rack Mount: 19" wide, 8¾" high, 13" deep.
Weight: Net 25 lbs. Shipping 45 lbs.
Price: $475.00.

-hp- 521C Industrial Counter

Same as the *-hp-* 521A except:
Accuracy: ±1 count, ±0.01%.
Registration: 5 places. Total count capacity 99,999.
Gate Time: 0.1, 1.0, and 10.0 seconds.
Time Base: Crystal controlled.
Self Check: Counts 10 KC derived from time base.
Price: $650.00.

Data subject to change without notice.

522B ELECTRONIC COUNTER

Advantages:

Measures frequency, period, or time
Broad applicability
High quality, low cost
Accurate within 1/100,000
Easily used by anyone
Direct, automatic readings
Bright, clear numerals
Compact, weighs just 52 lbs.

Use To Measure:

Frequency:
- Production quantities
- Nuclear radiations
- 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
- Precise event timing
- Interval stability
- Frequency ratios
- Phase delay

Versatile, Low Cost Precision Counter

IN AN ever-increasing variety of manufacturing and research measurements, this all-purpose Hewlett-Packard counter has more operating speed, simplicity and accuracy at lower cost than any equipment ever offered.

The 522B counter offers the unique convenience of frequency, period *and* time interval measurement over a broad frequency range. The instrument is completely contained in a small, bench cabinet, and no extra-cost modification is required to perform all functions. Results are displayed instantly and 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. Bright, clear illumination of numbers is assured during display since the counters use the high-dependability *-hp-* AC-4A Decade Counters with etched circuitry *(see page 71)*.

Operation

For frequency counting, *-hp-* 522B's range is 0.00001 cps to 120 KC. Counting is available over periods of 1/1,000, 1/100, 1/10, 1 and 10 seconds, or multiples of 10 seconds. Display time is variable at will, counts are automatically reset, and action is repetitive.

For period measurement, the unknown controls the opening and closing of the gate while the 522's decade counters record the number of cycles of an internal standard frequency. Period is presented in seconds, and milliseconds. By this method, frequency may be measured to 0.00001 cps.

Time interval is measured by a similar process except that gate time is governed by trigger pulses marking the beginning and end of the time interval to be examined. A threshold feature makes possible accurate measurement at each step of voltage *(see Figure 1)*. Time intervals from 10 μsec to 100,000 seconds (27.8 hours) can be measured; and again results are displayed directly in seconds or milliseconds. The count may be stopped or started on either positive or negative going waves at adjustable voltage levels from −100 to +100 volts.

Industrial Measurements

Many phenomena common to industrial research and manufacturing can be measured readily with *-hp-* counters using a simple transducer converting mechanical phenomena into electrical impulses. Such transducers include *-hp-* 508A/B/C/D Tachometer Generators. These transducers alone make possible a wide variety of measurements involving rotational motion (rpm of centrifuges, jet engines, superchargers, etc.). With suitable transducers linear motion such as projectile velocity can be analyzed to a fine degree of precision. For a more complete description of industrial use of 522B Counters, see Hewlett-Packard Journals, Vol. 4, No. 3 (Nov., 1952) and Vol. 5, Nos. 1-2 (Sept.-Oct., 1953).

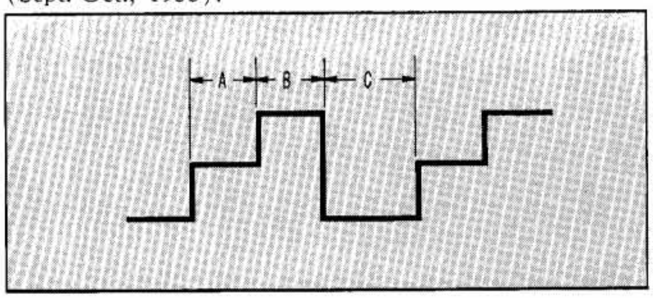


Figure 1. Threshold feature for time interval measurements permits measurement of duration of each step of voltage.

Specifications

Frequency Measurement:

Range: 10 cps to 120 KC.

Accuracy: ±1 count ± stability (see below).

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 μμf 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. Display can be held indefinitely if desired.

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: ±0.3% ± stability (see Frequency Measurement) for measurement of one period. Accuracy for more than one period is ±0.3% divided by number of periods ± stability.

Registration: Same as Frequency Measurement.

Input Requirements: 0.2 volt rms minimum. Direct-coupled input.

Input Impedance: Approx. 1 megohm, 50 μμf 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 the period being measured. Display can be held indefinitely if desired.

Reads In: Seconds or milliseconds with decimal point indicated.

Time Interval Measurement:

Range: 10 μsec to 100,000 seconds (27.8 hrs.).

Accuracy: ±1/std. freq. counted ± stability (See Frequency Measurement).

Registration: Same as for Frequency Measurement.

Input Requirements: 1 volt peak minimum. Direct-coupled input.

Input Impedance: Approx. 250,000 ohms, 50 μμf shunt.

Start and Stop: Independent or common channels.

Trigger Slope: Positive or negative 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 milliseconds with the decimal point indicated.

General:

Features: (a) Operates with *-hp-* 508A Tachometer Generator.

(b) Operates with *-hp-* 520A Decade Scaler for high speed nuclear scaling, or directly for peak rates up to 100,000 per second.

(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) 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.

Connectors: BNC.

Power: 115/230 v ±10%, 50/60 cps, 210 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 13½" deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 52 lbs. Shipping 72 lbs. (cabinet mount).

Accessories Furnished: 2 AC-16D Cable Assemblies.

Accessories Available: AC-16K Video Cable Assembly $5.00; 508A/B/C/D Tachometer Generator $100.00; *-hp-* 56A-16B Adapter Cable (connects *-hp-* 506A to *-hp-* 522B Counter), $15.00.

Price: ~~$915~~.00.

Data subject to change without notice.

523B ELECTRONIC COUNTER

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:

Frequency:
- Production quantities
- Nuclear radiation
- Power line frequencies
- Rps and rpm
- Very low frequencies
- Oscillator stability
- Repetition rates
- Weight, pressure, temperature and acceleration—remote if desired

Time Interval, Period:
- Time between impulses
- Pulse length, shutter speeds
- Projectile velocity
- Relay operating times
- Precise event timing
- Interval stability
- Frequency ratios, phase delay

New! Measures Period, Time or Frequency 10 cps to 1.1 MC!

VERSATILE *-hp-* 523B is a completely new electronic counter designed to cover the widest possible range of measurement at no sacrifice of speed or convenience, and at lowest possible cost.

Basically similar to the well-known *-hp-* 522B, new 523B offers a greatly broadened frequency range of 10 cps to 1.1 MC. Time interval coverage is also broadened—3 μsec to 100,000 seconds or 27.8 hours. Period measurement is available from 0.00001 cps to 10 KC.

Model 523B is conveniently contained in a small bench cabinet or can be rack mounted in a standard 19″ relay rack. No extra-cost modification is needed to perform all functions. Results are displayed instantly and automatically in direct-reading form on six panels numbered 0 to 9.

Number illumination is bright for easy readability in any light; results are displayed in seconds, milliseconds, microseconds or kilocycles with automatic illuminated decimal point. Display time is variable from 0.1 second to 5 seconds or indefinitely.

Unskilled Personnel Can Operate

The new Counter is particularly designed for easy use by non-technical personnel. In addition to the direct reading and automatic decimal features, panel controls are color-coded for simple operation.

For frequency counting, -*hp*- 523B covers the range 10 cps to 1.1 MC. Measurements are accurate within ± 1 count plus crystal stability; stability is controlled to within 2 parts per million per week. Time base generator crystals are subjected to prolonged aging before installation in the Counter; and further to insure accuracy, a front panel connector permits application of a 100 KC primary standard; five gate times are available: 0.001, 0.01, 0.1, 1 and 10 seconds; the gate may also be operated manually.

For period measurement, the unknown controls the opening and closing of the gates, while the instrument's high dependability -*hp*- AC-4 Decade Counters record the number of cycles of an internal standard frequency. This internal decade divider circuitry provides a 10-period averaging measurement which reduces ten-fold the time effect of any triggering uncertainty. Period may be measured from 0.00001 cps to 10 KC in seconds, milliseconds or microseconds.

Time Interval Measurements

In time interval measurements -*hp*- 523B measures time from 3 microseconds to 100,000 seconds (27.8 hours), presenting results directly in seconds, milliseconds and microseconds. A special threshold feature permits measurements to be started and stopped only by signals of predetermined amplitude, polarity and slope. Separate start and stop channels are provided and each channel is separately adjustable for maximum flexibility. Two dual concentric panel controls permit time interval measurements to be started or stopped at any voltage level from —300 to +300 volts, on either positive or negative slopes. Terminals at the rear of -*hp*- 523B provide start and stop pulse voltages adjusted by these two controls. Model 523B employs etched circuits and high quality components throughout for maximum operating accuracy and dependability. Function lights are also provided to insure that circuits are operating properly.

Figure 1. The exclusive start and stop output of -*hp*- 523B permits presentation on an oscilloscope of the portion of a waveform being measured by the Counter. Visual presentation can be particularly helpful when complicated waveforms are involved. Bright spots on the oscilloscope (provided from the start and stop pulse voltages of the 523B) indicate the interval being measured.

Many phenomena common to industrial research and manufacturing can be measured quickly and conveniently with -*hp*- 523B and a simple transducer converting mechanical phenomena into electrical impulses. Such transducers include -*hp*- 506A Optical Tachometer Pickup for measuring rpm without mechanical contact to 300,000 rpm; and -*hp*- 508A/B/C/D Tachometer Generators for direct reading shaft speed measurements 15 to 40,000 rpm. Other transducers enable -*hp*- 523B to measure flow, pressure, projectile speed, etc.

Specifications

Frequency Measurement:

Range: 10 cps to 1.1 MC.
Accuracy: ± 1 count ± stability (see General).
Input Requirements: 0.2 volt rms minimum.
Input Impedance: Approx. 1 megohm, 30 $\mu\mu$f shunt.
Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds.
Reads In: KC; decimal point automatically positioned.

Period Measurement:

Range: 0.00001 cps to 10 KC.
Accuracy: ±0.3% (for measurements of one period), ±0.03% (10 period average) at 1 volt rms. Improved by greater input voltage.
Input Requirements: 1 volt rms minimum. Direct coupled.
Input Impedance: Approx. 1 megohm, 40 $\mu\mu$f shunt.
Gate Time: 1 or 10 cycles of unknown.
Standard Frequency Counted: 10 cps, 1 KC, 100 KC, 1 MC, or external applied frequency.
Reads In: Seconds, milliseconds, microseconds; decimal point automatically positioned.

Time Interval Measurement:

Range: 3 μsec to 100,000 sec. (27.8 hours).
Accuracy: ± 1/std. freq. counted ± stability (see General).
Input Requirements: 1 v peak minimum. Dc coupled.
Input Impedance: Approx. 1 megohm, 25 $\mu\mu$f shunt.
Start and Stop: Independent or common channels.
Trigger Slope: Positive or negative on start and/or stop channels.
Trigger Amplitude: Continuously adjustable on both channels from —300 to +300 volts.
Std. Freq. Counted: 10 cps, 1 KC, 100 KC, 1 MC; External.
Reads In: Seconds, milliseconds, microseconds; decimal point automatically positioned.

General:

Registration: Six places on neon lamp decade units.
Stability: 2/1,000,000 per week. May be standardized against WWV.
Display Time: Variable approx. 0.1 to 5 seconds; display held indefinitely if desired.
Output Frequencies: Secondary standard frequencies available at front panel: 10 cps, 1 KC rectangular, 100 KC and 1 MC sine-wave (stability as above).
Trigger Output: Start and Stop pulse output (width approx. ½ μsec). Available for:

1. Voltage level selection of input signal for frequency measurements.
2. Z-axis modulation of oscilloscope for time interval measurements.

Self Check: Panel control provides automatic count of internal 100 KC and 1 MC frequencies to assure accuracy of gate and proper operation of counters.
External Standard: 100 KC from external primary standard can be applied to unit for highest accuracy.
Power: 115/230 volts ±10%, 50/60 cps, approx. 285 watts.
Dimensions: Cabinet Mount: 13¼" wide, 16¾" high, 20¼" deep. Rack Mount: 19" wide, 14" high, 19" deep.
Weight: Net 50 lbs. Shipping 80 lbs. (cabinet mount).
Accessories Furnished: 2 AC-16D Cable Assemblies.
Price: $1,175.00.

Data subject to change without notice.

Advantages:

- Direct, instantaneous automatic readings
- Easily used by non-technical personnel
- Resolution 0.1 microseconds
- Accuracy 1/1,000,000 ±1 count
- High sensitivity, high impedance
- Extreme reliability
- No calculation or interpolation
- Automatic decimal point
- Highest quality construction
- Compact; military design

Use For:

- Frequency measurements 10 cps to 220 MC
- Time interval measurements 1 μsec to 100 days
- Period measurements 0 cps to 10 KC
- Standard frequency outputs of 10 cps, 1 KC, 100 KC, 10 MC
- Time and frequency ratios

Measures Frequency 10 cps to 220 MC*—Time Interval 1 Microsecond to 100 Days

HERE is the revolutionary Electronic Counter that gives you exactly the frequency, time interval or period measuring coverage you want. You buy the basic *-hp-* 524B Counter with selected *-hp-* 525 or 526 series Plug-In Units covering your exact present requirements; later you can add other inexpensive Plug-Ins to double or triple the usefulness of the instrument.

Great Versatility

The compact, moderately priced 524B 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, pulse lengths and repetition rates or frequency drift. You make high accuracy ballistics time measurements or high resolution tachometry measurements. The instrument is also an ideal precision frequency standard, giving convenience and flexibility not found in the usual primary standards. It is simple to operate and readily used by non-technical personnel.

Basic Counter Details

In the basic 524B Counter (without Plug-In Units) frequency from 10 cps to 10 MC is read over 5 selected

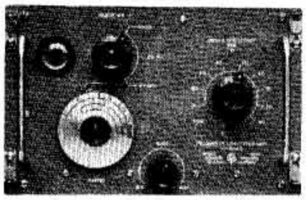
*With *-hp-* 525A/B Frequency Converter.

periods—0.001, 0.01, 0.1, 1 and 10 seconds. Display time is variable at will, counts are automatically reset, and action is repetitive. Low frequencies (300 cps or below) 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. Results are measured instantly and automatically, and presented in direct reading form with automatic illuminated decimal point.

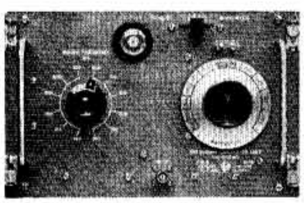
Counter Plug-in Units

Addition of *-hp-* 525 and 526 series Plug-In Units will extend the Counter's frequency range to 220 MC, provide increased sensitivity and a high impedance pickup probe, and make available uniquely flexible time interval circuits that may be started and stopped by *any electrical impulse.*

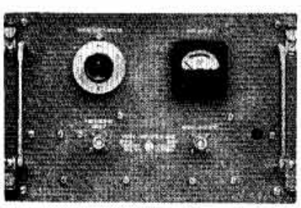
***-hp-* 525A Frequency Converter.** This instrument extends the Counter's 10 MC direct-reading range in decade steps through 100 MC. It maintains Counter accuracy throughout the extended range. It provides additional amplification to increase video sensitivity to 0.1 volt throughout the Counter's basic 10 cps to 10 MC range. It contains a tuned input circuit to simplify determining the correct frequency range and to reject harmonics and spurious signals.



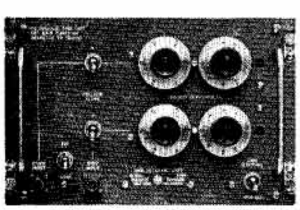
***-hp-* 525B Frequency Converter.** Similar to 525A, this unit extends the Counter's range from 100 MC to 220 MC in 10 MC steps, at the same time preserving the high accuracy of the basic counter. It maintains the same high sensitivity 0.2 volt minimum input throughout its range, and includes a wavemeter for determining the proper frequency decade range.



***-hp-* 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 enables monitoring at the input waveform visually.



***-hp-* 526B Time Interval Unit.** This instrument measures intervals from 1.0 μsec to 100 days with accuracy of 0.1 μsec ±0.001%. 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 period average measurements in steps of 10 to 10,000 period average. This insures greater accuracy for midrange frequency measurements.

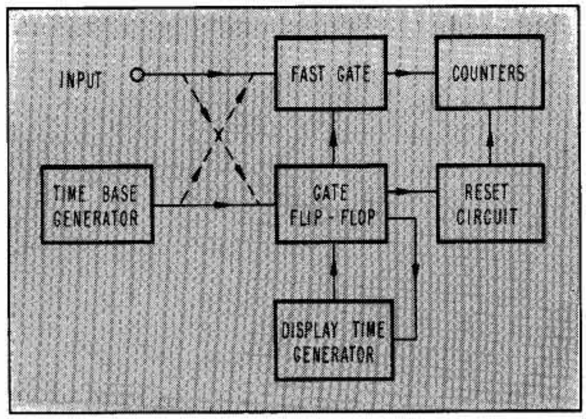


Figure 1. The block diagram illustrates the basic circuit arrangement of the 524B. The frequency to be measured is applied to an electronic gate. When the gate is open, the cycles are passed on to the counter circuits. When the gate is closed, the counters display the counted value. The operation of the gate is such that it is open for accurately-determined time intervals from 0.001 to 10 seconds. The counted value is then displayed directly in frequency. The time of opening and closing of the fast gate is controlled by the time base generator through the gate flip-flop. The flip-flop performs the actual operation of opening and closing the fast gate and also actuates the resetting circuit shortly before opening the gate. The resetting circuit clears the counting circuit preparatory to making the next count.

Specifications

-hp- 524B Electronic Counter

Basic Unit, for Frequency Measurements, 0 cps to 10 MC

Frequency Measurement: (without plug-in units)
- **Range:** 10 cps to 10 MC.
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 seconds or manual control.
- **Accuracy:** ± 1 count ± stability (see below).
- **Reads In:** Kilocycles; decimal point automatically positioned.

Period Measurement: (without plug-in units)
- **Range:** 0 cps to 10 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:** 8 places (99,999,999 maximum counts). First 6 places on neon lamp decades; last 2 on meters.
- **Stability:** 1/1,000,000 short-term; 2/1,000,000 per week. May be standardized against WWV or used with external 100 KC primary standard for highest accuracy.
- **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 accuracy of gate and proper operation of counters.

Input Voltage: 1 volt rms minimum.

Input Impedance: Approx. 1 megohm, 40 $\mu\mu$f shunt.

External Standard: 100 KC signal from external primary standard can be applied to unit for highest accuracy. 1 volt rms into 1 megohm, 40 $\mu\mu$f shunt required.

Connectors: BNC Type.

Power: 115/230 v $\pm$10%, 50/60 cps, 500 watts.

Dimensions: Cabinet Mount: 20″ wide, 21⅛″ high, 23½″ deep. Rack Mount: 19″ wide, 19¼″ high, 17″ deep.

Weight: Net 118 lbs. Shipping 206 lbs. (cabinet mount).

Accessories Furnished: 1 AC-16D Cable Assembly.

Accessories Available: AC-16K Video Cable Assembly, $5.00; 524B-16P and 524B-16Q Test Cable Sets for *-hp-* 525/526 units, $24.75.

Price: $2,150.00.

-hp- 525A Frequency Converter Unit

for Frequency Measurement, 10 cps to 100 MC

Plugged into *-hp-* 524B:

Range: As amplifier for counter, 10 cps to 10 MC. As converter for counter, 10 MC to 100 MC.

Accuracy: $\pm$1 cps $\pm$ stability (see General).

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 volt rms minimum, 10 cps to 10 MC; 10 mv rms minimum, 10 MC to 100 MC.

Input Impedance: Approx. 1 megohm shunted by 40 $\mu\mu$f, 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.

Dimensions: Storage Case: 12″ wide, 9″ high, 8″ deep.

Weight: Net 10 lbs. Shipping 19 lbs.

Price: $250.00.

-hp- 525B Frequency Converter Unit

for Frequency Measurement, 100 MC to 220 MC

Plugged into *-hp-* 524B:

Range: 100 MC to 220 MC.

Accuracy: $\pm$1 cps $\pm$ stability (see General).

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 volt rms minimum.

Input Impedance: Approximately 50 ohms.

Level Control: Same as 525A above.

Dimensions: Storage Case: 12″ wide, 9″ high, 8″ deep.

Weight: Net 10 lbs. Shipping 19 lbs.

Price: $250.00.

-hp- 526A Video Amplifier Unit

for Frequency Measurement, 10 cps to 10 MC high sensitivity

Plugged into *-hp-* 524B:

Range: 10 cps to 10 MC.

Accuracy: Same as basic 524B Counter.

Input Voltage: 10 mv rms minimum.

Level Control: Meter indicates input signal level, correct voltage adjustment.

Output Terminal: BNC connector provides 10 times input voltage from 93-ohm source. Allows oscilloscope monitoring of input signal without loading circuit.

Reads In: Same as basic 524B Counter.

Dimensions: Storage Case: 12″ wide, 9″ high, 8″ deep.

Weight: Net 10 lbs. Shipping 19 lbs.

Accessories Furnished: 1 526A-16A Probe.

Price: $150.00.

-hp- 526B Time Interval Unit

for Time Interval Measurement

Plugged into *-hp-* 524B:

Range: 1 μsec to 10^7 seconds.

Accuracy: $\pm$1/standard frequency counted.
$\pm$ stability (see General).

Registration: Same as indicated under General.

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

Input Impedance: Approx. 1 megohm, 40 $\mu\mu$f 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.

Dimensions: Storage Case: 12″ wide, 9″ high, 8″ deep.

Weight: Net 10 lbs. Shipping 19 lbs.

Accessories Furnished: 1 AC-16D Cable Assembly.

Price: $175.00.

-hp- 526C Period Multiplier Unit

for Period Measurement

Plugged into *-hp-* 524B:

Range: 0 to 10 KC.

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

Accuracy: $\pm$0.3%/gate time in cycles of the unknown $\pm$ stability (see General).

Standard Frequency Counted: 10 cps, 1 KC, 100 KC, 10 MC, or externally applied frequency.

Reads In: Seconds, milliseconds, or microseconds.

Input Voltage: 1 volt rms minimum.

Input Impedance: 1 megohm, 40$\mu\mu$f shunt.

Price: $225.00.

Data subject to change without notice.

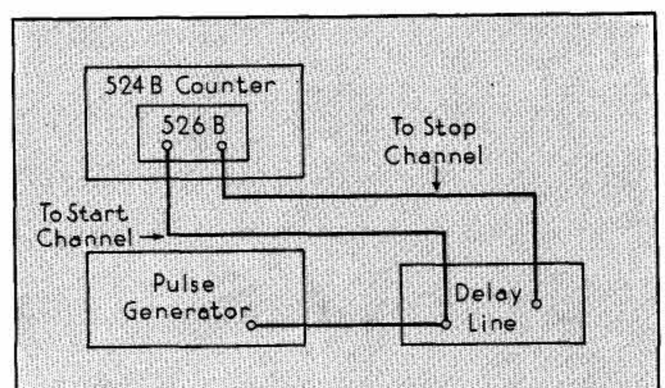
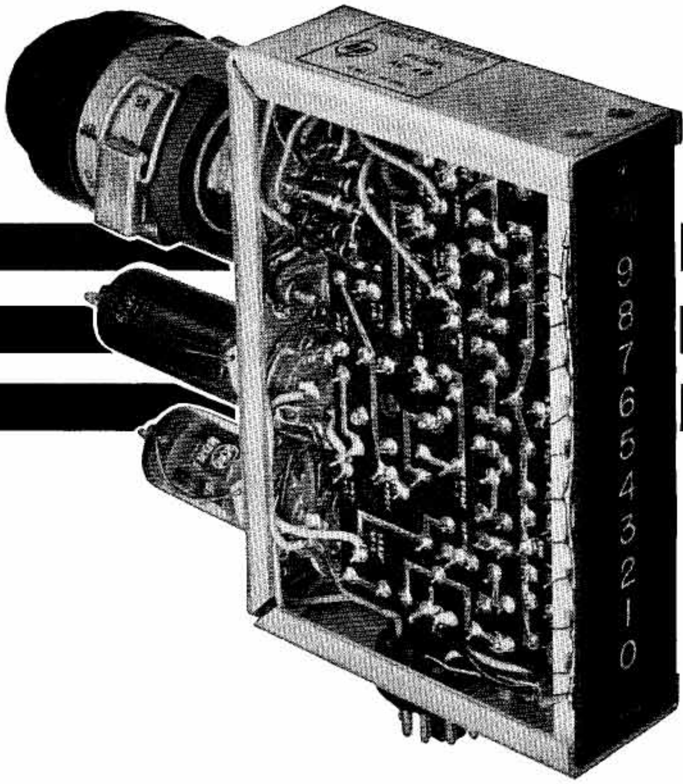


Figure 2. Measurement of time delay of a delay line with *-hp-* 524B Electronic Counter and *-hp-* 526B Time Interval Unit.



New! Counting Rates to 1.1 MC
Staircase Output

Now, dependable, convenient -*hp*- AC-4 Decade Counters are available with counting rates to 120 KC (AC-4A), 220 KC (AC-4B), and 1.1 MC (AC-4D). Each instrument is of improved design providing high reliability, brilliant illumination and staircase output voltage for remote register. Etched circuits are arranged schematically with components mounted by dip-soldering for ready identification, uniform control of stray capacities and balanced circuitry. Construction is open to permit free airflow. Resistors are premium quality 5% tolerance units; silver mica coupling condensers and computer type (5963) tubes are used. New -*hp*- AC-4D employs a magnetron beam switching tube providing 10 outputs capable of operating a neon lamp or other indicating device, including -*hp*- AC-4A/B.

Uses

Models AC-4A/B/D Decade Counters are recommended as replacement units in -*hp*- Electronic Counters, as remote indicators external to -*hp*- Electronic Counters, and in special purpose counting devices requiring high counting rates, brilliant illumination and outstanding reliability.

Specifications

	AC-4A	AC-4B	AC-4D
Counting Rate:	120 KC	220 KC	1.1 MC
Double Pulse Resolution:	7 μsec	4 μsec	0.6 μsec
Input Voltage:	80 v neg. pulse 1 μsec rise time	70 v neg. pulse 1.5 μsec rise time	15 v pos. pulse 0.15 μsec wide at ½ voltage point. 8 v neg. bias. Bias, pulse amplitude, width must not change more than ±10% with rep rate.
Output Voltage:	80 v neg.	80 v neg.	Drives AC-4A/B
Reset:	Zero or 9	Zero or 9	Zero
Staircase Output:	135 v at Zero 55 v at 9	135 v at Zero 55 v at 9	135 v at Zero 55 v at 9
Power Required:	6.3 v ac 300 v dc	6.3 v ac 300 v dc	6.3 v ac ±10% at 1.35 a 300 v dc ±10% at 1 ma 200 v dc ±2% at 20 ma −115 v dc ±2% at 10 ma
Socket:	Octal	Octal	11-pin
Dimensions:	(All models) 5⅝" deep x 1¼" wide x 6⅛" high		
Weight:	AC-4A/B—Net 1 lb., Shipping 2 lbs. AC-4D - Net 2 lbs., Shipping 3 lbs.		
Price:	$35.00	$70.00	$150.00

Data subject to change without notice.

540A TRANSFER OSCILLATOR

Advantages:

Extends frequency counter accuracy to microwave region

Permits measurement of pulsed, FM, CW, AM or noisy signals

Provides multiple check for positive accuracy

Measures FM deviation

Includes self-contained oscilloscope detector

Circuit elements usable separately

Simple to use, compact, eliminates complex set-ups

Use It For:

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

Now! Measure Frequency to 12 KMC With Electronic Counter Accuracy

THE development of the *-hp-* 540A Transfer Oscillator has made possible, for the first time, convenient frequency measurements far into the microwave region. These measurements can be made with accuracy heretofore available only at much lower frequencies.

Model 540A contains a highly stable, 100 to 220 MC oscillator generating harmonics to 12 KMC for comparison with the unknown. The comparison device is a diode mixer, amplifier, and built-in oscilloscope *(See Figure 1).* Combined with *-hp-* 524B Electronic Counter, *-hp-* 525B Frequency Converter (524B's appropriate plug-in unit) and oscillosynchroscope or detectors as required, the 540A extends the 524B's range to 12 KMC with new convenience and accuracy.

In operation, with approximate signal frequency known, the *-hp-* 540A is tuned until one of its harmonics zero beats with the unknown. The multiplying factor is noted. The transfer oscillator frequency is then measured directly on the 524B counter. The 524B 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 oscillator is tuned to an exact sub-multiple. Video amplifier frequency response controls can be used to simplify this procedure.*

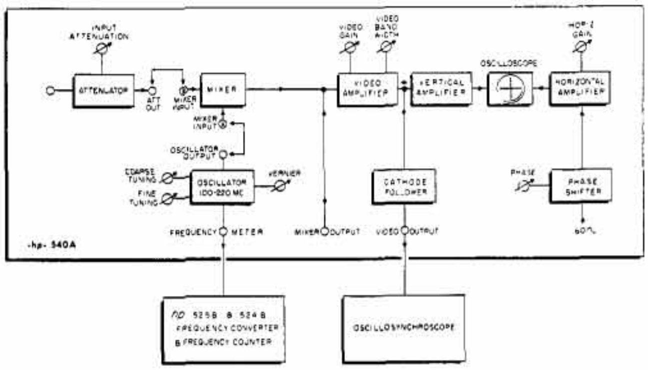


Figure 1. -*hp*- 540A with 524B, 525B and oscillosynchroscope.

In working with noisy or AM signals, the -*hp*- 540A response can be narrowed to obtain a more accurate indication of zero beat.*

In signals with appreciable FM, the 540A'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.*

Accuracy

The system's accuracy is approximately 1 part per 1,000,000 or better 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*- 540A often provides the only means of accurate measurement. Overall system accuracy is better than 10 times that of the best microwave wavemeters.

Quality Features

Each of the circuit elements of -*hp*- 540A *(Figure 1)* may be used separately by shifting front panel patch cords. Controls are provided for coarse and fine mechanical tuning. There is also 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. Input attenuation is variable from approximately 20 to 80 db to adjust signal for optimum mixing level.

**For complete discussion of microwave measuring with transfer oscillator and electronic counter, write -hp- for Hewlett-Packard Journal, Vol. 6, No. 12.*

Specifications

General

Frequency Range: 10 MC to 5,000 MC. (10 MC to 12,000 MC or higher with external detector such as -*hp*- 440A.)

Input Signal: CW, FM, AM or pulse.

Input Signal Level: Varies with frequency and individual crystals. Minimum input signal approximately 0 dbm to attenuator. Maximum input 0.5 watt average (5 volts into 50 ohms).

Accuracy: CW: Approximately 1/1,000,000 or better.

Oscillator

Fundamental Frequency Range: 100 MC to 220 MC.

Harmonic Frequency Range: Above 12,000 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.

Attenuator

Range: Approximately 20 db to 80 db.

Input Impedance: 50 ohms, SWR: 1.5 max. at 1 KMC; 3 max. at 5 KMC.

Amplifier

Gain: Variable. 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 volt 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. Sensitivity, 20 cps to 5 KC.

Miscellaneous

Connectors: Attenuator input, type N; all others type BNC.

Size: Cabinet Mount: 20½″ wide, 12½″ high, 15¼″ deep. Rack Mount: 19″ wide, 10½″ high, 12¾″ deep.

Power Supply: 115/230 v ±10%, 50/1,000 cps, approximately 110 watts.

Auxiliary Equipment:

-*hp*- 524B Electronic Counter, $2150.00.

-*hp*- 525B Frequency Converter, $250.00.

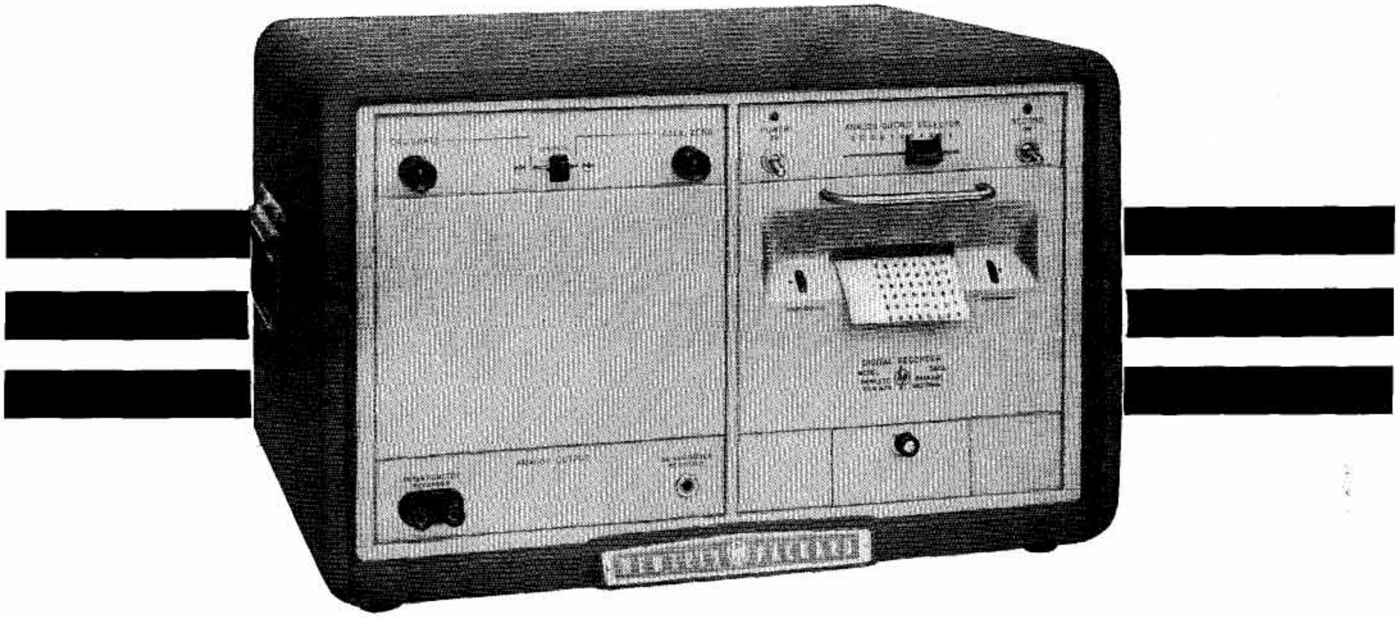
-*hp*- 440A Detector Mount, $85.00.

-*hp*- 150A High Frequency Oscilloscope (see page 12).

Price: -*hp*- 540A Transfer Oscillator, $615.00.

Data subject to change without notice.

560A DIGITAL RECORDER



Advantages:

Continuous digital record for frequency counters

Controllable by electronic or electro-mechanical devices

Basic print-out unit available separately

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 recorder

Expanded scale; full scale of strip-chart may represent only 1 part in 10^7

Suppressed axis; strip-chart never driven off scale

Uses:

Recorder for frequency counter

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

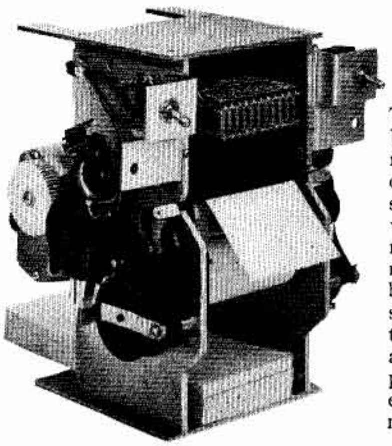
Investigating drifts in systems and equipment

Prints 11-Digit Information at Rates of 5 Lines Per Second

THE revolutionary *-hp-* 560A Digital Recorder is a completely new instrument based on a fresh design concept rather than an adaptation of conventional adding machines. Although specifically designed for use with *-hp-* electronic counters it is extremely versatile and useful in a wide variety of applications.

Basically, Model 560A consists of a motor-driven printing mechanism with inked ribbon, printing paper, eleven identical number wheels and eleven identical mixer and comparator circuits which position the number wheels according to the count appearing on an associated electronic counter.

The recorder is offered as a complete electronic measuring device. It is normally controlled by the staircase voltage and a print command pulse from an *-hp-* counter, but may be controlled by a staircase voltage and a print command pulse from other electronic or electro-mechanical devices. A printing speed of five, 11-digit lines per second is available. The 11-digit line allows secondary or coding data to be entered simultaneously with primary data. Since the *-hp-* 560A Recorder is literally a slave to the associated *-hp-* counter, the recorder accuracy is the same as the accuracy of the counter.



Mechanical Printing Unit Available Separately

The Mechanical Printing Unit is available separately for adaptation to other equipment. The position of each number wheel can be sensed by means of its built-in commutator and brush assembly. The wheel may be stopped at a desired position by deenergizing its associated solenoid. The print cycle is initiated by energizing the clutch solenoid.

Analog Output

Special features of the *-hp-* 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.

Operation

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. *(See Figure 1.)*

The command pulse then initiates a scanning cycle during which the number wheels are simultaneously positioned

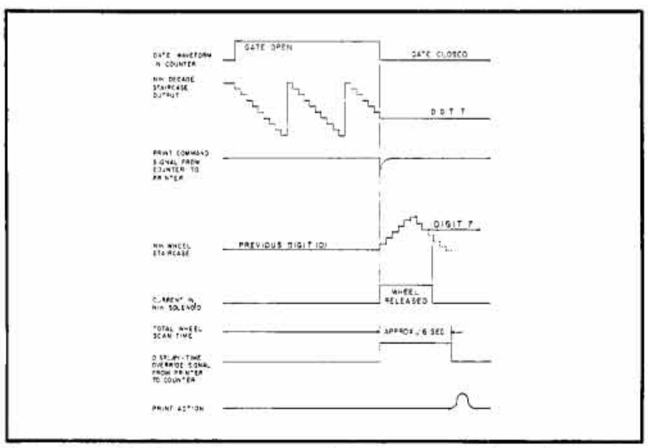


Figure 1. Timing sequence and event progression *-hp-* 560A Digital Recorder.

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.

Broadest Usefulness

In combination with an appropriate electronic counter, the new-*hp-* 560A Digital Recorder provides a convenient, compact and highly practical means of recording many measurements. Applications include the recording of measurement data at all stages of setup and testing, monitoring during tests, and even final tabulation and plotting of data. In developing systems and equipment, the ease and accuracy with which relatively unlimited scale expansions are obtained materially simplifies investigations of small drifts and drift components.

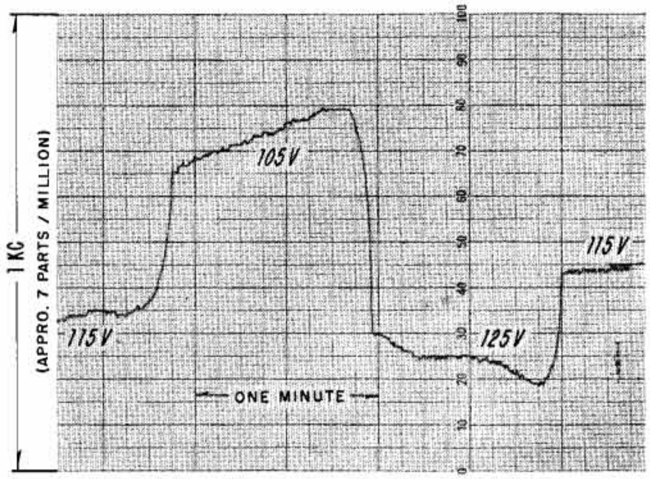


Figure 2. Strip chart recording showing frequency stability vs. line voltage for 150 MC oscillator. Frequency measured with 524B-525B combination and plotted from analog output of *-hp-* 560A.

Specifications

Accuracy: Identical to that of basic counter used.

Printing Rate: Controlled by counter, 5 lines/sec. max.

Digit Capacity: 11 digits per line.

Driving Source: Parallel entry staircase voltages derived from standard digital frequency counters such as Hewlett-Packard types. Staircase descends from +135 v to +55 v as the count progresses from 0 to 9. Internal impedance of staircase source should be approximately 700,000 ohms.

Print Command Signal: 1 μsec or greater, positive or negative pulse, 15 volts p-p or greater.

Paper Required: Standard 3″ roll or folded paper.

Line Spacing: Single or double, adjustable.

Analog Signal: Any three consecutive digits may be selected by selector switch. Output is the function of selected digits. For example, if consecutive digits were 3, 8, and 6, output voltage would be 38.6 millivolts or 0.386 ma.

Output Available: 1 milliamp for galvanometer strip-chart recorders. 100 millivolts for potentiometer strip-chart recorders.

Power: 105-125 volts, 60 cycles, 250 watts.

Dimensions: Cabinet Mount: 20½″ wide, 12½″ high, 18½″ deep. (Rack mount available.)

Weight: Net 60 lbs. Shipping 100 lbs.

Accessories Available: 1052-24, 3″ folded paper, 48/carton.

Price: On request.

Data subject to change without notice.

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.

Hewlett-Packard offers a complete easy-to-use line of vhf, uhf, and shf signal generators, 11 precision instruments operating at frequencies between 10 and 21,000 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.

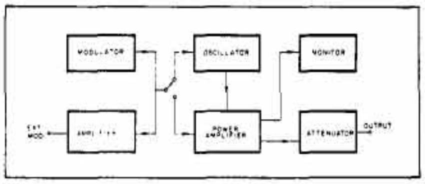


Figure 1. Block diagram of Signal Generators in Group I.

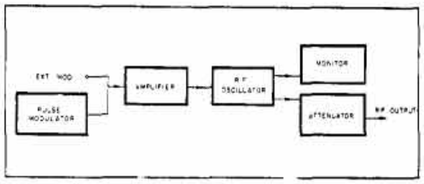


Figure 2. Block diagram of Signal Generators in Group II.

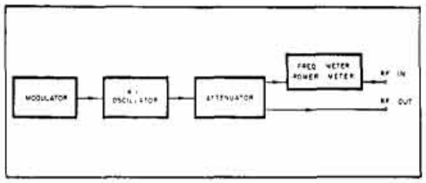


Figure 3. Block diagram of Signal Generators in Group III.

Group	Generator	Frequency Range (MC)	Frequency Accuracy	Calib. Output Range	Output Accuracy	Max. SWR of Output	Modulation: Internal	Modulation: External
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%	0 to −127 dbm	± 1 db −10 to −127 dbm	1.6	Pulse, FM	Pulse, Sq. Wave
II	616A	1,800-4,000	± 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 Sawtooth, Sq. Wave	Pulse, Sq. Wave FM
II	620A	7,000-11,000	± 1%	−10 to −127 dbm	± 2 db −10 to −127 dbm	2	Pulse, FM Sawtooth, Sq. Wave	Pulse, Sq. Wave FM
III	623B	5,925-7,725	* ± 0.03%	0 to −70 dbm	± 2 db 0 to −70 dbm	2	FM	Pulse, Sq. Wave FM
III	624C	8,500-10,000	* ± 0.03%	0 to −100 dbm	± 2 db −10 to −100 dbm	2	Pulse, FM	Pulse, Sq. Wave, FM
II	626A	10,000-15,500	± 1%	+ 10 to −90 dbm	± 2 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	± 2 db ± 2% of attenuation in db	2.5 at + 10 dbm 1.2 at 0 dbm	Pulse, Sq. Wave FM	Pulse, Sq. Wave FM

*As set by wavemeter. With temperature correction, higher accuracy available.

Table 1. Characteristics of *-hp-* signal generators.

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 have reflex klystrons, the cavity of which is an integral part of the tube. 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 to cover the frequency 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. In Group III tuning is achieved by mechanically distorting the cavity.

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 (and *-hp-* 624C in Group III) include a pulser which is used for internal modulation. Considerable care has been taken to achieve a modulating pulse that has good waveform and does not undergo deterioration in 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 Groups II and III. 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 *-hp-* 614A and 616A) and in Group III 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 generator. 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 *-hp-* 608C/D and 612A (which employ master oscillator-power amplifier circuits) as long as the bandwidth of the particular instrument is not exceeded.

All modulation in the 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 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 at high frequencies and better than 40 db at low frequencies.

In the *-hp-* 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 608C/D and 612A signal generators.

Signal generators in Groups II and III have similar requirements for external amplitude modulation. 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. A typical setup for applying modulation to these generators is shown in Figure 4. The amplitude of the modulating voltages should be approximately 50 volts.

Models 618B, 620A, 623B, 624C, 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.

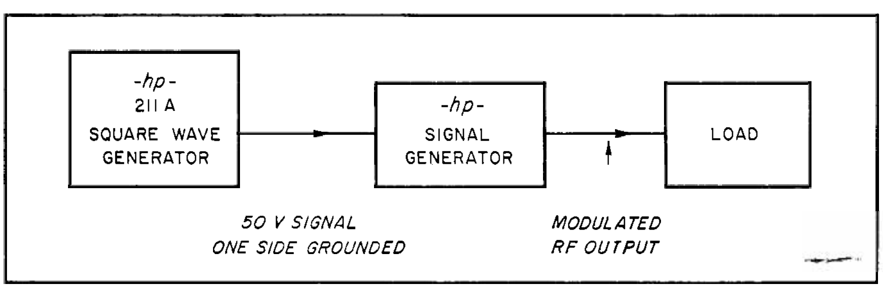


Figure 4. Typical setup for applying modulation to *-hp-* signal generators.

Output Section

The output sections of *-hp-* generators are designed to achieve high monitor accuracy, high attenuator accuracy and to eliminate mismatch between generator and load.

In Models 608C/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 *-hp-* 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 system are the waveguide-beyond-cutoff type, (except *-hp-* 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. 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 107).

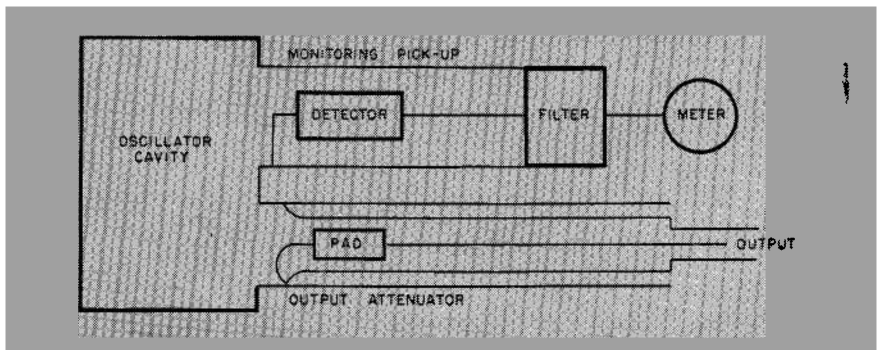


Figure 5. Monitoring and Attenuating system in *-hp-* signal generators.

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. 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.

626A/628A SHF Signal Generators

Models 626A and 628A generate accurate frequencies from 10 to 15.5 KMC and 15 to 21 KMC respectively at calibrated output levels of +10 dbm (10 mw) to −90 dbm (1 $\mu\mu$w). Although the rated output is 10 mw, the 626A and 628A usually provide at least 15 mw over the whole band and 30 mw or more over most of the band. Thus, these generators are useful as signal sources where relatively large signals are required.

In each generator the oscillator cavity is external to the klystron and is tuned by a non-contacting plunger. Repeller voltage is automatically tracked with the tuning plunger; the frequency dial is direct reading.

Following the klystron oscillator is an uncalibrated attenuator which is used for adjusting power level into the main attenuator to 10 mw. The power into the main attenuator is monitored by a meter connected in a temperature-compensated thermistor bridge. A 10 db multihole directional coupler picks up the power necessary to operate the thermistor bridge. Accuracy of the power set monitor system is better than ±1 db over the complete frequency range.

The main attenuator, a rotary type similar to *-hp-* 382A Broadband Precision Waveguide Attenuator, has a range of 100 db and is calibrated from +10 dbm to −90 dbm. Attenuation is varied by rotating a resistive film in a circular section of waveguide and is a function of the angle of rotation of the resistive film. A single attenuator of this type has a practical maximum attenuation of 50 db. For this reason, two of these attenuators are mechanically ganged and are operated as a single unit to achieve a range of 100 db. Since the attenuator operates only in circular guide, transitions to rectangular guide are provided at each end of the attenuator. The accuracy of the attenuator is ±2% of the attenuation inserted in db.

The attenuator is a good match to a waveguide system. This results in an SWR for each generator of not more than 1.2 at attenuator settings of 0 dbm or less. The output from *-hp-* 626A is terminated in WR-75 rectangular guide and that of *-hp-* 628A is terminated in WR-51 guide. Each generator is supplied with two waveguide adapters to permit use of *-hp-* 626A with X (8.2 - 12.4 KMC) and P (12.4 - 18 KMC) band systems and to permit use of *-hp-* 628A with P and K (18.0-26.5 KMC) band systems.

Pulse, square-wave, and frequency modulation is provided internally by a modulator designed to make the generators useful over a wide range of applications. Pulse and square-wave output is variable over a range of 40 to 4000 cps and the pulse width is variable from 0.5 to 10 μsec. Two sync signals are available at front panel terminals. One (Delayed Sync Out) is approximately coincident with the rf pulse and the other (Sync Out) is in advance of the rf pulse. This advance is continuously adjustable from 3 to 300 μsec.

The internal FM is at the power line frequency and is adjustable in amplitude and phase.

Terminals on the front panel allow modulation by external pulses and frequency modulation by external signals. In addition, a front panel terminal is provided which allows synchronization of the internal modulator with sine waves and pulses.

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 low pass filters between the signal generators and equipment following the generator (Figure 6).

Power Loss Due to Mismatch: Another source of error in determining power output is mismatch between a signal generator output impedance and the instrument

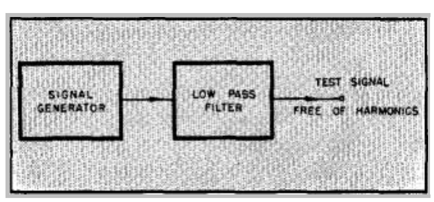


Figure 6. Typical setup for eliminating harmonics.

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 2:1 for all *-hp-* generators. With a knowledge of the value of SWR, the limits of the power loss can be calculated. It is necessary to know the phase of the reflection coefficient in order to determine the exact power loss.

A typical setup for making measurement on signal generators is shown in Figure 7. In order to determine the amount of error

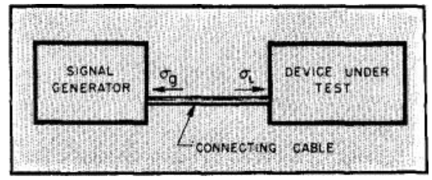


Figure 7. Typical setup for making measurement on signal generators.

due to mismatch, the values of SWR of the signal generator and the load should be measured. Maximum and minimum power loss is obtained by substituting the values of SWR in the equation below:

P_{max}—the maximum power loss in db is given by:

$$P_{max} = \left(20 \log \left[\sqrt{\sigma_g \sigma_L} + \frac{1}{\sqrt{\sigma_g \sigma_L}}\right] - 6\right) \text{db}$$

And P_{min}—the minimum power loss in db is given by:

$$P_{min} = \left(20 \log \left[\sqrt{\frac{\sigma_g}{\sigma_L}} + \sqrt{\frac{\sigma_L}{\sigma_g}}\right] - 6\right) \text{db}$$

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.)

These formulas can be drawn up in chart form as shown in Figure 8. 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 and 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 1.5 to 1 SWR, 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

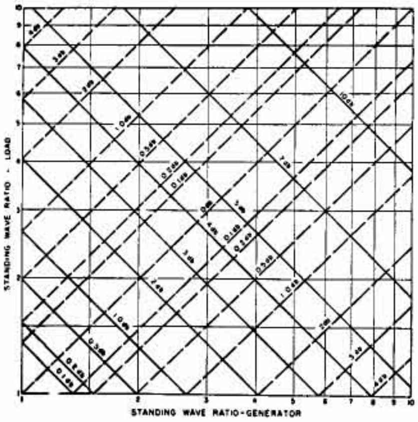


Figure 8. Power loss curves. Solid lines indicate ^{P}max; broken lines ^{P}min. (Courtesy Sperry Gyroscope Co.)

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. In order to eliminate this error, most *-hp-* generators are calibrated in terms of power at the end of the cable. 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 9.

Sweep Oscillators

In addition to *-hp-* precision signal generators there are five sweep oscillators available in the 2.6 to 12.4 KMC range. Of these, four are motor driven and employ reflex klystrons (*-hp-* 670 series), while the fifth is a voltage-tuned backward-wave oscillator.

-hp- 670 SHF Swept Oscillators

Models 670SM, 670GM, 670JM, and 670HM generate frequencies from 2.6 to 10 KMC at output levels of at least 10 mw (+10 dbm).

A motor drive is provided on each generator for automatic swept frequency operation over all or a portion of the frequency range. The swept frequency range is controlled by two adjustable stops located on the frequency dial. One stop locates the upper frequency limit; the other, the lower frequency limit. The minimum frequency range which can be swept varies from approximately 10% of the band for the lowest frequency unit (670SM) to approximately 20% of the band for the highest frequency unit (670HM). The sweep system operates at a constant velocity selected to provide an easily seen trace on a medium-persistence cathode-ray-tube. The velocity of the frequency dial is approximately 100 degrees of rotation per second.

In addition to driving the frequency dial, tuning plungers, the reflector tracking potentiometer, the motor also drives another potentiometer to obtain a sweep voltage for oscilloscopes which varies as the output frequency varies.

The attenuator is of the waveguide-beyond-cutoff type and provides a range of attenuation of 100 db.

An external power supply is required to furnish operating and modulating voltages to *-hp-* 670; Model 717A Klystron Power Supply was designed for this purpose. When using the Model 717A, the 670 may be reflector modulated by a 60 cps sine wave and may be grid or reflector modulated by a 400 to 1000 cps square wave supplied by *-hp-* 717A. External signals may also be applied to the 717A to modulate the 670.

New -hp- 686A Sweep Oscillator

Model 686A Sweep Oscillator generates CW and swept frequencies in the X band (8.2 to 12.4 KMC) at output levels up to 10 mw (+10 dbm) into a matched waveguide load. The rf output frequency is swept linearly with time. A voltage-tuned backward-wave oscillator tube is employed as the rf signal source and is swept electronically through the desired frequency range, Δ FREQ. This total frequency change, Δ FREQ., is selectable in steps from 3 MC to 4.2 KMC. In addition a vernier is provided to adjust the deviation to values between steps. The rate at which the oscillator frequency is changed is variable in decade steps from 40 MC/sec to 400 KMC/sec. The rf output frequency can be swept slowly enough for presentation on a recorder or fast enough for flickerless presentation on an oscilloscope. The rf sweep may be recurrent, triggered, or started manually for single sweep operation. A linear sweep voltage is provided which is concurrent with the rf sweep. This sweep voltage can be used for operating a recorder or an oscilloscope.

In addition to producing CW and swept frequency signals, *-hp-* 686A may be amplitude and frequency modulated. A 400 to 1,200 cps square wave modulator is provided to amplitude modulate the 686A internally when used in conjunction with standing wave indicators, ratio meters or other tuned vacuum tube voltmeter devices. The 686A may also be amplitude modulated by sine waves and pulses. The external modulation terminal is dc coupled to the backward-wave oscillator. This feature allows the use of external circuitry to provide inverse dc feedback to maintain a constant output level during swept frequency operation. Provision is also made for using external signals to frequency modulate the rf output of the oscillator.

During swept frequency operation the base frequency is chosen by the front panel dial and the RF SWEEP RATE and Δ FREQ. are set up by front panel selectors. Any of these adjustments may be changed during operation. The RF SWEEP RATE selector and the Δ FREQ. selector are differentially ganged so that impossible combinations are automatically avoided.

A cathode current control is provided to reduce the cathode current of the backward-wave oscillator tube when the full output (10 mw) is not required.

The rf output of *-hp-* 686A is terminated in a standard RETMA waveguide type WR 90.

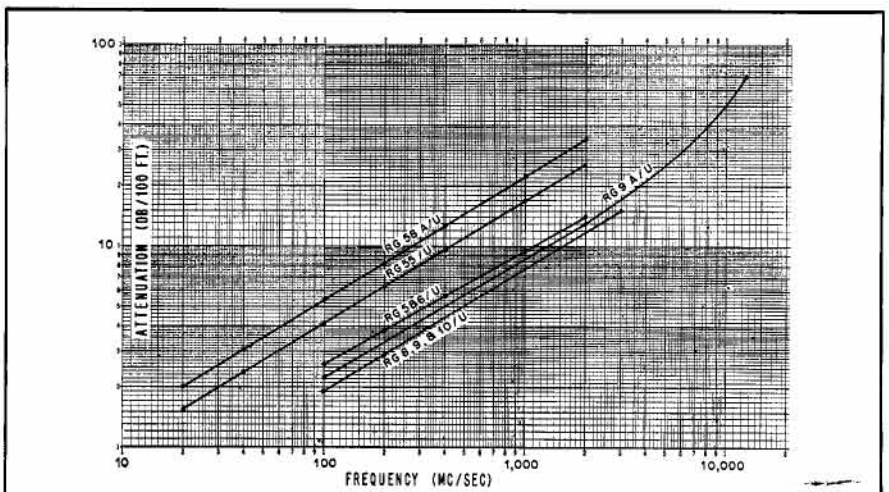


Figure 9. Attenuation vs. frequency curves for several cables.

608C/D VHF SIGNAL GENERATORS

Finest Tools Available for Measurements 10 to 480 MC

Advantages:

Premium-quality performance

Wide range, direct calibration

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, broad band amplifiers, and other vhf equipment

Driving bridges, slotted lines, antennas, filter networks, etc.

Hewlett-Packard 608C/D is designed as the ultimate in vhf signal generators. It offers the highest stability attained in production equipment of its type. There is almost a complete absence of incidental FM (less than 1 KC). Frequency drift is held to less than 0.005% over a 10-minute period (after warmup). This performance is possible because of the master oscillator buffer output amplifier construction and close filament regulation of the tubes.

Premium Quality 608D

Output of the premium-quality 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 a frequency check accurate within 0.01% in 1 and 5 MC steps throughout range. Modulation capabilities are extremely broad; the instrument can be AM modulated up to 95%; distortion is less than 5% at 30% modulation. It will provide high quality pulses as short as 1 μsec at rf output frequencies above 100 MC. Modulation circuitry has flat response from 20 cps to 1 MC, hence a wide range of audio, carrier current and video modulations may be employed. Percentage modulation is read directly on the front panel meter.

Direct Calibration

As with other -*hp*- signal generators, output and frequency are also calibrated directly for fast reading without charts. The output circuit reads direct in both volts and dbm. Frequencies 10 to 420 MC are covered in 5 bands, presented directly in MC on a drum-type dial with effective scale length of 45″. Tuning is highly accurate; there is no backlash. Resettability is better than 1 MC even at the high end of the band.

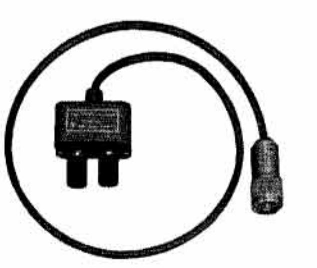
Finest Construction

An important feature of -*hp*- 608D is the new mechanical design and construction employed throughout. New aluminum castings and cabinets reduce weight at no sacrifice in strength or ruggedness. Circuitry is uniquely 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, broad band 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 Terminated Output Cable 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. $10.00 f.o.b. factory.

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: Frequency check points every 1 and 5 MC through range. Headphone jack for audio frequency output.

Frequency Drift: Less than 0.005% over 10-minute interval after warmup (except following a band change).

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 Modulation: 0 to 95%, 20 cps to 20 KC. For rf output above 100 MC, modulation frequencies up to 1 MC produce at least 30% modulation.

External Pulse Modulation: 5 v peak pulse required. Good pulse shape at 1 µsec.

Modulation Meter Accuracy: ±10% of full scale reading 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 1.0 µv.

Filament Regulation: Provides highest possible oscillator and amplifier stability for line voltage change.

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

Dimensions: Cabinet Mount: 13¾″ wide, 16¼″ high, 20⅜″ deep.

Weight: Net 61 lbs. Shipping 87 lbs.

Accessories Available: 608A-16D Cable Assembly, $10.00; AC-16K Video Cable Assembly, $5.00; AC-16F rf Cable Assembly, $7.50; 360A Low Pass Filter, $40.00; 608A-95A Fuseholder, $20.00.

Price: $1,050.00.

-hp- 608C

Same as -*hp*- 608D, except:

Frequency Range: 10 to 480 MC, 5 bands.

Frequency Calibration Accuracy: ±1% full range.

Modulation Percentage: 0 to 95% at output of +7 dbm and below.

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: $950.00.

Data subject to change without notice.

612A UHF SIGNAL GENERATOR

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

All-Purpose Uhf Signal Generator 450 to 1230 MC

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 unique master oscillator-power amplifier circuit in *-hp-* 612A provides a high output power of 0.5 v into 50 ohms over the full frequency range of 450 to 1230 MC. There is very low incidental FM (less than 0.002% at 30% AM) and excellent modulation capabilities by all frequencies from 20 cps to 5 MC. The 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 *-hp-* 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 band width. (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.

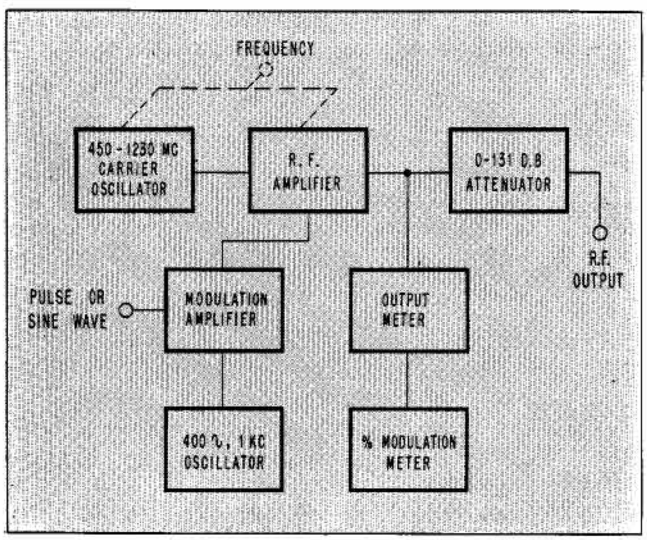


Figure 1. Block diagram, *-hp-* 612A Signal Generator.

The *-hp-* 612A covers the 450 to 1230 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 1230 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, entire frequency and attenuation range.

Internal Impedance: 50 ohms. Maximum SWR 1.2.

Leakage: Negligible. Permits receiver sensitivity measurements down to 1 μv.

Amplitude Modulation: 0 to 90% at af, indicated by panel meter. Accuracy, ±10% of reading, 30% to 90% modulation.

FM Due to Amplitude Modulation: 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, 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, positive or negative pulses, 4 to 40 v peak. No rf output during off time. Minimum rf output pulse length, 1.0 μsec.

Connectors: (a) rf Output, Type N.
(b) Modulation Input, Type BNC.

Power: 115/230 v ±10%, 50/1,000 cps, 200 watts.

Dimensions: Cabinet Mount: 13¾″ wide, 16¾″ high, 22″ deep.

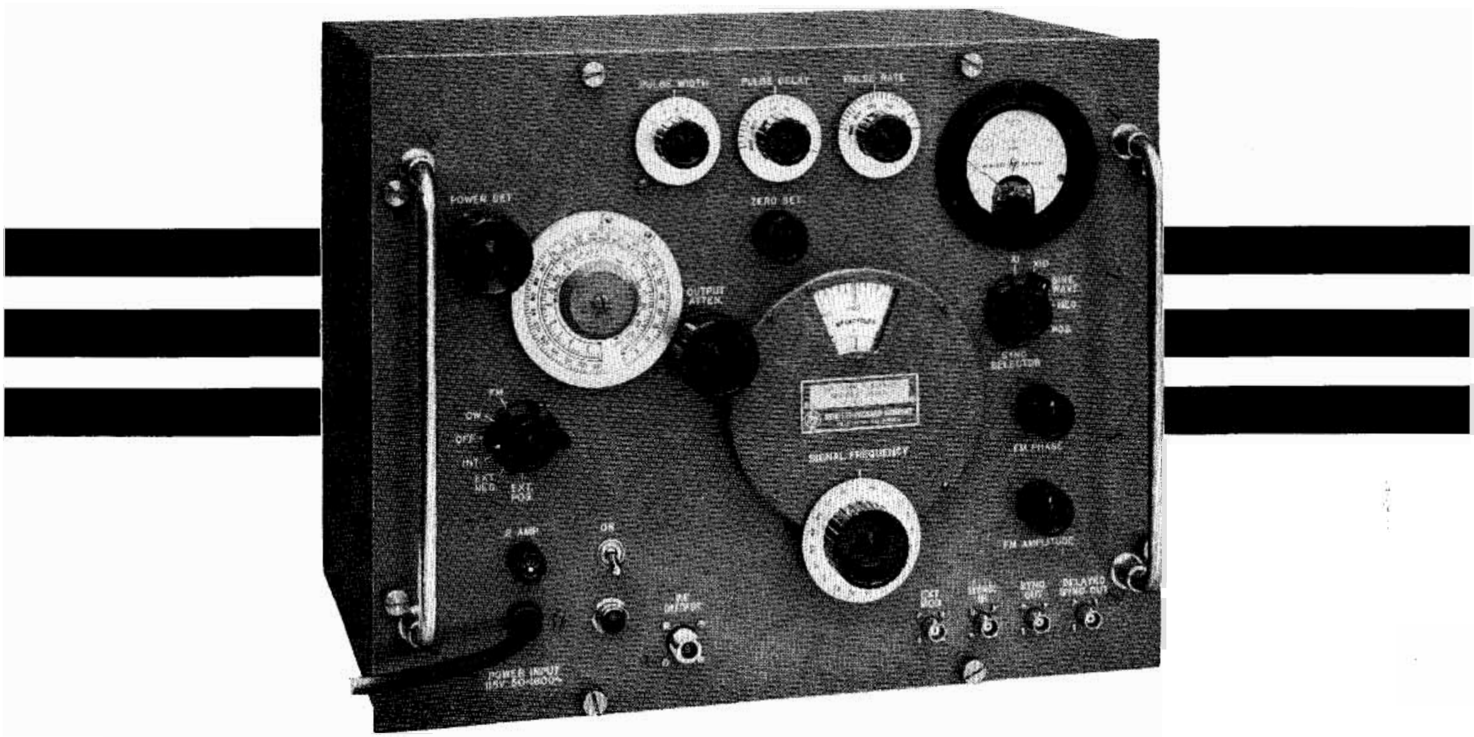
Weight: Net 57 lbs. Shipping 85 lbs.

Accessories Available: AC-16F rf Cable Assembly, $7.50; AC-16K Video Cable Assembly, $5.00; 360B Low Pass Filter (may be used where harmonic output must be reduced to a minimum, as in slotted line measurements), $40.00.

Price: $1,200.00.

Data subject to change without notice.

614A/616A UHF SIGNAL GENERATORS



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

Direct Reading, Direct Control
800 to 2,100 MC, 1,800 to 4,000 MC

EASE of operation, direct reading without calibration charts, one-dial frequency control, high stability, precision 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- 616A gives complete coverage of frequencies from 1,800 to 4,000 MC, 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 in MC is set and read directly on the large tuning dial. No voltage adjustments are necessary during operation because of the unique 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 616A consists of a reflex klystron in an external coaxial resonator. Frequency of oscillation is determined by a movable plunger which varies the resonant frequency of the resonator. Oscillator output is monitored by a temperature-compensated thermistor bridge circuit which is virtually unaffected by ambient temperature conditions. Voltage beyond the monitored output level is passed through a piston attenuator designed so that attenuation is linear over a range of 120 db or more. Voltage output is read directly on the scale.

Because of their wide range and great stability, *-hp-* 614A and 616A 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 0.01% frequency change.

Output Range: 1 milliwatt or 0.223 v to 0.1 μv (0 dbm to −127 dbm). Directly calibrated in μv and db; continuously monitored. Attenuator accuracy ±1 db from −10 dbm to −127 dbm.

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. Pulse rise and decay approx. 0.1 μsec.

External Pulse Modulation: By external pulses, pos. or neg. peak amplitude 40 to 70 v, 1.0 μsec to square wave.

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, height 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. ±5 MC.

Power: 115/230 v ±10%, 50/1,600 cps, 130 watts.

Dimensions: Cabinet Mount: 17″ wide, 13½″ high, 13⅝″ deep.

Weight: Net 60 lbs. Shipping 102 lbs.

Accessories Furnished: 1 AC-16F rf Cable Assembly.

Accessories Available: 360C Low Pass Filter, $40.00. AC-16K Video Cable Assembly, $5.00.

Price: $1,950.00.

-hp- 616A

Frequency Range: 1,800 to 4,000 MC. Selection is made by means of a single directly-calibrated control covering the entire range. No charts are necessary.

Frequency Calibration Accuracy: ±1%.

Frequency Stability: 0.005%/°C change in ambient temperature; line voltage changes of ±10 v cause less than 0.01% frequency change.

Output Range: 1 milliwatt or 0.223 v to 0.1 (0 dbm to −127 dbm). Directly calibrated in microvolts and db; continuously monitored.

Attenuator Accuracy: Within ±1.5 db from −7 dbm to −127 dbm without correction charts. A correction chart is provided when greater accuracy is desired.

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 1.0 μsec to square wave.

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, height 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 ±5 MC.

Power: 115/230 v ±10%, 50/1,600 cps, 160 watts.

Dimensions: Cabinet Mount: 17″ wide, 13½″ high, 13⅝″ deep.

Weight: Net 62 lbs. Shipping 105 lbs.

Accessories Furnished: 1 AC-16F rf Cable Assembly.

Accessories Available: 360D Low Pass Filter, $40.00. AC-16K Video Cable Assembly, $5.00.

Price: $1,950.00.

Data subject to change without notice.

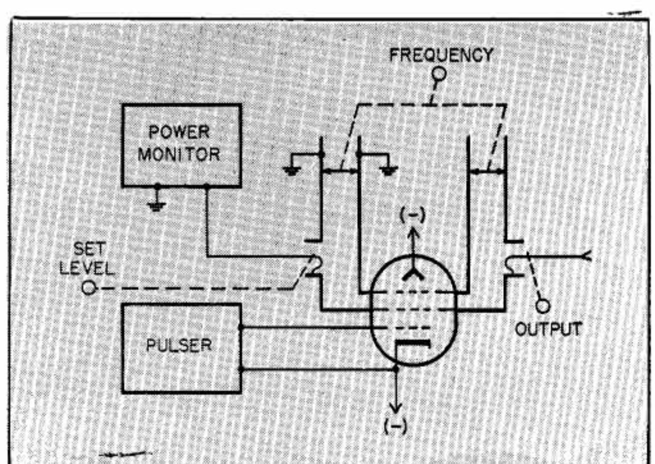


Figure 1. Block diagram, *-hp-* 614A Signal Generator.

618B/620A SHF SIGNAL GENERATORS

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

Widely Varied Pulsing Capabilities for Measurements 3,800 to 11,000 MC

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 MC 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 microseconds. Sync-out signals are simultaneous with the rf pulse, or in advance of the rf pulse by any time span from 3 to 300 microseconds. The instruments may be synchronized with an external sine wave or with positive or negative pulse signals.

Saw-tooth Sweep

For internal frequency modulation, both *-hp-* 618B and 620A have a saw-tooth voltage variable from 40 to 4,000 pps providing a frequency deviation variable up to ±3 MC. For external FM, the instruments provide capacitive coupling to the repeller of the klystron oscillator. Maximum deviation is approximately ±5 MC.

Both generators maintain the same high standards of accuracy found in *-hp-* vhf and uhf Signal Generators. Both also feature the same simple operation. Carrier frequency is set and read directly on the large central tuning dial. (Calibration of this dial is linear.) No voltage adjustments are necessary during operation because of an exclusive *-hp-* 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.

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. Voltage beyond the monitored output level is passed through a piston attenuator. Attenuation is linear over a range of 120 db or more.

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 uniquely clean and accessible. The generators are designed for years of dependable service with little or no maintenance.

Specifications

-hp- 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 15 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, 13⅞″ high, 19½″ deep.

Weight: Net 95 lbs. Shipping 175 lbs.

Accessories Furnished: 1 AC-16Q rf Cable Assembly.

Accessories Available: AC-16K Video Cable Assembly, $5.00.

Price: $2,250.00.

-hp- 620A

(Same as *-hp-* 618B except:)

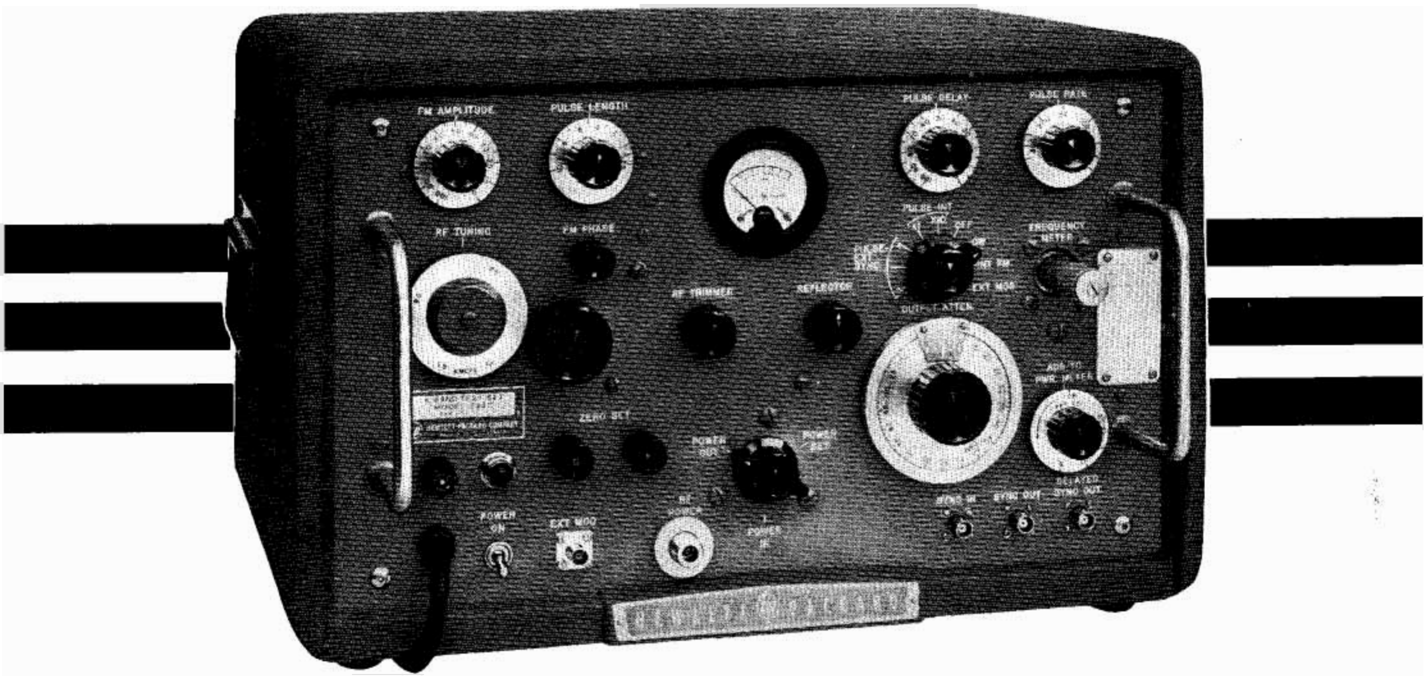
Frequency Range: 7,000 to 11,000 MC covered in a single band. Repeller voltage automatically tracked and proper mode automatically selected.

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). Uncalibrated output at least 2 milliwatts over band.

Output Accuracy: Within ±2 db from −7 dbm to −127 dbm at panel connector, terminated in 50 ohm load.

Price: $2,250.00.

Data subject to change without notice.



High-Level, Direct-Reading Test Sets for Laboratory, Field Work

Advantages:

- 0.223 volt maximum rf output
- Direct tuning, direct reading
- Pulse and FM modulated output
- Stable, accurate 100 db attenuator
- Variety of high-quality rf pulses
- Compact, sturdy, easily portable

Uses:

- Measure receiver sensitivity
- Measure selectivity
- Transmitter tuning, power level
- Testing complete radar, gunfire control or beacon systems
- Determine external rf power or external frequency

MODEL 624C Test Set is a high-level, accurate, multipurpose instrument designed to speed and simplify a wide variety of tests between 8,500 and 10,000 MC. It is an ideal one-piece unit for measuring receiver sensitivity or selectivity, transmitter tuning or power level, and is particularly adapted to testing complete radar or gunfire control systems or beacon equipment. The instrument includes pulsing circuitry providing a variety of high-quality rf pulses.

-hp- 624C consists of a signal generator and a power and frequency meter section. The generator includes a modern klystron generator with excellent frequency stability and an output attenuator of the waveguide-beyond-cutoff type, insuring high accuracy and stability. The attenuator is not subject to temperature, humidity or age changes. The power and frequency meter section can be used to adjust the signal generator's frequency and level as well as measure external rf energy. The instrument employs 50 ohm Type N coaxial connectors, and for maximum versatility includes an adapter for waveguide connection.

-hp- 623B Test Set is designed for operation at any frequency between 5,925 MC and 7,725 MC. This overall frequency range is covered in three bands, each of which is

approximately 600 MC wide. Bands are selected by installation of the proper klystron tube (see specifications). The instrument is particularly useful in field-testing shf radio relay stations and communications equipment as well as general tests involving FM modulated equipment. It includes a 1,000 cps modulator and may also be square-waved or pulsed by external sources with frequencies ranging from 60 cps to 100 KC.

Both -*hp*- 624C and 623B can be supplied either for cabinet or rack mount. The 624C has the Model AC-44 cabinet shown at left while the 623B has a splash proof metal case, the cover of which can be used for storing accessories for transit.

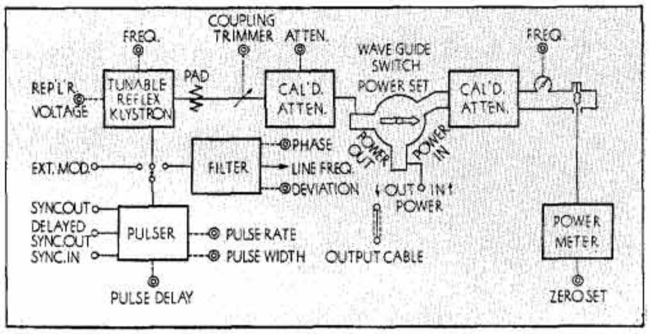


Figure 1. Simplified circuit diagram -*hp*- 624C Test Set.

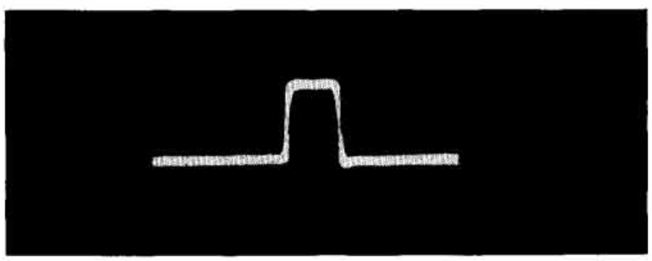


Figure 2. Typical rf pulse, 0.25 μsec, 624C.

Specifications

-hp- 624C X-Band Test Set

Range: 8,500 to 10,000 MC.

Output: 0 dbm (1 mw) to −100 dbm (0.223 v to 2.23 μv) into 50-ohm load. Type N jack. SWR less than 2.

Output Accuracy: Within ±2 db, −10 to −100 dbm into matched load.

Internal Modulation: Pulsed or FM.

External Modulation: Pulse, FM or square wave.

Internal Pulse Modulation: Length variable from 0.25 to 10 μsec. Rise time less than 0.06 μsec. Decay time less than 0.12 μsec. Rate variable 35 to 3,500 pps.

External Sync: Internal pulser operates free-running or in sync with external 5 to 50 v peak pulse, pos. or neg., or 5 to 50 v rms sine waves, or 5 to 50 v peak square wave. May be externally square-waved modulated. BNC jack.

FM: Internal FM at power line frequency. ±7.5 MC deviation max. Also FM modulation by external 35 to 3,500 cps voltage.

Trigger Pulses: (a) Simultaneous with rf pulse, positive. (b) Variable, 2 to 250 μsec ahead of rf pulse, positive. In either case amplitude greater than 10 v across 10,000 ohms. Pulse duration approx. 2 μsec; rise time less than 0.8 μsec.

Power Meter: Calibration range −6 dbm to +3 dbm, accurate within ±1 db. Input attenuator calibrated 0–25 db. Total input range, −6 to +28 dbm.

Frequency Meter: Full range, accurate within 0.03% at 25°C. ambient.

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

Dimensions: Cabinet Mount: 20¾" wide, 12⅝" high, 16¼" deep. Rack Mount: 19" wide, 10½" high, 14" deep.

Weight: Net 56 lbs. Shipping 96 lbs. (cabinet mount).

Accessories Furnished: 1 AC-16Q rf Cable Assembly; 1 X281A Adapter.

Accessories Available: AC-16K Video Cable Assembly, $5.00.

Price: $2,265.00.

-hp- 623B shf Test Set

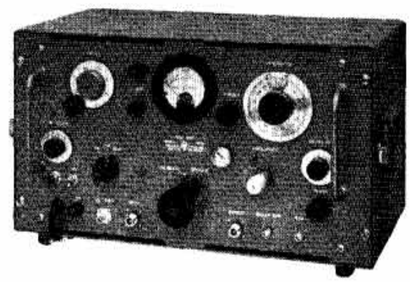
Overall Frequency Range: 5,925 to 7,725 MC.

Operating Ranges

5,925 – 6,575

6,575 – 7,175

7,175 – 7,725



NOTE: Test set supplied with one klystron for any one of the above frequency ranges.

Output: 0 dbm (1 mw) to −70 dbm (0.223 v to 70 μv) into 50 ohm load. Direct-reading control.

Output Accuracy: Within 2 db, 0 to −70 db, into matched load. SWR less than 2.

Internal Modulation: FM from 1,000 cps internal source. Phase and deviation adjustable. Max. deviation at least ±10 MC.

External Modulation: FM, 30 cps to 10 KC. May be pulsed or square-waved externally, 30 to 100,000 cps.

Detector Output: Crystal detector to provide rectified output when FM or pulsed power applied.

Power Meter: Range −6 dbm to +3 dbm, accurate within ±1 db.

Power: 115/230 v ±10%, 50/60 cps, 150 watts.

Dimensions: Cabinet Mount: 21" wide, 12" high, 14" deep. Rack Mount: 19" wide, 10½" high, 14" deep.

Weight: Net 56 lbs. Shipping 96 lbs. (cabinet mount).

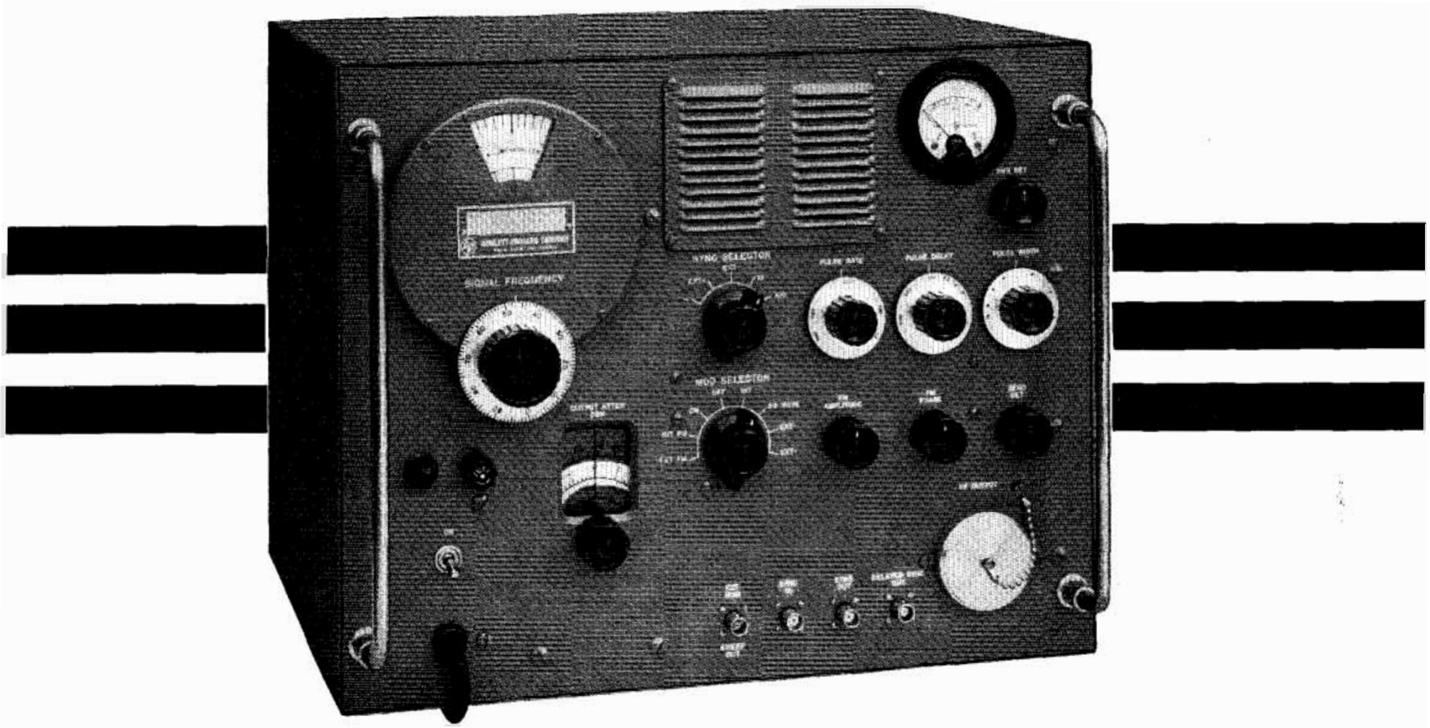
Accessories Furnished: 2 AC-16Q rf Cable Assemblies; 1 J281A Adapter; 1 212-44 Spare Crystal; 1 Spare Thermistor, 623B-28A.

Accessories Available: AC-16K Cable Assembly, $5.00.

Price: $1,750.00.

Data subject to change without notice.

626A/628A SHF SIGNAL GENERATORS



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

Use To Measure:

- Receiver sensitivity
- Selectivity or rejection
- Signal-to-noise ratio
- Conversion gain, SWR
- Antenna gain
- Transmission line characteristics

Direct Reading, High Power 10 to 15.5 KMC, 15 to 21 KMC

HERE are two *-hp-* signal generators which extend the measuring versatility, convenience and accuracy of *-hp-* vhf signal generators to 21 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 the unique *-hp-* coupling device causes oscillator repeller voltage to track frequency changes automatically. Oscillator output is also set and read directly, and no frequency correction is necessary throughout operating range.

Versatile Modulation

Both *-hp-* 626A and 628A offer internal and external pulse modulation as well as internal square wave modulation and FM. Pulse repetition rate is continuously variable from 40 to 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 ± 5 MC. For external FM, the generators have capacitive coupling to the klystron oscillator repeller.

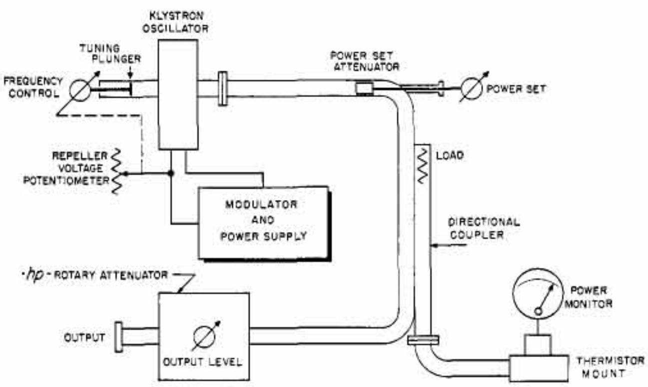


Figure 1. Basic circuit, *-hp-* 626A/628A.

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 a rotary vane power set attenuator. The attenuator is adjusted to provide a fixed reading on the power monitoring meter.

The directional coupler provides very uniform coupling over the entire frequency range. The 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 RETMA guides suitable for the 10 to 21 KMC range.

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 $\mu\mu$w. ($+10$ 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.

Output Connector: 626A, 0.850″ by 0.475″ waveguide, WR-75, Flat Cover Flange. 628A, 0.590″ by 0.335″ waveguide, WR-51, Flat Cover Flange.

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 ± 5 MC.

Sync Out Signals: 20 to 50 volts peak into 1,000 ohm load. Better than 1 μsec rise time.

(1) Simultaneous with rf pulse—positive.

(2) In advance of rf pulse—positive, 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 volts $\pm 10\%$, 50/60 cps, approx. 200 watts.

Dimensions: Cabinet Mount: 17″ wide, 14″ high, 14¾″ deep.

Weight: Net 65 lbs. Shipping 100 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, $5.00. *-hp-* 626A, M362A Low Pass Filter. *-hp-* 628A, N362A Low Pass Filter.

Price: *-hp-* 626A, $3,250.00. *-hp-* 628A, $3,000.00.

Data subject to change without notice.

Advantages:

- Coverage of all frequencies 2.6 to 10 KMC
- 10 mw output full range
- Adjustable motor-driven frequency sweep
- Full modulation capabilities
- Direct-reading frequency dial

Use Them For:

- Reflectometer measurements
- Waveguide test voltages
- Slotted line measurements
- Microwave system frequency response
- Antenna checks

Four Automatic-Sweep Microwave Oscillators Cover 2.6 to 10 KMC

THESE unique new instruments are compact, efficient, versatile sources of test voltages for measurements in the S, G, J and H microwave bands. They provide at least 10 milliwatts of power throughout their ranges. Waveguide-beyond-cutoff attenuators provide a convenient method of varying the output level.

Automatic Frequency Sweep

Frequency control is operated by a directly calibrated dial. An unusual feature is the automatic, adjustable motor drive provided for this dial. Two adjustable stops determine upper and lower limits of the automatic sweep. The sweep may be set to cover a 10% to 20% segment, or any larger portion of the instrument's frequency range. The sweep system operates at a constant velocity selected to provide an easily seen trace on a medium-persistence cathode ray tube. A linear sweep voltage proportional to the sweep is available for horizontal oscilloscope deflection. Use of this sweep voltage enables the dc oscilloscope to present a frequency panorama with horizontal sweep distance approximately proportional to frequency.

-hp- 670 oscillators are supplied with or without mechanical sweep. The automatic sweep feature is easily added later.

Varied Modulation Capabilities

-hp- 670 series oscillators include provision for grid and reflector modulation. In conjunction with *-hp-* 717A Klystron Power Supply (see page 100) the following modulations are available—*Reflector Modulation:* FM, 60 cycle sine wave; Square Wave, repetition frequency continuously variable 400 to 1,000 cps. *Grid Modulation:* Square Wave, repetition frequency continuously variable 400 to 1,000 cps. For greater versatility, external modulation voltages can also be applied.

During automatic sweeping, grid modulation only is used because reflector voltage must track frequency changes. In manual use, either grid or reflector modulation may be used. AM or FM reflector modulation is available provided reflector voltage is adjusted for optimum output at each operating frequency. (This adjustment is provided on *-hp-* 717A Klystron Power Supply.)

Wide Applicability

-hp- 670 oscillators are versatile sources of both fixed and swept frequencies for all types of microwave measurements where high level test signals are required. The instruments are particularly useful in slotted line measurements and checks of transmission system characteristics. They are also ideal sources of fixed or swept frequencies for reflection coefficient measurements. Motor-driven models are particularly useful with *-hp-* 416A Ratio Meter (see pages 118, 119) in forming high speed, accurate systems for measurement of reflection coefficients. Suggested arrangement of equipment for such measurements is given on pages 116 and 119, on Technical Data sheet for *-hp-* 416A Ratio Meter, and in Volume 6, No. 1-2 of the Hewlett-Packard Journal.

Operation

The operating principle of the *-hp-* 670 series oscillators is illustrated in Figure 1. The sweep motor produces three simultaneous actions: (1) through a rack and pinion gear assembly, shorting plungers are moved in and out within the resonant cavity; (2) reflector voltage is tracked to insure accurate frequency control; (3) sweep voltage is generated as a horizontal oscilloscope input.

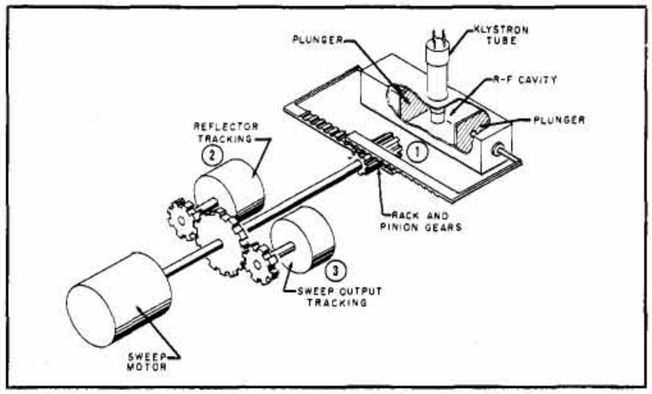


Figure 1. Operating diagram of *-hp-* 670 series Swept Frequency Oscillator with sweep motor drive.

Specifications

Frequency Range: *-hp-* 670S—2.6 to 4.0 KMC; *-hp-* 670G—4.0 to 6.0 KMC; *-hp-* 670J—5.85 to 8.2 KMC; *-hp-* 670H—7.0 to 10.0 KMC.

Output Power: At least 10 mw full range.

Attenuator Range: 100 db (not calibrated).

Modulation: (a) Grid modulation for optimum swept-frequency performance. (b) Reflector modulation for optimum single-frequency performance. Modulating signals must be provided from external source (normally *-hp-* 717A Klystron Power Supply which may be externally modulated).

Mechanical Sweep: Adjustable to cover any 10% to 20% or larger segment of instrument's frequency range. Sweep rate approx. 30 to 50 cycles per minute depending on swept frequency range.

Sweep Voltage Provided: Linear voltage proportional to mechanical sweep. (Approx. 100 v change equivalent to maximum swept frequency range.)

Connectors: Type N rf output, BNC sweep voltage. Special power cables mating with *-hp-* 717A provided.

Power: 115 v ±10%, 50/60 cps, 25 watts. Requires external power supply for Klystron. (*-hp-* 717A Power Supply recommended.) Requires: 1,000 v, 20 ma; 0 – 600 v, 5 ma; 6.3 v ac, 0.6 ma.

Dimensions: Cabinet mount: 7½" wide, 11½" high, 20¼" deep.

Weight with Motor: Net 33 lbs. Shipping 60 lbs.

Weight without Motor: Net 24 lbs. Shipping 60 lbs.

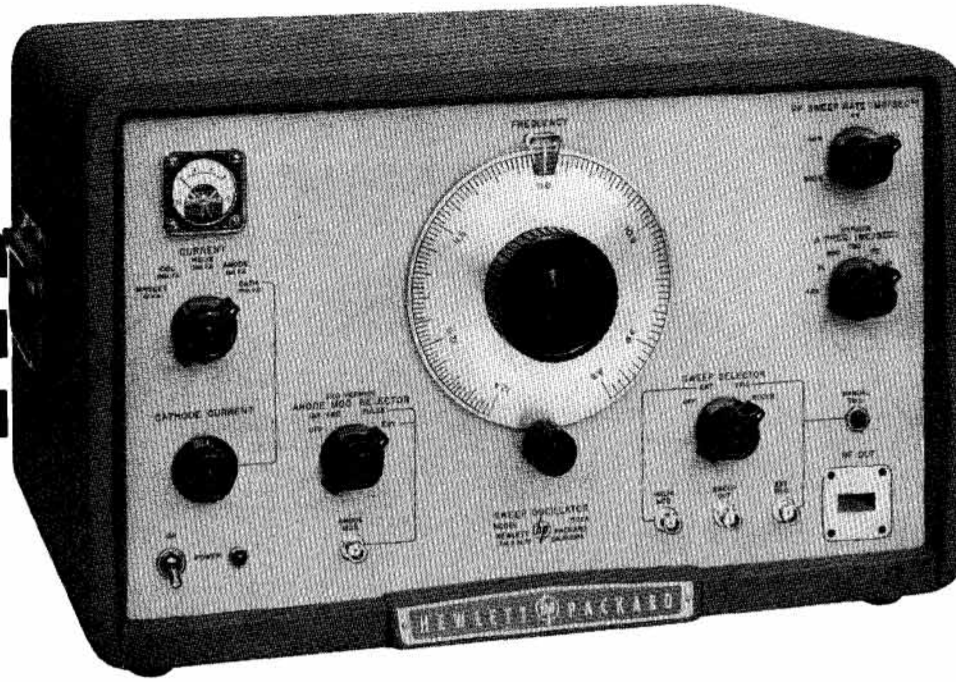
Accessories Furnished: 1 Power Supply Special Mating Connector.

Accessories Available: *-hp-* AC-16D Video Cable Assembly, $2.65; *-hp-* AC-16F rf Cable Assembly, $7.50; *-hp-* AC-16Q rf Cable Assembly, $12.00; *-hp-* 717A Klystron Power Supply, $375.00; *-hp-* AC-97A Sweep Motor Assembly, $75.00; *-hp-* AC-97B Sweep Motor Assembly (¼ Normal Speed), $100.00.

Price: *-hp-* 670SM, 670GM, 670JM, 670HM, $1,175.00 (Includes AC-97A sweep motor assembly installed.) *-hp-* 670S, 670G, 670J, 670H, manually operated, $1,100.00.

Data subject to change without notice.

686A ELECTRONIC SWEEP OSCILLATOR



Advantages:

- Electronic sweep
- Covers all or part of X-band
- 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:

- New, convenient source of X-band CW and swept rf frequencies for
  - Reflectometer measurements
  - Slotted line measurements
  - Antenna checks
- Transfer characteristics of:
  - Networks
  - Filters
  - Attenuators
  - Amplifiers
  - Ferrite devices

New Electronic Sweep for Simple, Error-free X-Band Coverage

Now Hewlett-Packard offers a new kind of backward-wave sweep oscillator that eliminates sweep motors, tuning plungers, previous range limitations and mechanical problems . . . *and covers all or part of the X-band with a simple, flexible, broadly adjustable, quiet electronic sweep!*

With the new Model 686A, you have complete freedom of sweep combination—both sweep width and rate of change of frequency (sweep rate) are independently controlled and direct reading. X-band CW or swept rf frequencies may be obtained over any part of the range 8.2 to 12.4 KMC; sweep width may be adjusted instantly without interrupting operation. The full range of 8.2 to 12.4 KMC can be covered in periods ranging from 105 seconds (slow sweep for high resolution mechanical recordings) to 0.0105 seconds (fast sweep for flickerless oscilloscope presentation). Sweep rate is adjustable in decade steps from 40 MC/second (megacycles per second per second) to 400 KMC/second.

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.

For greatest convenience the sweep may be operated recurrently, triggered manually by means of a pushbutton on the front panel or by an externally generated voltage for operation of the 686A in synchronism with other equipment. Single sweeps may be generated through the use of the manual button, or by external trigger voltages. To facilitate oscilloscope and mechanical recordings, a 30 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.

Output of *-hp-* 686A is at least 10 milliwatts full range into a reflectionless waveguide load, and output variation over the whole X-band is only a few db. For single frequency use the output may be reduced to zero smoothly by either the cathode current control or a modulating signal applied to the anode. Output connection is an X-band waveguide with cover flange, brought to the front panel of the oscillator.

Broad Modulation Capabilities

In addition to its swept frequency output, *-hp-* 686A 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 an amplifier built into the *-hp-* 686A. Pass band of this amplifier is dc to 300 KC, and a 20 volt input change reduces the output level from rated to zero. Pulses up to 5 milliseconds long may be used for this modulation.

Pulse modulation is also available on *-hp-* 686A. 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.

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

RF

Frequency Range: 8.2 to 12.4 KMC.

Power Output: At least 10 milliwatts into matched waveguide load. Continuously adjustable to zero by cathode current control.

Output Impedance: SWR less than 2:1.

Output Connector: X-band waveguide cover flange.

Sweep

Characteristics: Rf frequency change linear with time and down from frequency dial setting.

Triggering: Recurrent, external, or manual.

Sweep Width: 3 MC to 4.2 KMC in seven steps. Vernier permits continuous adjustment between steps.

Sweep Rate: 40 MC/sec. to 400 KMC/sec. in decade steps.

Sweep Time: 0.0105 to 105 seconds for full band sweep.

Sweep Output: 30 volt peak saw-tooth generated during frequency sweep. Available at panel connector.

Modulation

Internal: 400 to 1,200 cps square-wave amplitude modulation. Peak power is equal to CW level.

External: Amplitude—anode modulation through DC to 300 KC amplifier. 20 volt input change will reduce level from rated output to zero.

Pulse—no rf output except during pulse. Input of 10 volts or more peak yields peak rf power equal to CW level. 5 milliseconds maximum pulse length. Fastest rf rise time 1 μsec.

Frequency—helix modulation: panel connector capacitively coupled to helix voltage supply.

General

Power Requirements: 115 volts, 50/60 cps, approximately 375 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 18½" deep.

Weight: Net 80 lbs. Shipping 120 lbs.

Price: $2,250.00.

Data subject to change without notice.

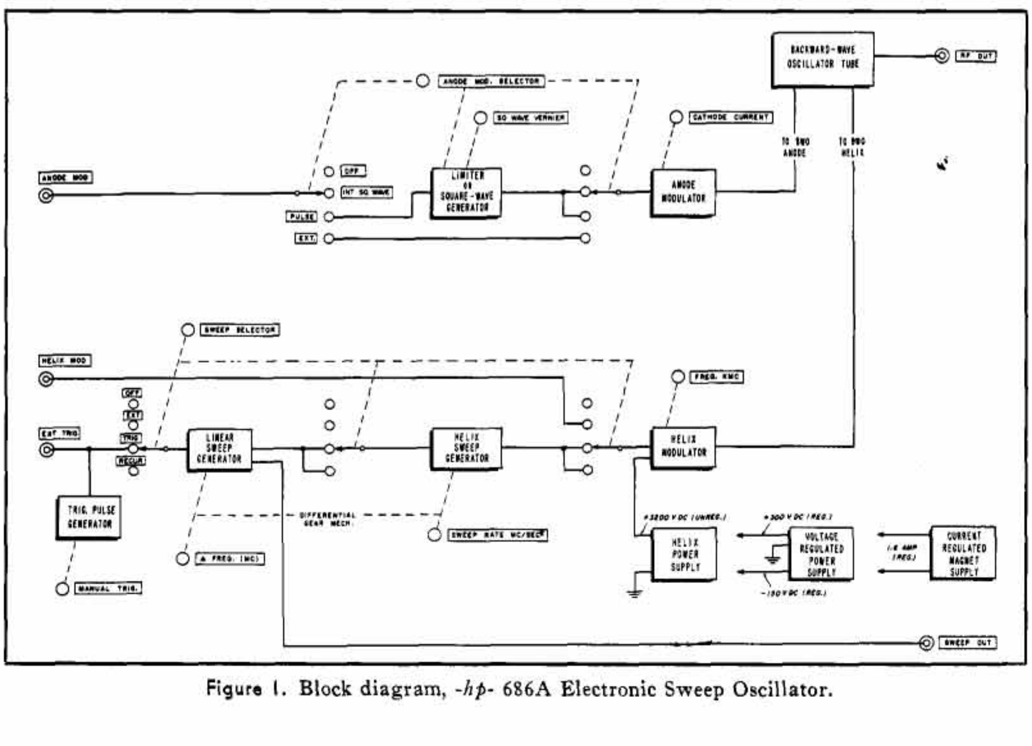


Figure 1. Block diagram, *-hp-* 686A Electronic Sweep Oscillator.

710B POWER SUPPLY

Specifications

Voltage Range: Output continuously variable from 100 to 360 volts. Either positive or negative output terminal may be grounded. 6.3 volts ac, center-tapped, also provided.

Regulation: Output constant to approximately 1% for loads of from 0 to 75 ma, and line voltage variations of ±10 volts for any setting. A maximum of 100 milliamperes can be drawn.

Noise and Hum: Total noise and hum is less than 0.005 volts for any condition of operation.

Power: 115/230 v ±10%, 50/1,000 cps, 90 watts.

Dimensions: Cabinet Mount: 7¾″ wide, 8¾″ high, 11¾″ deep. Rack Mount: 19″ wide, 8¾″ high, 11″ deep.

Weight: Net 17 lbs. Shipping 22 lbs.

Price: $100.00.

Data subject to change without notice.

High-Stability Regulated dc or ac

THE *-hp-* Model 710B Power Supply is an excellent source of dc power for every laboratory and production department use. It has been designed to give the ultimate in flexibility, compactness, portability, and economy. Output is continuously variable between 100 and 360 volts, and is practically independent of either line voltage or applied load for any setting. The noise and hum level is very low for any condition of operation. The output is stable over long periods of time. Its small size requires a minimum of bench space when in use, and little storage space when idle. Since many setups which call for a source of well-regulated dc also require an ac source for supplying filaments, a center-tapped, 6.3 volt source which will supply 5 amps ac has been included. The low cost makes it practical and economical to employ several of these instruments simultaneously.

Uses

Because of its stability and low noise level, the *-hp-* Model 710B Power Supply can be used in place of batteries in many applications. In such service its long life, dependability, and portability result in real savings, both in time and money. It may be used to power low-level amplifiers, constant frequency oscillators, and any equipment requiring a voltage source of high stability. One of its outstanding uses is in supplying power for temporary setups, "breadboard" layouts, and the like.

High Regulation, 0 to 500 Volts, Separate Meters

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

Similar to *-hp-* 710B except for its much wider voltage range, Model 711A can be used in place of batteries, or 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 wrap-around cabinet equipped with leather strap for easy portability. Its moderate price makes it an exceptional value in the power supply field.

Specifications

Output Voltages:

Dc Regulated High Voltage: 0 to 500 volts (without switching), 100 ma maximum load.

Ac Unregulated: 6.3 volts CT, 5 amps maximum load.

Regulation: (for line voltage 115 volts ±10%.) Less than ±0.5% change or 1.0 volt change, whichever is greater, no load to full load.

Ripple: Less than 1.0 mv.

Metering:

Current Meter: 0 to 100 ma; 0 to 10 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 ±10%, 50/1,000 cps. Approximately 150 watts depending on load and line voltage.

Dimensions: 7½" wide, 11½" high, 14¼" deep.

Weight: 20 lbs. Shipping weight, 26 lbs.

Price: $225.00.

Data subject to change without notice.

712B REGULATED POWER SUPPLY

0.01% Regulation at 500 Volts, 200 ma

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 response 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 having high instantaneous current demands such as radar modulators; 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 condensers 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 (without switching), 200 ma max. load.

Dc Regulated Fixed Bias: −300, 50 ma max. load.

Dc Variable Bias: 0 to −150, 5 ma max. load.

Ac Unregulated: 6.3, CT, 10 amps max. load.

Regulation: (For line voltage 115 ±10%.)

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.

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, 450 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¼" deep. Rack Mount: 19" wide, 10½" high, 14⅛" deep. Also can be used with *-hp-* AC-17 End Frames.

Weight: Net 69 lbs. Shipping 90 lbs. (cabinet mount).

Price: $365.00.

Data subject to change without notice.

Versatile Power Source for Low-Power Klystrons

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-waved internally at the nominal frequency of 1,000 cps; and 60 cps sine wave modulation is provided on the reflector voltage.

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 resonator.

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; 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 ±5%.

Modulation: Square wave modulation provided on supply No. 2; amplitude adjustable from 0 to 120 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, 150 watts.

Dimensions: Cabinet Mount: 7½" wide, 11¾" high, 13¾" deep.

Weight: Net 18 lbs. Shipping 32 lbs. (cabinet mount).

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

Accessories Available: AC-16A Cable Assembly, $4.00. AC-16B Cable Assembly, $4.25.

Price: $300.00.

Data subject to change without notice.

717A KLYSTRON POWER SUPPLY

Power Source for Type 5721 and Similar Klystrons

THIS instrument is designed specifically to power *-hp-* 670 series Swept Frequency Oscillators, Type 5721 external cavity klystrons, and other tubes having similar power requirements. It also has broad usefulness as a general purpose laboratory instrument.

Model 717A provides a high regulation beam supply of 800 to 1,000 volts at 25 milliamperes. The reflector supply is continuously variable from 0 to 600 volts in three ranges with wide overlap. The instrument furnishes grid voltage as well as filament potential for Type 5721 Klystrons.

Modulation may be applied to either the reflector or grid of the tube, and is available as a 60-cycle sine wave for FM with the reflector or as a square wave with repetition frequency continuously variable 400 to 1,000 cps. The internal square wave generator has rise and decay times of less than 10 μsec. External modulating voltages may also be applied, and circuitry will pass external pulses as short as 3 μsec with good wave shape.

A special output terminal operates the horizontal sweep circuit of an oscilloscope in synchronization with FM voltages applied to the klystron tube. A phase adjustment varies this voltage ±30 degrees with respect to modulating potential to facilitate oscilloscope presentation.

Model 717A has a panel meter monitoring cathode current supplied to the klystron, and circuitry protecting the klystron by preventing the reflector from becoming excessively positive.

Specifications

Beam Supply:
- **Voltage Range:** 800 to 1,000 volts at 25 ma maximum.
- **Regulation:** (a) For constant load, less than ±0.1% output voltage change for line voltage variations of nominal value ±10% (103 to 127 volts). (b) For line voltage of nominal value ±10%, less than ±1% output voltage change for output currents from 0 to 25 ma.
- **Hum:** Less than 10 millivolts.

Reflector Supply:
- **Voltage Range:** 0 to 600 volts in 3 ranges: 0–300, 200–400, 300–600 v at 1 ma maximum.
- **Regulation:** For constant load, less than ±0.05% for line voltage variations of nominal value ±10%.
- **Hum:** Less than 10 millivolts.
- **Square Wave Modulation:** (a) Amplitude adjustable 0 to 60 volts, peak-to-peak. (b) Rise and decay times less than 10 μsec. (c) Frequency adjustable 400 to 1,000 cps.
- **Sine Wave Modulation for FM'ing:** (a) Amplitude adjustable 0 to 275 v, peak-to-peak. (b) Frequency: line voltage frequency. (c) Oscilloscope horizontal sweep voltage: 15 v, peak-to-peak, phase adjustable ±30° with respect to modulating voltage.
- **External:** Terminals for external modulating voltage. System will pass 3 μsec pulses.

Grid Supply:
- **Voltage Range:** 0 to 30 volts open circuit.
- **Square Wave Modulation:** (a) Amplitude adjustable 0 to 45 volts, peak-to-peak. (b) Rise and decay times less than 10 μsec. (c) Frequency adjustable 400 to 1,000 cps.
- **External:** Terminals available for applying external modulating voltage. System will pass 3 μsec pulses.

Filament Supply: 6.3 volts ac, 2 amps.
Power: 115/230 v ±10%, 50/60 cps, 150 watts.
Dimensions: Cabinet Mount: 7½" wide, 11⅝" high, 20⅜" deep.
Weight: Net 34 lbs. Shipping 70 lbs.
Accessories Furnished: 1 717A-16C Output Cable Assembly.
Accessories Available: AC-16B Cable Assembly, $4.25; AC-16K Cable Assembly, $5.00.
Price: $375.00.

Data subject to change without notice.

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, attenuation, 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 insulation 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.

General information concerning use and application of *-hp-* microwave equipment is presented on the following pages and on pages 108, 109, 115, 116 and 117. Details of *-hp-* microwave instruments, themselves, begin on page 103. *-hp-* Signal Generators for microwave use are shown separately in a section beginning on page 76 of this Catalog.

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. Eight designator prefixes are used:

"S"	3″ x 1½″	2.6 to 3.95 KMC
"G"	2″ x 1″	3.95 to 5.85 KMC
"J"	1½″ x ¾″	5.3 to 8.2 KMC
"H"	1¼″ x ⅝″	7.05 to 10.0 KMC
"X"	1″ x ½″	8.2 to 12.4 KMC
"P"	.702″ x .391″	12.4 to 18.0 KMC
"K"	.500″ x .250″	18.0 to 26.5 KMC
"R"	.360″ x .220″	26.5 to 40 KMC

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 the letter immediately following the model numbers indicates a new, modified or special version of a basic model. Thus, *-hp-* 430C Microwave Power Meter is the latest version of *-hp-* 430A Microwave Power Meter (the original instrument in its classification).

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 cover flange system under actual operating conditions *-hp-* 290A Cover to Choke Flange Adapters may be used.

Waveguide Equipment

Hewlett-Packard Broad Band Waveguide Instruments are based on an entirely new design approach. The fundamentals of this new 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 new *-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 Measurements

General information and techniques for the use of Hewlett-Packard microwave test equipment in making power measurements are presented on pages 108 and 109. A similar discussion concerning microwave impedance measurements appears on pages 115, 116 and 117. 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 usually made by a substitution or modified substitution method. In this method the signal source is connected to a detector mount through a length of lossless transmission system in which place the attenuator pad 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 pad being measured. The power attenuation at the output indicator is a measure of the pad 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 pad.

The type of detecting equipment used will depend on the range of the attenuation measurement. A power monitoring combination such as *-hp-* 430C Microwave Power Meter and a bolometer mount will allow attenuation measurement over approximately 20 db. A wider 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.

For even greater ranges of attenuation (such as checking the calibration of a piston attenuator) a linear receiver may be substituted for the detector. The output of the receiver's second detector should be connected to a tuned voltmeter, such as -*hp*- 415B, to eliminate errors such as distortion present in the receiver's audio system. -*hp*- 415B is calibrated on the basis of a square law detector, and when it is used with a linear detector, the db readings will be one-half the correct value.

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.

Another method of measuring attenuation is applicable when the signal generator has an accurately calibrated attenuator. When using this method the output of the signal generator is fed to the attenuator being measured and then into the load or 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 output 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 -*hp*- 382A Precision Attenuator and a signal source.

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.

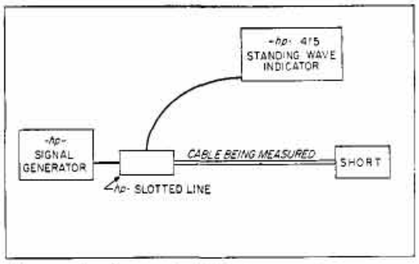


Figure 1. Suggested instrument arrangement for measuring small values of cable attenuation. Unknown cable is placed between slotted line and short.

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:

$$\tanh \alpha L = \frac{1}{SWR} \text{ Nepers}$$

If αL is much smaller than 1, $\tanh \alpha L$ is approximately αL, and this formula reduces to

$$\alpha L = \frac{1}{SWR} \text{ Nepers or } \frac{8.686}{SWR} \text{ db}$$

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 -*hp*- 803A VHF Bridge (*page 120*). 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:

$$Z_o = \sqrt{Z_s\,(op).\,Z_s\,(sh)}$$

where Z_o = 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:

$$Z_o = \frac{101{,}000}{VC}$$

where Z_o = characteristic impedance
V = velocity of propagation
C = capacity in $\mu\mu$f/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.

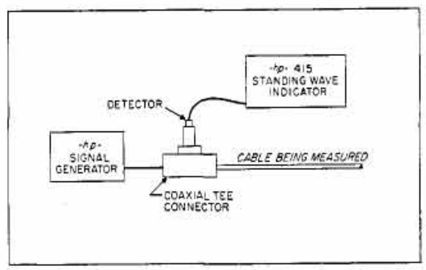


Figure 2. Arrangement of instruments for measuring velocity of propagation.

To measure velocity of propagation,

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:

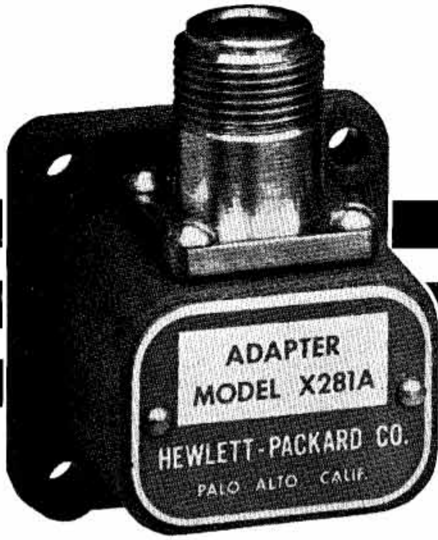
$$V = \frac{Lf_1}{2.46K}$$

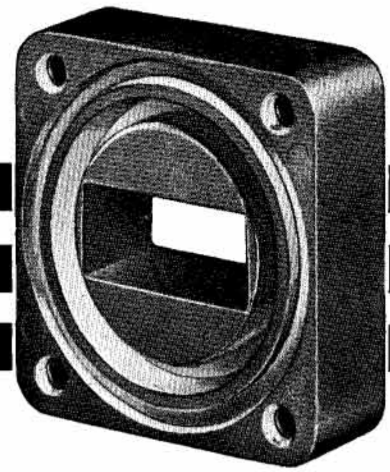
where L = cable length in feet
f_1 = recorded frequency
$K = \frac{2f_1}{f_2 - f_1}$

3. Substitute the values of capacitance and velocity of propagation in the formula:

$$Z_o = \frac{101{,}000}{VC} = \text{characteristic impedance}$$

(See Terman & Pettit, "Electronic Measurements," 2nd edition, page 135.)





-hp- 281A Waveguide—Coax Adapter

These adapters provide a convenient means of transmission between waveguide and coaxial systems. Power may be fed in either direction, and each adapter covers the full frequency range of its waveguide size with SWR of less than 1.25. These instruments use a probe with a low-loss dielectric sheath to transform waveguide impedance into coaxial cable impedance. They are fitted with a standard Type N plug connecting to a coaxial cable and a plain AN flange for connection to waveguide.

-hp- 290A Cover to Choke Flange

These instruments consist of a short waveguide section with a plain AN cover flange on one end and a choke flange on the other. If it is desired to measure a choke flange system, the input end of which is a non-precision cover flange, then it may be desirable to insert an *-hp-* 290A between the *-hp-* waveguide test equipment and the equipment to be measured to simulate actual operating conditions. The precision cover flanges of *-hp-* equipment may always be connected together.

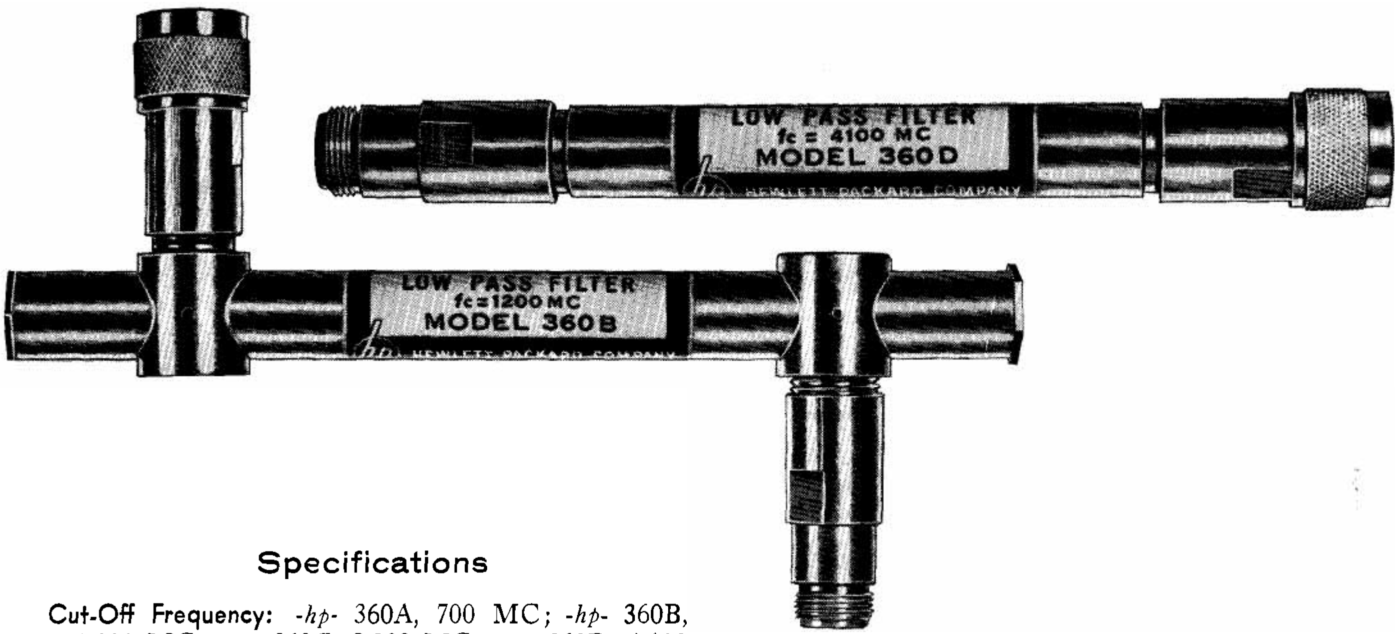
Specifications

-hp- 281A Adapters		*-hp-* 290A Adapters				Frequency Range KMC	Waveguide Size (in.)
Model	Price	Model	Cover Flange	Choke Flange	Price		
S281A	$50.00	S290A	UG53/U	UG54A/U	$65.00	2.60 - 3.95	3 x 1½
G281A	40.00	G290A	UG149A/U	UG148B/U	50.00	3.95 - 5.85	2 x 1
J281A*	35.00	J290	UG344/U	UG343A/U	35.00	5.30 - 8.2	1½ x ¾
H281A	30.00	H290A	UG51/U	UG52A/U	25.00	7.05 - 10.0	1¼ x ⅝
X281A	25.00	X290A	UG39/U	UG40A/U	15.00	8.2 - 12.4	1 x ½
		P290A	UG419/U	UG541/U	20.00	12.4 - 18.0	.702 x .391

*SWR 1.30 from 5.3 to 5.5 KMC; other models 1.25.

Data subject to change without notice.

360 LOW PASS FILTERS



Specifications

Cut-Off Frequency: *-hp-* 360A, 700 MC; *-hp-* 360B, 1,200 MC; *-hp-* 360C, 2,200 MC; *-hp-* 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.

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, $7.50; AC-16C rf Cable Assembly, $7.50.

Fittings: 1 Type N Male (UG 21/U); 1 Type N Female (UG 23/U).

Price: $40.00.

Data subject to change without notice.

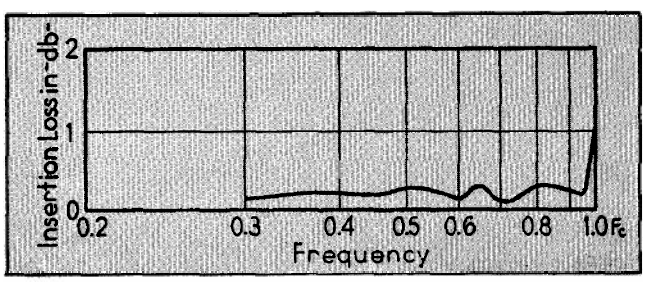


Figure 1. Typical band pass characteristics.

Eliminate Harmonics. Transmit Energy at a Single Frequency

Model 360 Low Pass Filters are designed to facilitate microwave measurements by eliminating harmonics and permitting the transmission of energy at a single known frequency. Such isolation of a single frequency is of particular importance in the making of slotted line measurements, in checking filter characteristics, in determining receiver response and other applications where harmonics are objectionable.

No Spurious Responses

These *-hp-* filters consist of brass tubes fitted with a multi-section coaxial type filter. The ends are terminated in Type N fittings, one male and one female. Attenuation in the pass bands less than 3 db; and attenuation in the rejection band is more than 50 db. There are no spurious responses up to 3 times cut-off frequency.

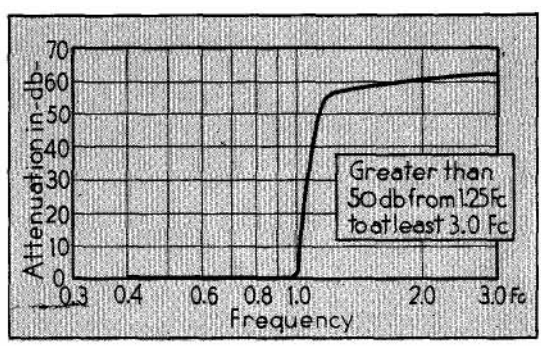


Figure 2. Typical rejection characteristics.

One New Instrument Covers 8.2 to 12.4 KMC

HERE is the first of a new series of ferrite isolators offering full coverage of a given frequency band and flat rejection over the entire range.

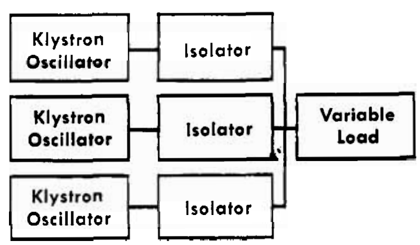
Model X365A, for X-band use, provides at least 25 db attenuation in the reverse direction and has a maximum attenuation in the forward direction of only 1.5 db. The SWR does not exceed 1.2 anywhere in the band. The instrument employs the Faraday principle of field rotation. Two axially magnetized ferrite rods mounted inside a round, vaned waveguide, rotate the planes of polarization 45° each. This rotation, in combination with precisely located attenuator cards, permits forward power to pass almost without loss, while reverse power is virtually absorbed.

Uses

This new instrument is extremely useful in isolating microwave signal sources from pulling due to load variations, reducing measuring error due to mismatch or modulated signal leakage in a homodyne system, and preventing cross-modulation when two or more klystron oscillators supply the same waveguide.

Typical Applications

Arrangement for using Isolator to prevent shifting of klystron oscillator frequency due to load variations.



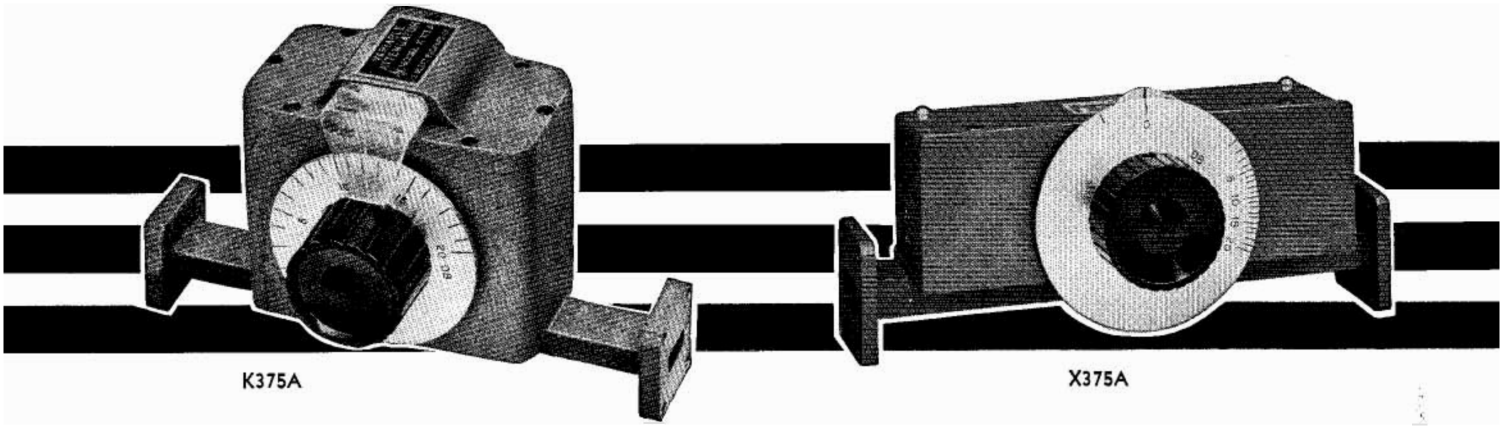
Arrangement for using Isolator to prevent mutual coupling of klystron oscillators.

Specifications

Frequency Range: 8.2 to 12.4 KMC.
Minimum Reverse Attenuation: 25 db.
Maximum Forward Attenuation: 15 db.
Maximum SWR (either end): 1.2.
Maximum Power Dissipated: 5 watts.
Overall Length: 9¾″.
Weight: Net 4 lbs. Shipping 6 lbs.
Price: $225.00.

Data subject to change without notice.

370/375/380 WAVEGUIDE ATTENUATORS



K375A X375A

-hp- 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. The instruments consist of a rectangular waveguide in which a strip of resistive material is mounted. Position of the strip is factory-adjusted to give an exact attenuation value at mid-frequency of the waveguide band. Model 370 handles power to a 1 kw peak, 1 watt average. Attenuation of 3, 6, 10 and 20 db is offered, accurate to within ±0.2 db at the calibration frequency. Attenuation varies less than ±20% over the waveguide frequency range. Maximum SWR is 1.15 over the full band width.

-hp- 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 single 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.

Model 375 Attenuators have a maximum SWR of less than 1.15 over the guide frequency range. Attenuation is variable 0 to 20 db; the equipment dissipates average power of 1 watt (except small waveguides where maximum dissipation is 0.5 watts). Dial calibration is accurate within ±1 db from 0 to 10 db, ±2 db from 10 to 20 db.

-hp- S380 Calibrated Variable Attenuator

Here is a convenient, efficient instrument for setting exact power level or measuring attenuation in a waveguide system. The equipment 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 as the plate nears the center of the guide. Maximum average power is 1 watt; peak power level is 1 kilowatt.

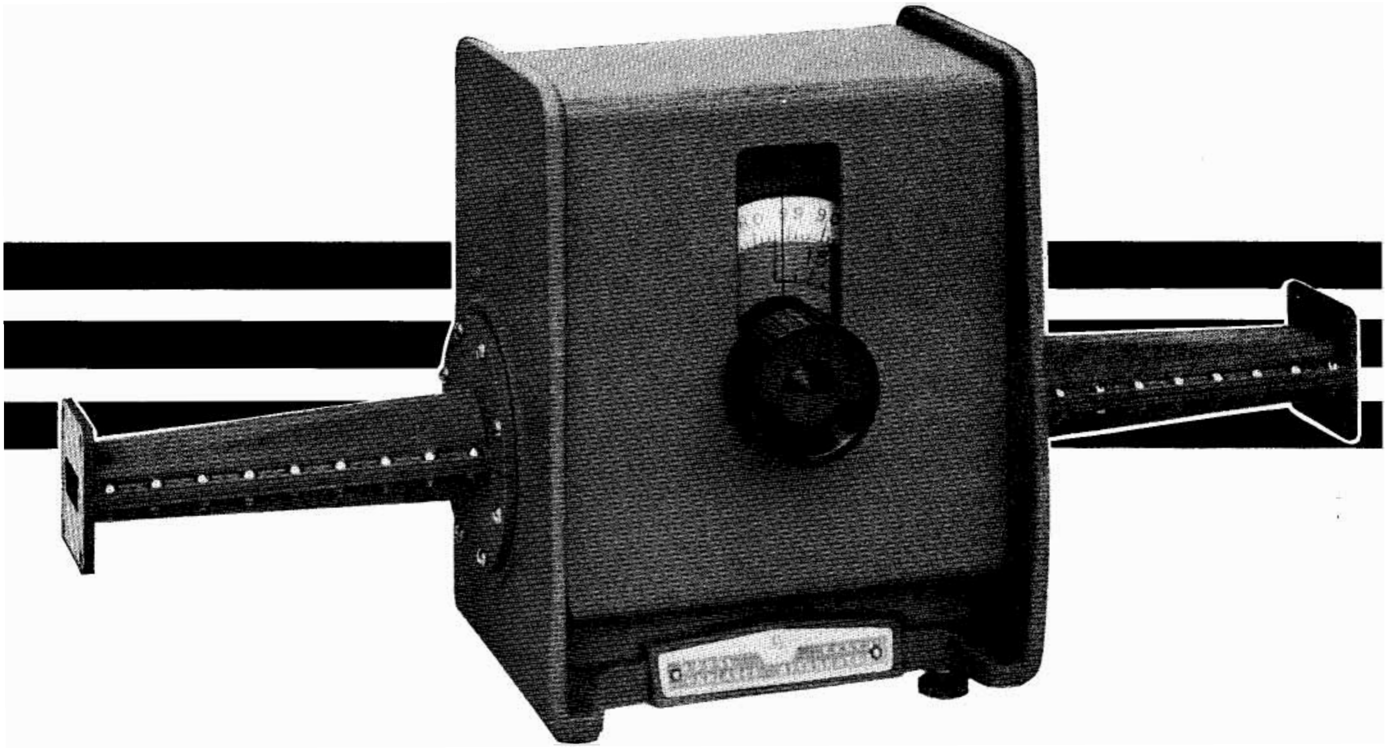
Specifications S380A: Frequency range 2.60 to 3.95 KMC. Waveguide size 3″ x 1½″. Maximum attenuation 10 db. Insertion loss less than 0.5 db. SWR 1.15. Power dissipation 1 watt. Calibration frequency 3 KMC. Calibration accuracy 0.3 db. Calibration for other frequencies available on request. Price $260.00.

Specifications, -hp- 370, 375 Attenuators

-hp- Model 370*					*-hp-* Model 375A				Frequency Range KMC	Waveguide Size (in.)
Model	Calib. Freq. KMC	Power Dissipation Watts	Length (in.)	Price	Model	Power Dissipation Watts	Length (in.)	Price		
S370	3.0	1.0	12	$75.00	S375A	1.0	14¼	$120.00	2.60 - 3.95	3 x 1½
G370	4.5	1.0	10⅛	65.00	G375A	1.0	13	110.00	3.95 - 5.85	2 x 1
J370	7.0	1.0	7⅜	65.00	J375A	1.0	13	100.00	5.30 - 8.2	1½ x ¾
H370	8.6	1.0	6⅜	60.00	H375A	1.0	7¼	90.00	7.05 - 10.0	1¼ x ⅝
X370	10.0	1.0	5¼	55.00	X375A	0.5	7⅜	65.00	8.2 - 12.4	1 x ½
P370	15.0	1.0	4⅛	60.00	P375A	0.5	7¼	80.00	12.4 - 18.0	.702 x .391
					K375A	0.5	4⅝	60.00	18.0 - 26.5	.500 x .250
					R375A	0.5	4½	70.00	26.5 - 40.0	.360 x .220

Maximum SWR 1.15 for all models. (*Note: Model number suffix indicates db attenuation of 370 series attenuators. Suffix "A", 3 db. Suffix "B", 6 db. Suffix "C", 10 db. Suffix "D", 20 db. Example: Model G370B is a 6 db attenuator for the 3.95 to 5.85 frequency range.)

Data subject to change without notice.



Rotary Design Provides High Accuracy, Stability, 0 to 50 db

THIS revolutionary waveguide attenuator provides the convenience of direct readings and a high order of measuring accuracy never before found in commercial attenuators.

Model 382 attenuates from 0 to 50 db, full range, independently of frequency. Phase shift is constant with attenuation. Accuracy is within ±2% of db reading. Power handling capacity is high. The instrument is set and read directly on a large easily read dial without interpolation or charts.

The secret of reliability and accuracy of this instrument is that attenuation depends on angular position of the attenuating film rather than specific resistivity. The attenuator uses three resistive films—two mounted in the same plane and the third rotatable axially in the center section. (Figure 1.) When all films are in the same plane, there is no attenuation. Rotation of the center film increases attenuation proportional to the cosine squared of the angle of rotation.

Specifications

Model	Maximum Dissipation Watts	Length (in.)	Frequency KMC	Waveguide Size (in.)	Price
G382A	15	31 5/8	3.95 - 5.85	2 x 1	$500.00
J382A	10	25	5.30 - 8.2	1 1/2 x 3/4	350.00
H382A	10	19 7/8	7.0 - 10.0	1 1/4 x 5/8	350.00
X382A	10	15 1/2	8.2 - 12.4	1 x 1/2	250.00
P382A	5	12 1/8	12.4 - 18.0	.702 x .391	275.00

SWR is less than 1.15 for all models. Calibrated range 0-50 db. Attenuation at zero setting less than 1 db. Calibration accuracy plus frequency deviation is ±2% of reading in db, or 0.1 db, whichever is greater. Includes calibration error plus frequency error.

Variation in phase shift is less than 1° for all values of attenuation up to 40 db.

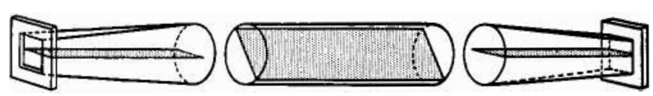


Figure 1. Cutaway shows relationship of fixed films (in waveguide extensions) and rotating film (center).

Data subject to change without notice.

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.

The measurement of power is accomplished by means of a bolometer which changes the rf energy into heat energy. This causes the resistance of

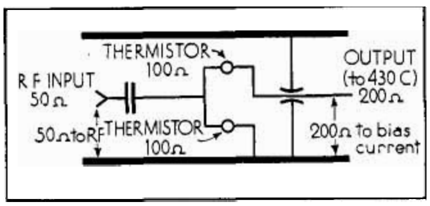


Figure 1. Arrangement for using two thermistors in coaxial systems (*-hp-* 477B Coaxial Thermistor Mount).

the bolometer to change. The resistance change is measured and used to determine the rf energy.

Bolometers used for microwave measurements are of two general types—metallic wire or film in which the temperature coefficient of resistance is positive, and thermistors in which it is negative. Both barretters and instrument fuses are used as positive

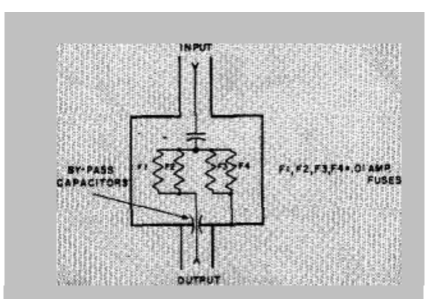


Figure 2. Arrangement for using four instrument fuses in series parallel combination in *-hp-* 476A.

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. They may or may not be capsulated.

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 or more, 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. 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 transmission system used and to the power meter. *-hp-* bolometer mounts are available for coaxial and waveguide systems with a low SWR through their operating range. Barretters are usually operated at 200 ohms, while thermistors usually operate at 100 or 200 ohm levels. Unique series-parallel combinations of the bolometer element are used in *-hp-* coaxial mounts. *-hp-* 477B Coaxial Thermistor Mount, for example, uses two thermistor elements which present 200 ohms to a microwave power meter but present 50 ohms to the rf energy. (Figure 1.)

The power measured by a bolometer mount also depends upon the relationship between the load and the source impedance. In order 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 stub-line stretcher, an E-H tuner, or a slide-screw tuner. These tuners

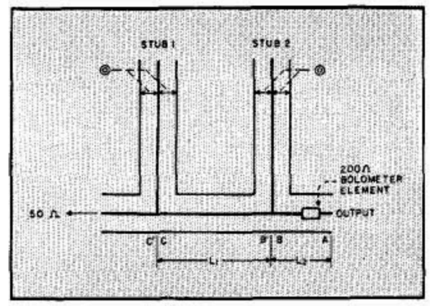


Figure 3. Diagram of Tunable Bolometer Mount (*-hp-* 475B).

transform the magnitude and phase of the source impedance in order to conjugate match it to the load impedance. *-hp-* Model 475B Tunable Bolometer Mount operates on this principle. Errors that result from generator and load mismatch have been discussed under the section of this catalog dealing with Signal Generators. Such errors, however, are generally small and may usually be disregarded.

-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 magni-

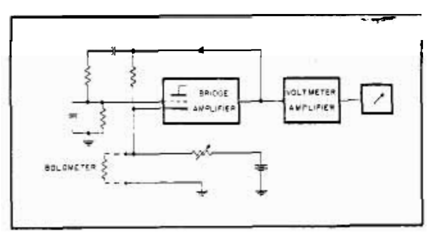


Figure 4. Basic Circuit of Power Meter.

tude of the bridge amplifier output, (Figure 4). 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. Then there being sufficient gain, the circuit oscillates at an amplitude such that the bridge is balanced. When the rf power is applied to the element, the amplitude of oscillation decreases the amount necessary to maintain the element's resistance constant. This 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.

-hp- bolometer mounts have been designed for both coaxial and waveguide systems at frequencies between 10 MC and 26.5 KMC. These mounts are extremely simple to use, have low SWR, and may be used with *-hp-* 430C Power Meter to provide direct reading measurements. *-hp-* bolometer mounts may be classified according to the type of bolometer element employed—thermistor, barretter, or crystal—and whether the mount is untuned (broadbanded) or tunable.

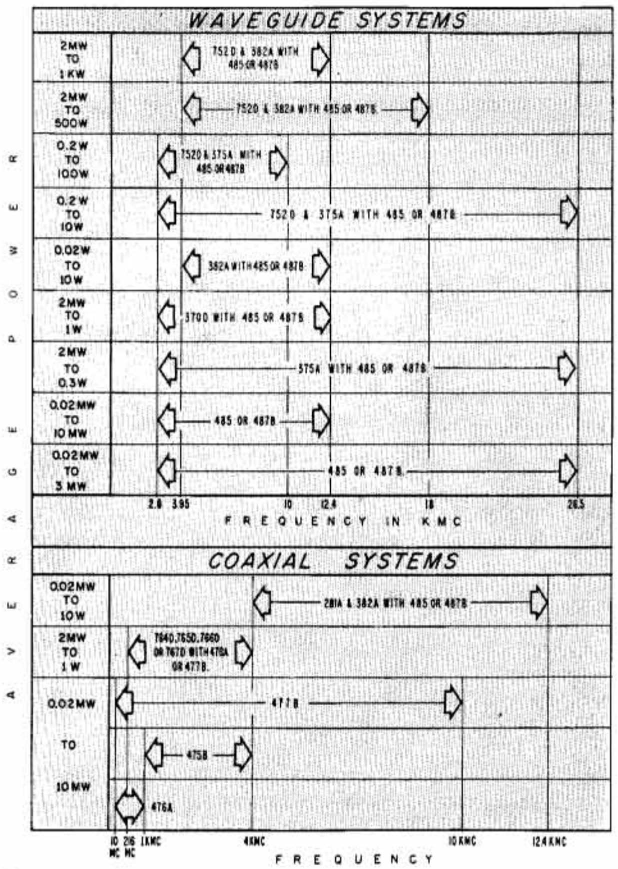


Figure 5. *-hp-* equipment for use with *-hp-* 430C Microwave Power Meter.

New *-hp-* fixed tuned thermistor mounts are exceptionally broad band bolometers. Model 477B Coaxial Thermistor Mount covers the frequency range of 10 MC to 10 KMC, while *-hp-* 487B (waveguide series) are available from 3.95 to 26.5 KMC (use P485C for 12.4 to 18 KMC). No tuning is required and an extremely low SWR is maintained throughout frequency bands.

Model 485B Detector Mounts employ a single tuning control to match the applicable waveguide to a bolometer element (barretter or crystal). In general, their SWR is less than 1.25 over the rated frequency range.

-hp- 476A Universal Bolometer Mount is a fixed tuned bolometer in the frequency range from 10 to 1,000 MC. The bolometer element consists of 1/100 ampere fuses. *-hp-* 475B is a double stub tuner matching 50 ohm coaxial systems into 100 or 200 ohm bolometers. It covers a frequency range of 1,000 to 4,000 MC, for extremely accurate microwave power measurements.

In general, square-wave 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 *-hp-* 430C Power Meter, these limitations are not serious.

When used with barretters or fuses, precautions should be taken if the modulation frequency is below about 200 cps. For sine and square-wave modulated power, the meter reading will tend to increase at such low modulating frequencies. For use with thermistor, precautions should be taken for frequencies less than 100 cps.

Furthermore, care should be taken to avoid modulating frequencies approaching the bridge frequency (10.6 KC) or its sub-multiples. At pulse frequencies near sub-multiples of the 10.6 KC, beats are produced which show on the meter. At modulation frequencies which are exact sub-multiples of the oscillator frequency, the oscillator may lock in with the modulation frequency causing the meter pointer to dip to a low value. In either case, the effect can be avoided by changing the repetition frequency slightly. This solution can be used down to frequencies at least as low as 200 cps.

A tabulation of *-hp-* equipment to be used with Model 430C Power Meter for a specific transmission system, frequency range and power level is given in Figure 5.

Power levels greater than the highest range of the 430C Power Meter can be measured by attenuating the power by pads or by directional couplers to the range of the Model 430C.

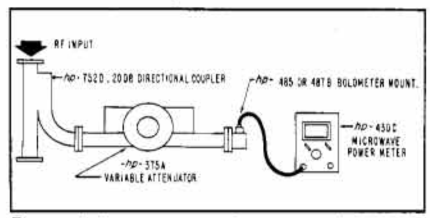


Figure 6. Arrangement for measuring average power up to 100 watts, 2.6 to 10 KMC, or to 10 watts, 2.6 to 26.5 KMC, in waveguide systems.

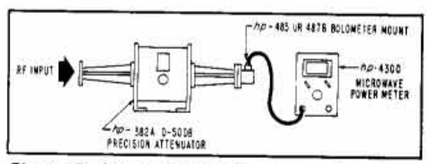


Figure 7. Arrangement for measuring average power up to 10 watts, 3.95 to 12.4 KMC or to 5 watts, 3.95 to 18 KMC, in waveguide systems.

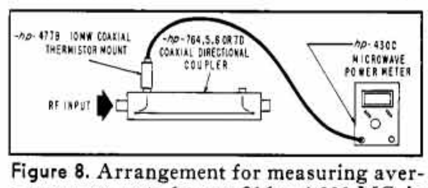


Figure 8. Arrangement for measuring average power up to 1 watt, 216 to 4,000 MC, in coaxial systems.

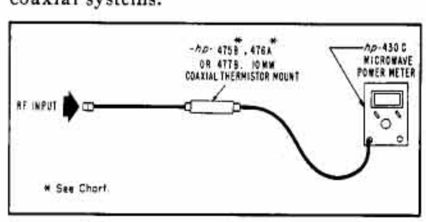


Figure 9. Arrangement for measuring average power up to 10 milliwatts, 10 MC to 10 KMC, in coaxial systems.

430C MICROWAVE POWER METER

Direct, Automatic, Instantaneous Pulsed or CW Power Readings

Advantages:

Reads direct in db or mw; no tedious calculations

Wide power range; nominal range extendable with directional couplers and attenuators

Automatic operation; usable with many different bolometers

Highest quality; unique stability and accuracy

Uses:

Instantaneous microwave power measurements, pulsed or CW

Use on waveguide or coaxial systems

THIS *-hp-* Microwave Power Meter gives you instantaneous rf power readings direct in db 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 CW power, *-hp-* 430C uses either an instrument fuse, barretter or thermistor as a bolometer element. CW or pulsed power may be measured using either a negative or positive temperature coefficient element at 100 or 200 ohm levels. Power is read direct in milliwatts, 0.02 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 KMC. Barretters and thermistors can be used for these measurements at much higher frequencies; up to 12.4 KMC for barretters (in *-hp-* mounts) and up to 26.5 KMC for certain thermistors.

Hewlett-Packard waveguide bolometer mounts are now available covering, collectively, the frequency spectrum from 2.6 KMC to 26.5 KMC. Each bolometer mount covers a complete waveguide band. In addition, three coaxial bolometer mounts cover the frequency spectrum from 10 MC to 10 KMC. 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

-hp- 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

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 in microwave system.

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: *-hp-* 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: $\pm 5\%$ of full scale reading.

Power: 115/230 v $\pm 10\%$, 50/1,000 cps, 75 watts.

Dimensions: Cabinet Mount: 7½″ wide, 11½″ high, 14″ deep. Rack Mount: 19″ wide, 7″ high, 14¼″ deep.

Weight: Net 14 lbs. Shipping 21 lbs. (cabinet mount).

Accessories Available: AC-16K Video Cable Assembly, $5.00; AC-16D Cable Assembly, $2.65.

Price: $250.00.

Full Frequency Coverage, Low SWR, No Tuning Required

This thermistor mount provides full frequency coverage 10 MC to 10 KMC 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 KMC.

SWR: Less than 1.5 (less than 1.3—50 MC to 5 KMC).

Power Range: 0.02 to 10 mw (with *-hp-* 430C Microwave Power Meter).

Connectors: Input—Type N Male; Output—Type BNC.

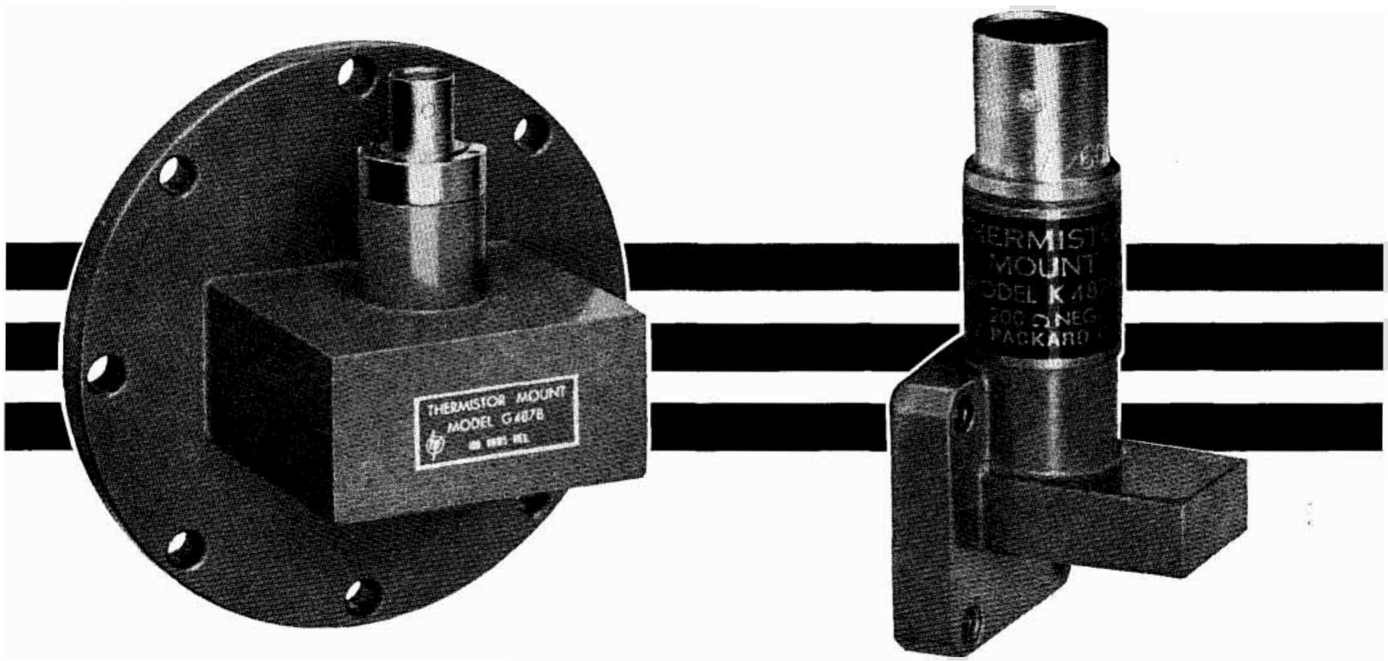
Element: 200 ohm, negative temperature coefficient.

Accessories Available: AC-16K Video Cable Assembly, $5.00.

Price: $75.00.

Data subject to change without notice.

487B WAVEGUIDE THERMISTOR MOUNTS



Low SWR, No Tuning. Covers Full Waveguide Frequency Range

HEWLETT-PACKARD 487B series Waveguide Thermistor Mounts are dependable, accurate and convenient instruments that materially simplify setups and save operator time in microwave power measurement.

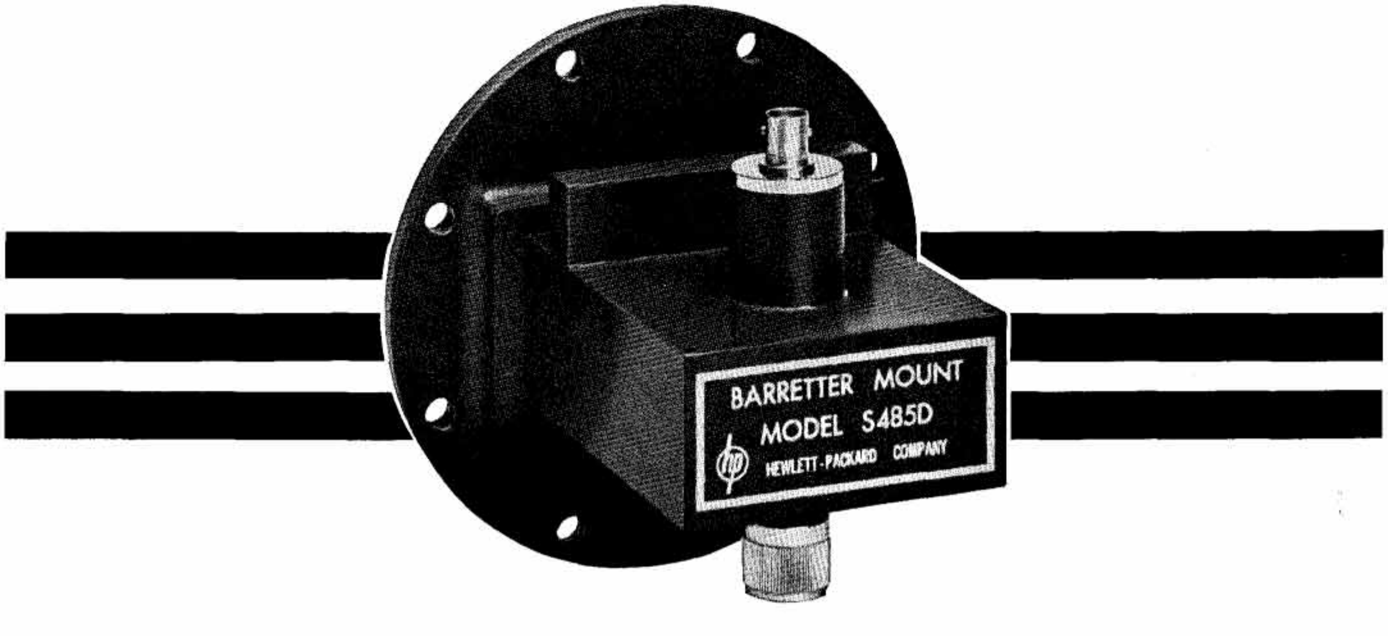
Series 487B instruments collectively cover all frequencies from 3.95 to 12.4 KMC and 18.0 to 26.5 KMC. (For measurements 12.4 to 18.0 KMC, *-hp-* provides Model P485C Detector Mount, opposite page.)

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 487B mounts are equipped with cover flanges and BNC output connectors. They are designed for use with microwave power meters such as *-hp-* 430C (pages 110 and 111), or other instruments responsive to negative temperature coefficient bolometers operating at the 100 ohm level.

Specifications

Model	Maximum Power	Maximum SWR	Frequency Range (KMC)	Waveguide Size (in.)	Price
G487B	10 mw	1.5	3.95 - 5.85	2 x 1	$95.00
J487B	10 mw	1.5	5.3 - 8.2	1½ x ¾	90.00
H487B	10 mw	1.5	7.05 - 10.0	1¼ x ⅝	80.00
X487B	10 mw	1.5	8.2 - 12.4	1 x ½	75.00
K487B	10 mw	2.5	18.0 - 26.5	½ x ¼	85.00



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.

-hp- S485A, 2.6 to 3.95, 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.

-hp- 485B series, for higher waveguide frequencies (3.95-12.4 KMC), are 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. *-hp-* 485B Mounts employ either a 1N21 or 1N23 silicon crystal or a Sperry 821 or Narda N821 barretter. Detector elements can be quickly interchanged.

-hp- P485C (12.4-18.0 KMC) is similar to the 485B series but has a permanently installed 200 ohm thermistor which can operate at levels up to 3 mw when used with *-hp-* 430C.

-hp- 485D Waveguide Barretter Mounts are available in S, G, and J bands covering 2.6 to 8.2 KMC. 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 square-law characteristic is ±0.5 db. No tuning is required. Matched pairs are available for use with the *-hp-* 416 Ratio Meter. *-hp-* AC-60K Barretter Matching Transformer is required to interconnect the 485D and 416A.

All models have BNC output connectors mating with UG88/U plugs.

Specifications

Model	Maximum SWR	Frequency Range KMC	Waveguide (Size In.)	Length (In.)	Price
S485A	1.35	2.60 - 3.95	3 x 1½	4⅝	$125
G485B	1.25	3.95 - 5.85	2 x 1	10⅝	$ 95
J485B	1.25	5.85 - 8.20	1½ x ¾	7¾	$ 90
"	1.35	5.50 - 5.85			
"	1.50	5.30 - 5.50			
H485B	1.25	7.05 - 10.0	1¼ x ⅝	5⅞	$ 85
X485B	1.25	8.20 - 12.4	1 - ½	5⅞	$ 75
P485C	1.25	12.4 - 18.0	.702 x .391	5¼	$110
S485D	1.35	2.60 - 3.95	3 x 1½	4½	$145
G485D	1.5	3.95 - 5.85	2 x 1	3⅛	$140
J485D	1.5*	5.20 - 8.20	1½ x ¾	4¼	$135

All mounts accept either crystal or barretter except *-hp-* S485A, which employs barretter only, and P485C, which employs permanently installed thermistor (supplied with P485C).

*From 5.2 to 7.5 KMC. Increases to approximately 2.0 at 8.2 KMC.

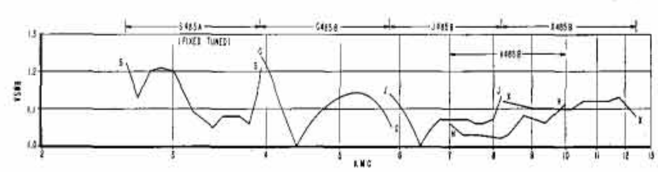
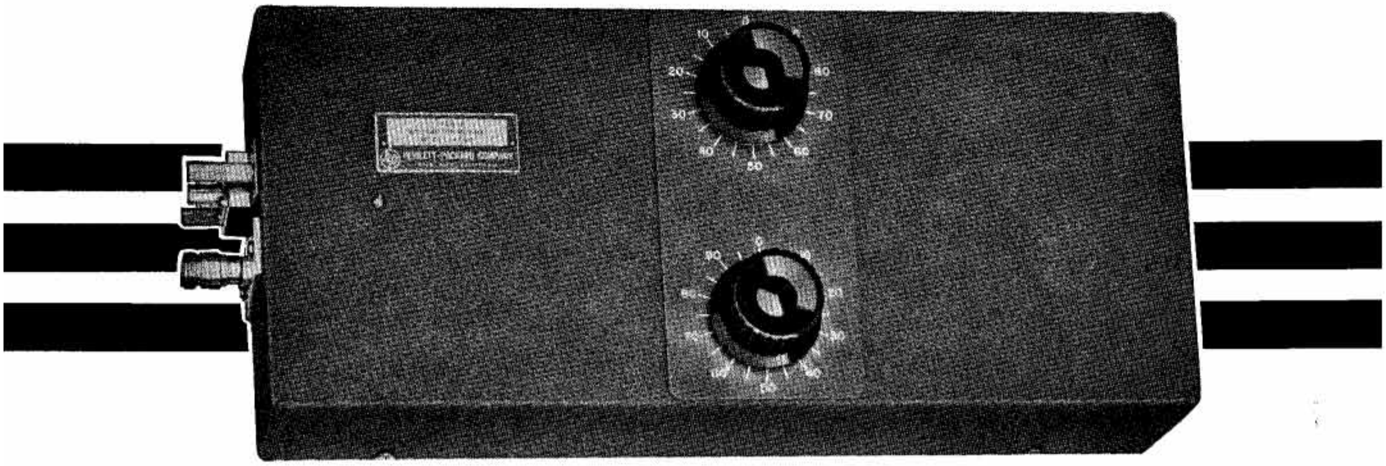


Figure 1. Typical SWR vs. Frequency, *-hp-* 485, when used with barretter.

Data subject to change without notice.

475B TUNABLE BOLOMETER MOUNT



Wide-Band Matching System for Microwave Power Measurements

The -*hp*- 475B Bolometer Mount (above) is convenient for making accurate microwave power measurements. It is a double-stub tuner capable of matching 50-ohm coaxial systems into 100 or 200-ohm bolometers and is continuously tunable, 1,000 to 4,000 MC. The instrument uses a Sperry 821 or Narda N821 barretter, a thermistor or a 1/100-ampere instrument fuse. Rf energy absorbed by the bolometer is measured by means of a bolometer bridge, or by using a self-balancing bridge such as -*hp*- 430B or 430C Microwave Power Meter *(see page 110)*.

Specifications

Frequency: Approx. 1,000 to 4,000 MC. (Varies with SWR, phase of source and value of bolometer load.)

Fittings: Type N female, (UG23/U) for incoming power; BNC Type (UG89/U) for bolometer dc connection. Type N connector fitting supplied to replace BNC connector, so mount may be used as a conventional double-stub transformer.

Power Range: 0.1 mw to 10 mw full scale (with -*hp*- 430B/C).

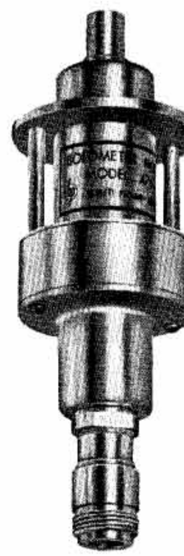
Power Sensitive Element: -*hp*- G-28A instrument fuse, specially selected and installed. May also be used with Sperry 821, Narda N821 Barretter or Western Electric Type D166382 Thermistor.

Dimensions: Cabinet Mount: 7⅜″ wide, 18″ long, 4″ deep.

Accessories Furnished: 2 475B-34V Barretter Adapters; 1 UG21/U Type "N" Male Connector.

Accessories Available: AC-16F rf Cable Assembly, $7.50. AC-16K Video Cable Assembly, $5.00; spare G-28A Fuse, $1.00.

Price: $200.00.



476A UNIVERSAL BOLOMETER MOUNT

No Tuning, No Adjustment. 10 to 1,000 MC

Used with -*hp*- 430B/C 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.

RF Connector: Type N, UG23/U.

Output Connector: Type BNC, UG625/U.

Bolometer Element: Four 1/100 ampere Buss instrument fuses, specially selected and treated. (-*hp*- G-28B.)

Accessories Available: AC-16F rf Cable Assembly, $7.50; AC-16K Video Cable Assembly, $5.00.

Price: $85.00.

Data subject to change without notice.

IMPEDANCE MEASUREMENTS

OF ALL the possible measurements to be made in design and production, probably the most important is impedance. With distributed parameters an impedance varies with the position of measurement. Hence all impedance measurements must be referred to some reference plane. Since impedance is a measure of reflected energy caused by the load, information concerning a load can often 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 can be measured. The usual practice is to amplitude modulate the signal source and to use a crystal or bolometer to detect the probe output. 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. A proper transformation of this information can be entered on a Smith Chart from which the point of measurement can be referred back to the load or point of interest. In this way, one can quickly determine the value of the impedance and the reflection coefficient in magnitude and phase.

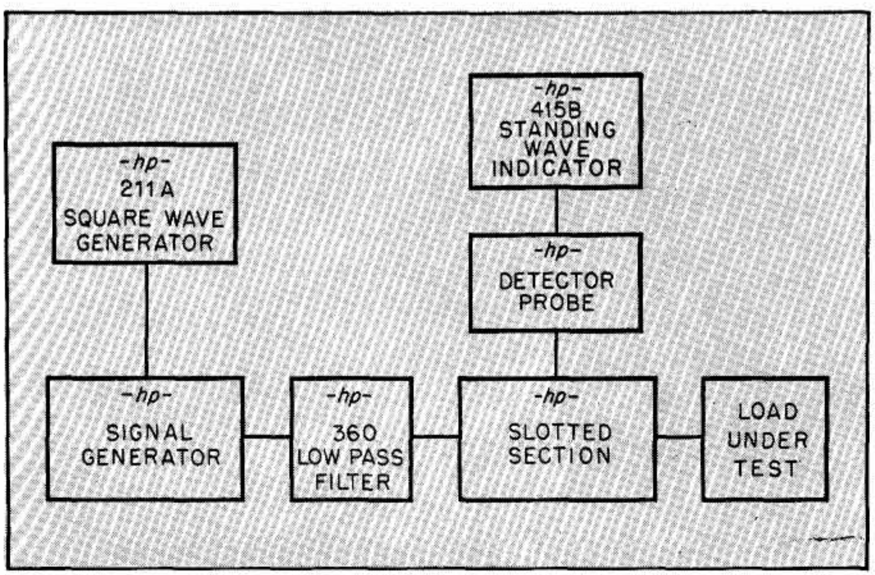


Figure 1. Typical setup for impedance measurements.

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 generator signals.

Harmonics and spurious signals can be minimized by use of low pass filters such as Hewlett-Packard 360 series. Proper modulation techniques are explained in the signal generator section of this catalog (pages 76–79). 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 detector 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 essentially 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 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.

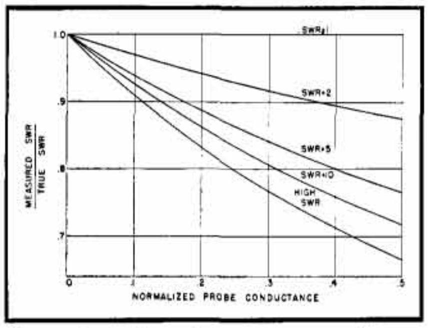


Figure 2. Effect of probe penetration on measured SWR.

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 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 the 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 to 1 or less). In this case, a moderately good match between the generator and load is desirable. In general, the match of an *-hp-* signal generator is sufficient for this purpose, providing the cables and connectors do not introduce spurious reflection. However, when klystrons are used directly to feed a waveguide network, the match is poor. Therefore, the klystron should always be followed by a pad or an isolator.

Various methods of measuring SWR's have specific advantages for different SWR ranges. Straight-forward measurement of SWR by conventional methods is generally preferred when measuring SWR's in the range of 10 to 1 or less. But when the SWR is high, coupling to the probe must be high in order to obtain readings at the minimum. This may result in deformation of pattern when the maximum is measured. There is also a possibility of error due to a change in detector characteristics because of rf level changes.

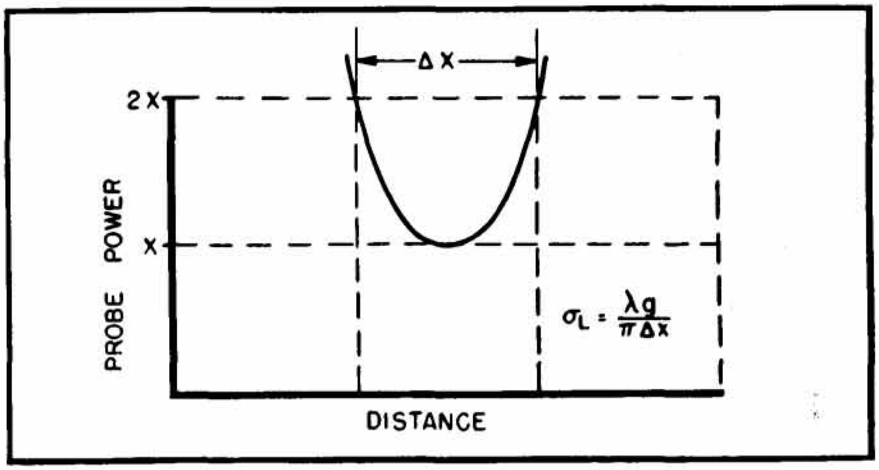


Figure 3. Twice minimum power method for measuring SWR.

To measure SWR's greater than 10 to 1 within 1% accuracy, the twice-minimum-power method is recommended. Here, it is only necessary to establish the electrical distance between the points that are twice the amplitude of the minimum. The SWR can be obtained by substituting this distance into the following expression as shown in Figure 3:

$$\sigma_L = \frac{\lambda_g}{\pi \Delta x}$$

σ_L = Voltage Standing Wave Ratio of Load.

λ_g = Guide wavelength

Δx = Distance between "twice-minimum-power" points

The value referred to in this method is the twice-power value. Therefore,

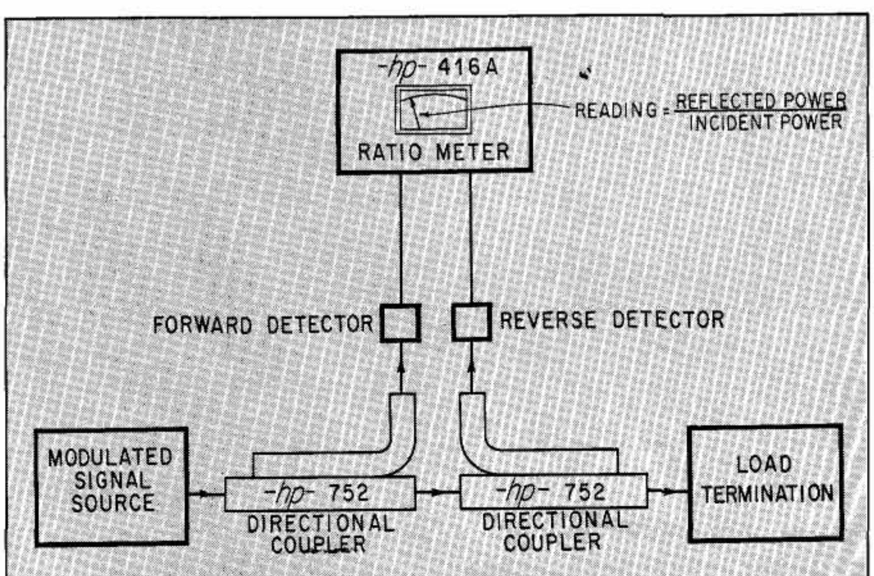


Figure 4. Typical Reflectometer setup.

if the linear voltage indicator is used with a square-law detector, the voltage indication of the twice-power point will be twice that of the minimum. If a standing wave indicator (calibrated for use on a square-law detector such as the *-hp-* 415B or a linear receiver) is used, the voltage ratio of the two readings will be 1.4 to 1 or 3 db.

Reflectometer Measurements

An additional method of making impedance measurements conveniently is by use of a reflectometer. The reflectometer will indicate magnitude of the impedance but will not provide phase angle information as does the slotted line. The reflectometer is most useful for fast, swept frequency, production measurements.

A typical reflectometer setup is shown in Figure 4. This arrangement determines the magnitude of the reflection coefficient by use of directional couplers which sample the input wave and the reflected wave. The couplers feed to detectors and then to a ratio meter (such as *-hp-* 416A, page 118) where a direct comparison is made. The resultant ratio of the two sampled powers is read directly on the ratio meter. For best results in reflectometer operation the input power should be kept to a low level by means of input attenuators so that the power at the forward detector is in the order of -20 dbm. At the reverse detector it should be in the order of -10 dbm at the calibration point. This will more nearly insure square-law operation of the crystal.

-hp- Reflectometers are available to measure the magnitude of reflection coefficients rapidly and with good accuracy in the popular waveguide frequencies. This method is most practical for measuring reflection coefficients up to approximately 0.5 (SWR of 3.0). When the reflectometer is used with swept-frequencies and is calibrated with a short, accuracies of approximately ± 0.02 can 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 ± 0.04 (SWR of 1.08) can be obtained. The potential accuracy of the reflectometer is greatest at low SWR's when using a fixed frequency, a sliding short for calibration, a slide screw tuner, and a moving load. Under ideal conditions errors of less than ± 0.005 in reflection coefficient equal to residual SWR of 1.01 are attainable.

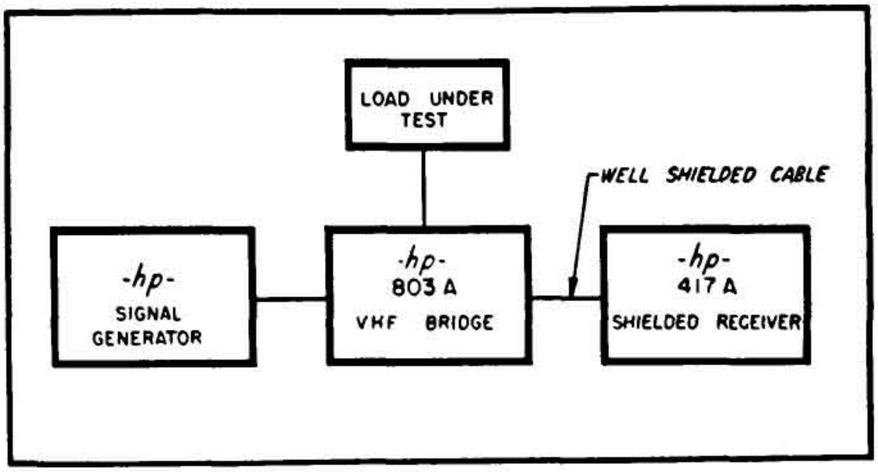


Figure 5. Impedance measurements for frequencies below 500 MC.

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, *-hp-* Model 803A vhf Bridge is ideal. (See Figure 5.)

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 *-hp-* 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 simple form of which is shown in Figure 6.

This structure 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.

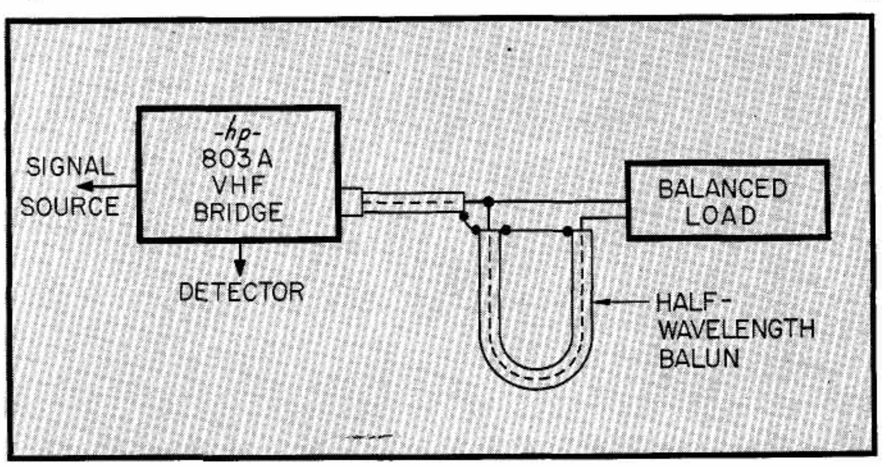


Figure 6. Measurement setup using balun with balanced load.

416A RATIO METER

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

Ease and Accuracy for Reflection Coefficient Measurements

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-* 670 and 686), such setups make possible direct and continuous oscilloscope presentation of reflection coefficient over a wide frequency range.

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.

Reflectometer Setup

Arrangement of a typical reflectometer setup with *-hp-* 416A Ratio Meter is shown in Figure 1. 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 *-hp-* 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.

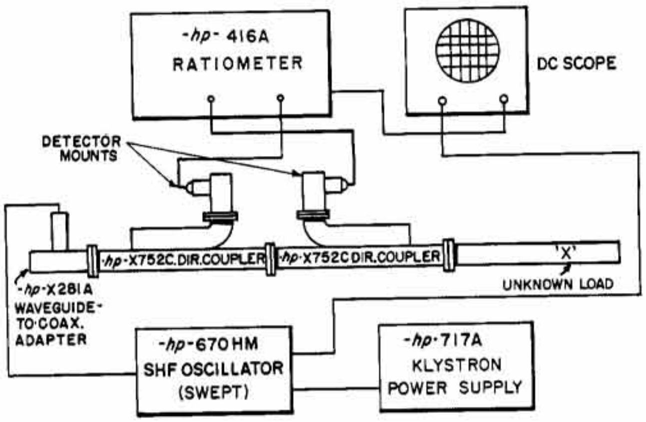


Figure 1. Typical Reflectometer Setup. Note use of two directional couplers back-to-back, with individual detectors, for simultaneous evaluation of incident and reflected powers.

Simple Operation

The *-hp-* 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 *-hp-* 916A (see page 134) 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 *-hp-* 870A (see page 131) to compensate for the small directivity deficiency of *-hp-* 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: 0.3 μv to 100 mv rms. (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.

Connectors: Type BNC.

Power: 115/230 v ±10%, 50/60 cps, 90 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 14½" deep.

Weight: Net 36 lbs. Shipping 58 lbs. (cabinet mount).

Accessories Available: AC-16K Video Cable Assembly, $5.00. AC-60K Barretter Matching Transformer, $45.00.

Price: $450.00.

-hp- AC-60K Matching Transformer

This instrument consists of two step-up transformers and appropriate bias circuitry for impedance matching between *-hp-* 485 series Barretter Mounts and the *-hp-* 416A Ratio Meter. Designed specifically for reflectometer application, *-hp-* AC-60K uses 200 ohm barretters such as Sperry 821 or Narda N821B as detector elements. 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. $45.00.

Data subject to change without notice.

803A VHF BRIDGE

Reads Any Impedance Directly Between 50 and 500 MC

Advantages:

Direct reading,
2 to 2,000 ohm impedances
$-90°$ to $+90°$ phase angle

Wide range, 50 to 500 megacycles

Simple, easy operation

Faster than slotted lines

Compact size

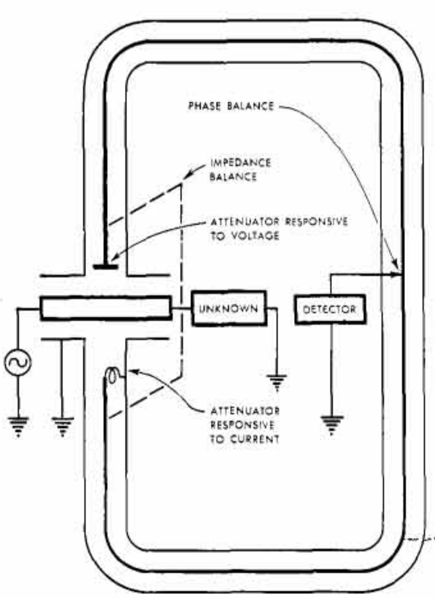
Standard Type N connector

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 is the first commercial equipment built to provide 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 $-9°$ to $+9°$.

External rf Generator: Requires an AM signal source of at least 1 mw. High signal level is desirable. (*-hp-* Model 608C vhf Signal Generator 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.)

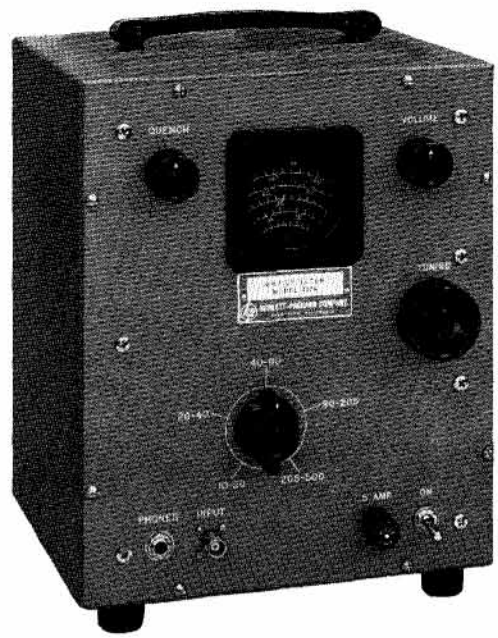
Dimensions: Cabinet Mount: 14¼″ wide, 15¼″ high, 9″ deep.

Weight: Net 25 lbs. Shipping 40 lbs.

Accessories Furnished: 1 803A-16D Cable Assembly; 1 803A-16E Cable Assembly; 1 803A-76G Shorting Plug.

Price: $495.00.

-hp- 417A VHF DETECTOR



This *-hp-* instrument is a super-regenerative (AM) receiver covering all frequencies between 10 and 500 MC in 5 bands. It is designed for use with the *-hp-* 803A Bridge. It offers 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 light weight 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 v ± 10 v, 50/60 cps, 30 watts.

Dimensions: Cabinet Mount: 9¼″ wide, 12½″ high, 9″ deep.

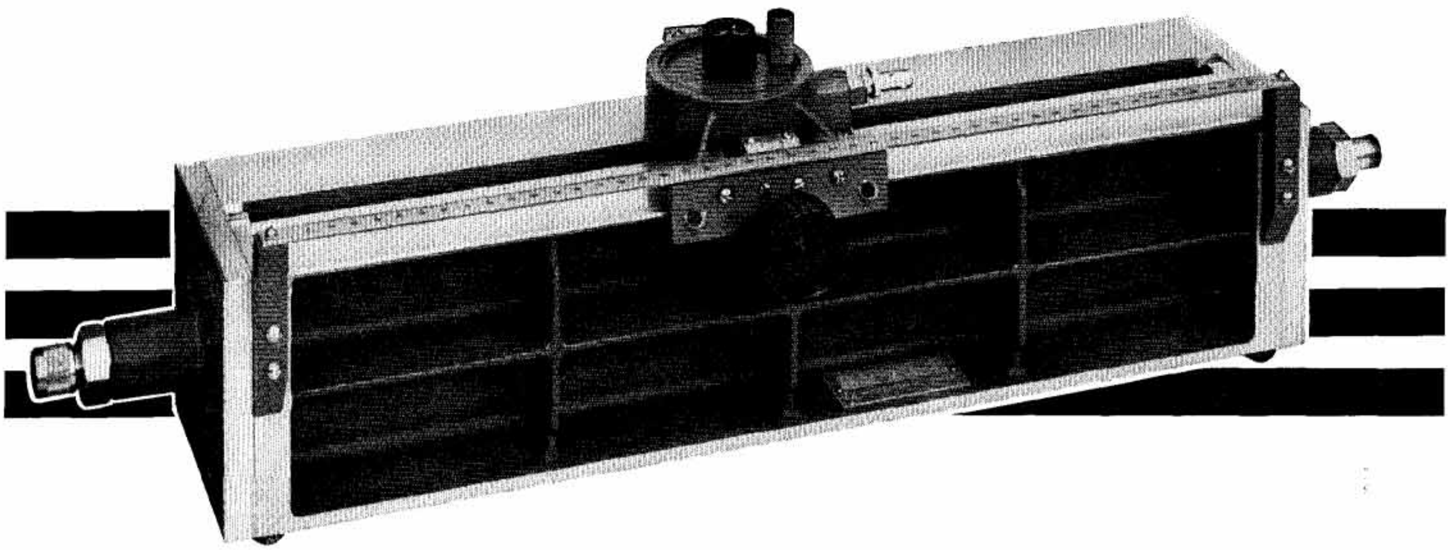
Weight: Net 18 lbs. Shipping 31 lbs.

Accessories Available: AC-16B Cable Assembly, $4.25; AC-16K Cable Assembly, $5.00; 803A-16E Input Cable Assembly, $8.75.

Price: $250.00.

Data subject to change without notice.

805A/B SLOTTED LINES



Specifications

-hp- 805A

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.

Dimensions: Carrying case 29" wide, 9½" high, 9½" deep.

Weight: Net 33 lbs. Shipping 75 lbs.

Accessories Furnished: 1 Steel and dural carrying case; 1 803A-76G shorting plug; 1 8A-76H shorting jack; 1 8A-76E crystal adapter; 1 1N21B crystal detector.

Accessories Available: AC-16F Cable Assembly, $7.50; 475B-34V Barretter Adapter, $1.00; AC-16K rf Cable Assembly, $5.00.

Price: $475.00.

-hp- 805B

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.

Price: $475.00.

(Other specifications same as *-hp-* 805A)

Data subject to change without notice.

"Parallel-Plane" Design Gives Utmost Electrical Stability

THE *-hp-* 805 Slotted Line incorporates a radically different structural design with precision manufacture, resulting in an instrument of unvarying accuracy for the measurement of microwave circuits.

Greater Inherent Accuracy

This instrument employs two parallel planes and a rigid central conductor in place of the conventional coaxial arrangement. This configuration has several important advantages over the standard slotted section.

For example, it permits the parallel planes to be made mechanically rigid; thus insuring greater accuracy and providing 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 therefore carriage inaccuracies are minimized. Leakage is also low because the effective slot opening is small. This design permits SWR of the basic section to be held to less than 1.02.

The probe circuit is tunable over the instrument's entire frequency range, 500 to 4,000 megacycles. Depth of probe penetration can be quickly and easily adjusted.

Two versions of the *-hp-* 805 are offered, the 805A being provided with Type N connectors and the 805B with connectors suitable for mating to RG 44/U stub supported coaxial cable.

Reads Direct in SWR and db

THE *-hp-* 415B is designed for use with *-hp-* 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 8.4 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 frequency from 315 to 3,000 cps. 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.

Specifications

Frequency: 1,000 cps ±2%.

Sensitivity: 0.1 μv at a 200 ohm level for full scale deflection.

Noise Level: Less than 0.03 μf 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.

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 approx. 30 db.

Input: "Bolo" (200 ohms). Bias provided for 8.4 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.

Input Connector: BNC.

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

Dimensions: Cabinet Mount: 7½" wide, 11½" high, 12¼" deep. Rack Mount: 19" wide, 7" high, 11" deep.

Weight: Net 19 lbs. Shipping 21 lbs. (cabinet mount).

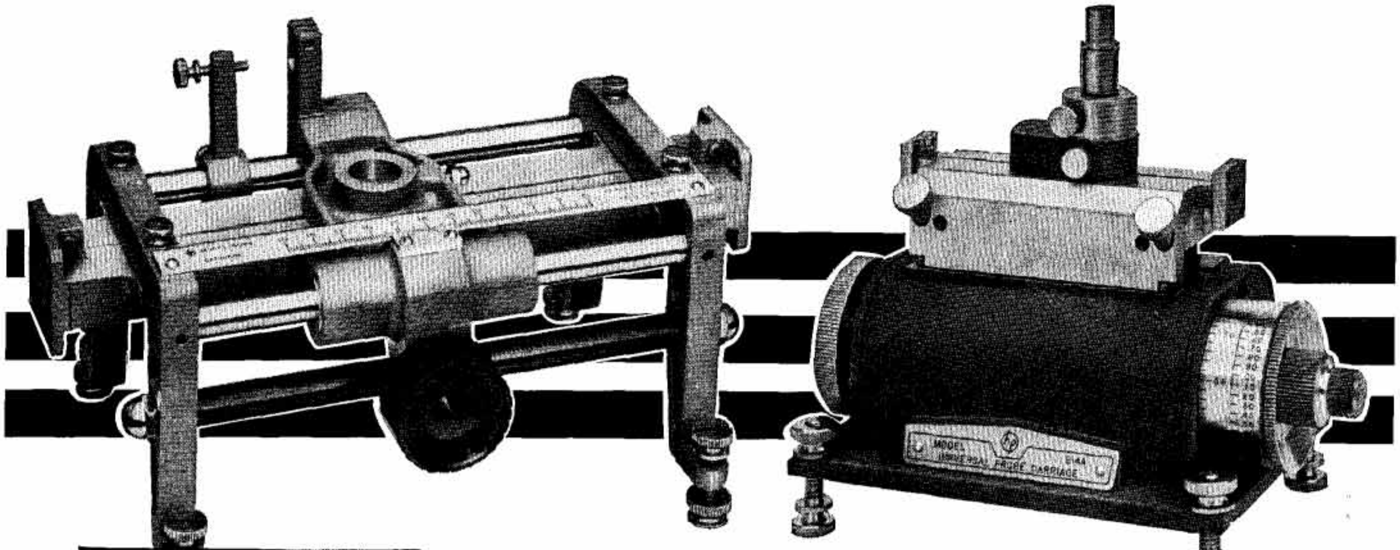
Accessories Furnished: 1 41A-16E Cable Assembly.

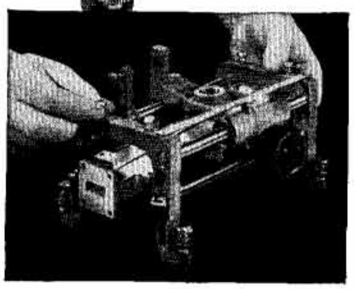
Accessories Available: 415B-42B Plug In Filter (315-3,000 cps), $27.50. AC-16K Video Cable Assembly, $5.00. AC-16D Cable Assembly, $2.65.

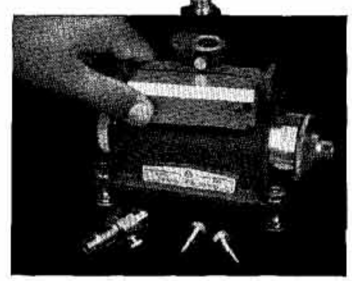
Price: $200.00.

Data subject to change without notice.

809B/814A UNIVERSAL PROBE CARRIAGES







Advantages:

Universal mounting for different slotted sections

Slotted sections interchange in 30 seconds

Broad usefulness, 3 to 40 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

Per cent of transmitted or reflected power

Low Cost, Precision Tools for Microwave Readings to 40 KMC

Models 809B and 814A Universal Probe Carriages are precision-built mechanical assemblies designed to operate, respectively, with *-hp-* 810B series and 815 series slotted sections. The combination of 809B Carriage and 810B series sections covers 3.95 to 18.0 KMC. Model 814A Carriage and 815 series sections cover 12.4 to 40.0 KMC.

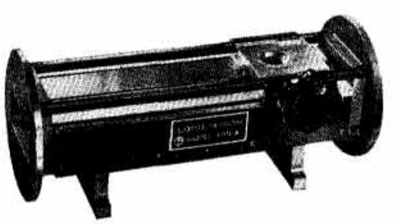
These Universal Probe Carriages greatly simplify measurements involving a number of waveguide bands, and eliminate the cost of a special probe for each band. There is an appreciable saving on engineering time since waveguide sections can be interchanged in seconds. Manufacture of both carriages is of highest quality throughout, to assure maintenance-free service, positive mechanical positioning of interchangeable waveguides, and precise installation of the mating *-hp-* probes (see page 126). *-hp-* 809B has a vernier scale permitting readings to 0.1 mm and provision for mounting a dial gauge for greater accuracy. *-hp-* 814A has a cylindrical dial which may be read directly to 0.1 mm and interpolated to 0.01 mm.

-*hp*- 810B Waveguide Slotted Sections (for 809B) are accurately machined sections of waveguide in which a small

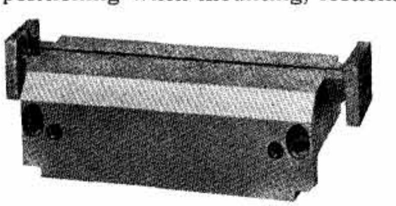
longitudinal slot is cut. They fit the 809B Carriage in a precisely indexed position. A traveling probe mounted on the 809B samples the waveguide's electric field along the slot, and permits precise plotting of variations throughout the length of probe travel. Slotted sections are accurately machined 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 KMC. 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 KMC) S band frequency range only. It uses *-hp-* Broadband Probes and Detector Mounts shown on page 126.



***-hp-* 815A Waveguide Slotted Sections** (for 814A). Available in P, K, and R bands (12.4 to 40.0 KMC), these waveguide slotted sections are carefully machined for time-saving accuracy in measurement. To insure positive positioning when mounting, sections seat on two eccentric rods. These rods are factory-adjusted so that the longitudinal plane of the waveguide is always parallel to probe travel.



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 page 126.)

Probe Travel: 10 centimeters.

Calibration: Metric. Vernier permits readings to 0.1 mm. Provision for dial gauge installation.

Leveling Scews: Knurled thumb screws provided on all 4 carriage legs.

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: $160.00.

-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 KMC.

Waveguide Size: 3″ x 1½″.

Length: 12¾″.

Price: $450.00.

-hp- 806B Coaxial Slotted Section

Carriage: Fits *-hp-* 809B Universal Probe Carriage.

Frequency Range: 3 to 12 KMC.

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 KMC.
Approximately 1.06, 8 to 10 KMC.
Approximately 1.1, 10 to 12 KMC.

Pickup Error: Probe pickup variation along line is less than 0.1 db except at extreme ends where variation is less than 0.2 db.

Price: $200.00.

-hp- 814A Universal Probe Carriage

Carriage: Mounts all *-hp-* 815A Waveguide Slotted Sections.

Probe Required: *-hp-* 446A Untuned Probe (see page 126).

Probe Travel: 4 centimeters.

Calibration: Metric. Vernier dial reads direct to 0.1 mm and interpolates to 0.01 mm.

Accuracy: SWR of 1.02 can be read. Slope error can be eliminated by adjustment.

Leveling Screws: Knurled thumb screws provided on all 4 carriage legs.

Dimensions: 7″ long, 4¼″ wide, 5″ high.

Price: $225.00.

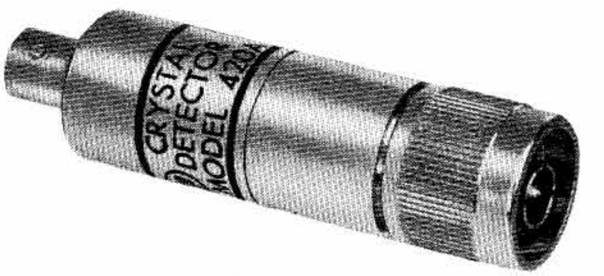
-hp- 810B/815A Slotted Sections

Model	Frequency Range KMC	Waveguide Size (in.)	Overall Length (in.)	Price
G810B	3.95 - 5.85	2 x 1	10¼	$110.00
J810B	5.85 - 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
P810B	12.4 - 18.0	.702 x .391	10¼	110.00
P815A	12.4 - 18.0	.622 x .311	5¼	200.00
K815A	18.0 - 26.5	.420 x .170	4½	200.00
R815A	26.5 - 40.0	.280 x .140	4½	200.00

Discontinuity due to slot results in SWR of less than 1.01.

Data subject to change without notice.

DETECTOR MOUNTS, PROBES



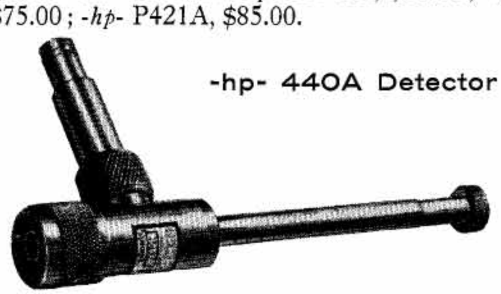
-hp- 420A/B Crystal Detector

-hp- 420A, operating from 10 MC to 12.5 KMC, couples a Type N coaxial line to a modified 1N26 silicon crystal for detection of rf signals. Sensitivity is approximately 0.1 v/mw, and frequency response is ±3 db full range. Maximum SWR is 3, output polarity is negative. Uses Type N input and BNC output connector. Diameter ¾″, length 3″, shipping weight 1 lb. *-hp-* 420B Coaxial Reflector Crystal, same as 420A, is available in matched pairs whose frequency response difference is within ±1 db from 1 to 4 KMC. *-hp-* 420A, $50.00; *-hp-* 420B, $75.00.

-hp- 421A Crystal Detectors

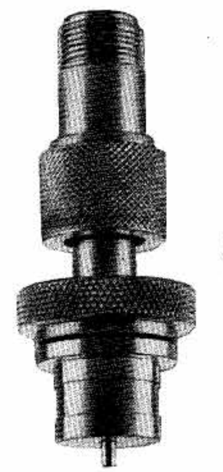
Now available for H, X and P bands, Model 421A is an accurate, square-law detector specifically designed for reflectometer measurements. *-hp-* H421A covers 7 to 10 KMC; *-hp-* X421A covers 8.2 to 12.4 KMC; *-hp-* P421A covers 12.4 to 18.0 KMC. Reflection coefficients as low as 0.01 may be measured with sensitivity of 0.1 volt per milliwatt, maximum SWR of 1.5, and frequency response of ±2 db. The square-law characteristic is within ±1 db from 0 to −40 dbm when operated into a selected value video load resistor. These resistors are internal and factory installed. Detectors include a modified 1N26 crystal and video resistor. Output is through a BNC connector. 421A detectors are also available in matched pairs whose individual specifications are the same as the single unit but whose frequency response difference is not greater than ±1 db. *-hp-* H421A, $85.00; *-hp-* X421A, $75.00; *-hp-* P421A, $85.00.

-hp- 440A Detector Mount



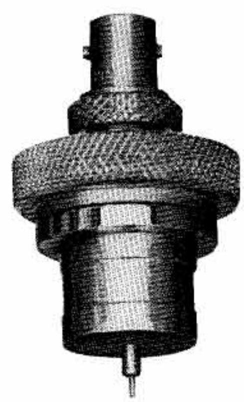
A simple, easily used instrument for detecting rf energy in coaxial or waveguide systems. In coaxial use, covers all frequencies 2.4 to 12.4 KMC. Uses either 1N21 or 1N23 silicon crystal, 1/100 amp. instrument fuse or Sperry 821 barretter. Simple single stub tuning. Type N rf input connector, BNC output jack. With *-hp-* 442B (below) becomes sensitive, easily tuned detector for slotted waveguide sections. (Detector element not furnished as a part of instrument.) $85.00.

-hp- 442B Broadband Probe



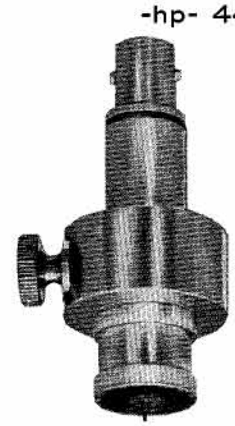
For use with waveguide slotted sections and *-hp-* 809 Universal Probe Carriage (or others having a ¾″ diameter mounting hole). Probe penetration depth into a waveguide is variable and is easily fixed in position by a locking ring. Sampled rf appears at Type N jack, permitting direct connection to a receiver, spectrum analyzer, etc. With *-hp-* 440A (left) the 442B forms a sensitive detector for slotted waveguides sections. Probe is shielded and provided with poly-iron inserts to prevent spurious resonances. $35.00.

-hp- 444A Untuned Probe



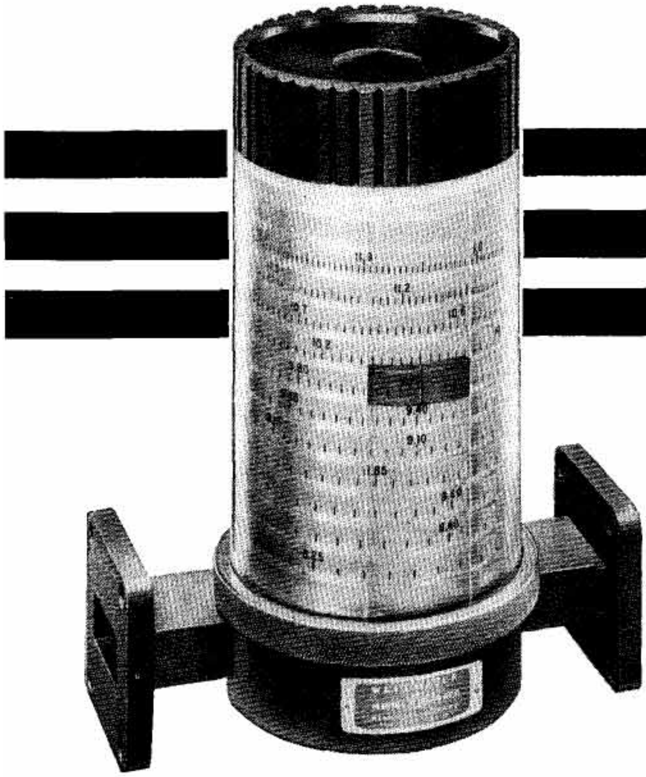
A modified crystal (1N76 or 1N26) plus a small antenna in a convenient housing permitting probe penetration to be varied quickly and easily. Probe position is fixed by a locking ring. Requires no tuning; and sensitivity surpasses most elaborate single and double-tuned probes (particularly between 8 and 18 KMC). Poly-iron inserts damp spurious resonances. Frequency coverage 2.4 to 18 KMC; BNC output jack. For ¾″ mounting hole as on *-hp-* 809B Carriage (page 124). $35.00.

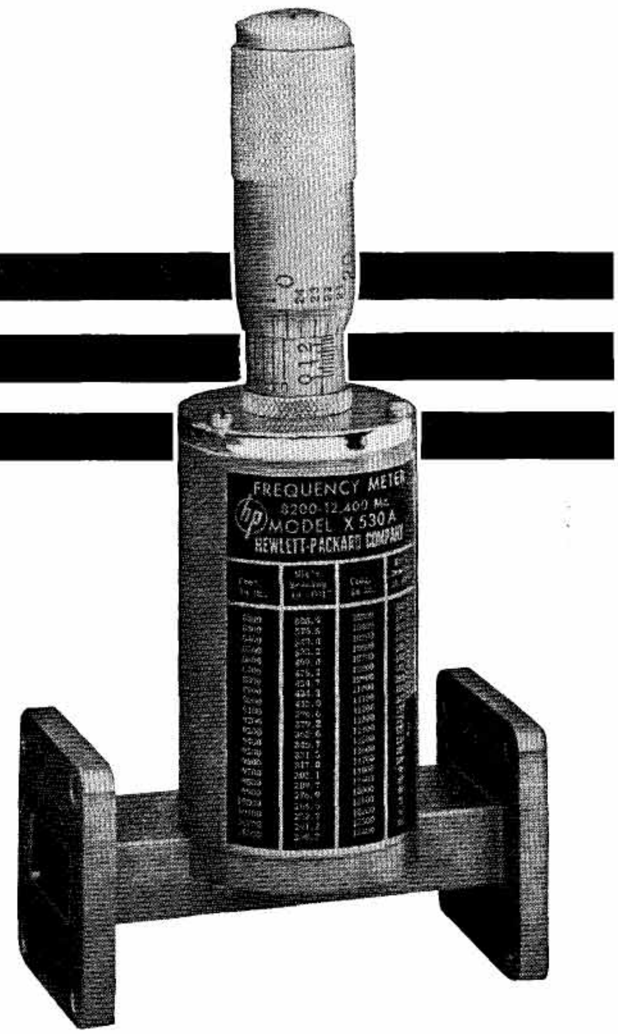
-hp- 446A Untuned Probe



New Model 446A is a broadband detector and probe designed for use with *-hp-* 814A Universal Probe Carriage and *-hp-* 815A Waveguide Slotted Sections. (See pages 124, 125.) It covers P, K and R band frequencies, 12.4 to 40.0 KMC, and consists of a modified 1N53 silicon diode detector in a carefully designed housing. No tuning is required; probe penetration is quickly and easily varied. Output is through a standard BNC connector. $145.

Data subject to change without notice.





Precision General-Purpose Meters for Lab or Production Use

NEW *-hp-* X532A Frequency Meter is a wide band, direct reading X band instrument offering quality construction, convenience and outstanding value at lowest cost. Frequency is read directly in KMC with accuracy of 0.08%. No interpolation or charts are required.

The instrument comprises a special waveguide 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 1.5 db dip in output indicates resonance. Tuning is by a precision lead screw, spring-loaded to eliminate backlash. Effective length of the spiral scale is approximately 77″ with calibration in 5 MC increments. Resettability is 0.01% (1 MC at 10 KMC).

-hp- 530A Microwave Frequency Meters are inexpensive general purpose instruments giving high accuracy over a complete waveguide band. Available for frequencies from 5.20 to 18.0 KMC, the 530 series offers accuracy of better than 0.1%, constant reaction at resonance over the entire waveguide range, and freedom from spurious modes or resonances.

Model 530A is tuned by a micrometer unit, and readings are quickly converted to frequency by a calibration chart on the instrument.

Specifications

Model	Accuracy	Frequency Range KMC	Waveguide Size (in.)	Length (in.)	Price
J530A	0.1%	5.85 - 8.20	1½ x ¾	4	$120.00
J530B	0.1%	5.20 - 7.05	1½ x ¾	4	150.00
H530A	0.1%	7.05 - 10.0	1¼ x ⅝	3½	120.00
X530A	0.1%	8.20 - 12.4	1 x ½	3	120.00
P530A	0.1%	12.4 - 18.0	.702 x .391	3	150.00
X532A	0.08%	8.20 - 12.4	1 x ½	4½	150.00

Note: -hp- 532A series Meters for other waveguide bands will be announced soon.

Data subject to change without notice.

Easy-to-Use, Precision Couplers Simplify Waveguide Measurements

DIRECTIONAL couplers such as *-hp-* 752 and *-hp-* 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."

-hp- 752 Multi-Hole Couplers

In this *-hp-* 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 ¼ 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.

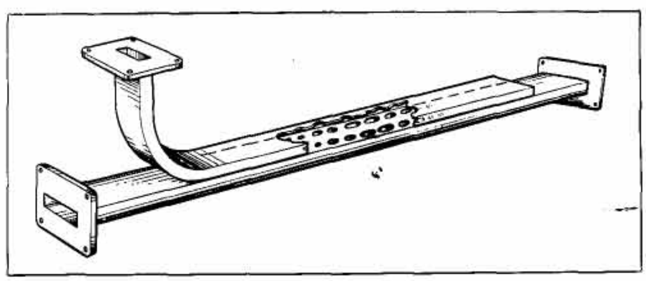


Figure 1. Construction, *-hp-* 752 Directional Couplers.

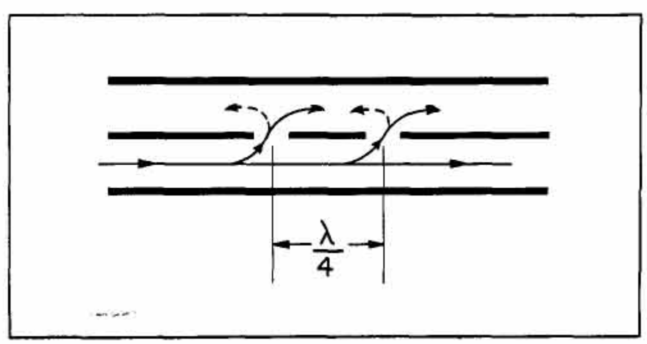


Figure 2. Cross-section, two-aperture coupler.

The auxiliary guide of Model 752 is terminated in a low reflection load at one end and in a plain 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.

-hp- 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) and frequency sensitivity of coupling is ± 0.5 db over the waveguide frequency range.

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 115-117 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 proportional to this frequency is applied to the horizontal plates of the oscilloscope. The resulting trace is a plot of reflection vs. frequency.

-hp- 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 *-hp-* 750 Cross-Guide Coupler.

This unit consists of two waveguide sections joined at right angles across their broad faces. It is available in coupling factors of 20 or 30 db, 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.

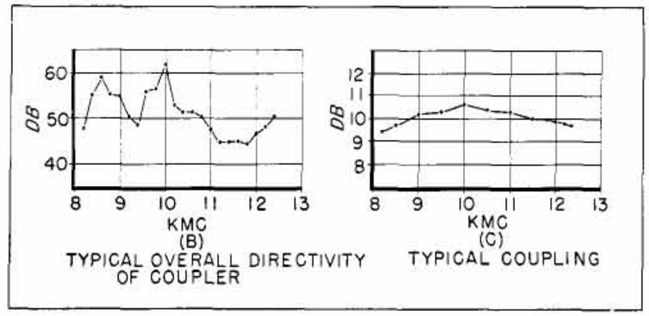


Figure 3. Characteristics, *-hp-* 752 Coupler - 10 db model.

Specifications

-hp- 752 Multi-Hole Couplers

Model	Coupling (db)	Frequency Range (KMC)	Wave-guide Size (in.)	Approx. Length (in.)	Shipping Weight (lbs.)	Price
S752A	3	2.6 - 3.95	3 x 1½	50¼	75	$375.00
S752C	10	2.6 - 3.95	3 x 1½	48	75	375.00
S752D	20	2.6 - 3.95	3 x 1½	48	75	375.00
G752A	3	3.95 - 5.85	2 x 1	34⅝	23	250.00
G752C	10	3.95 - 5.85	2 x 1	33	23	290.00
G752D	20	3.95 - 5.85	2 x 1	33	23	250.00
J752A	3	*5.85 - 8.2	1½ x ¾	26½	18	140.00
J752C	10	*5.85 - 8.2	1½ x ¾	25 9/16	18	140.00
J752D	20	*5.85 - 8.2	1½ x ¾	25 9/16	18	140.00
H752A	3	7.05 - 10.0	1¼ x ⅝	18⅝	10	120.00
H752C	10	7.05 - 10.0	1¼ x ⅝	17½	10	120.00
H752D	20	7.05 - 10.0	1¼ x ⅝	17½	10	120.00
X752A	3	8.2 - 12.4	1 x ½	16 11/16	8	75.00
X752C	10	8.2 - 12.4	1 x ½	15 11/16	8	75.00
X752D	20	8.2 - 12.4	1 x ½	15 11/16	8	75.00
P752A	3	12.4 - 18.0	.702 x .391	13¾	4	100.00
P752C	10	12.4 - 18.0	.702 x .391	12¼	4	100.00
P752D	20	12.4 - 18.0	.702 x .391	12¼	4	100.00
K752A	3	18.0 - 26.5	.702 x .391	10	2	100.00
K752C	10	18.0 - 26.5	.500 x .250	9½	2	100.00
K752D	20	18.0 - 26.5	.500 x .250	9½	2	100.00
R752A	3	26.5 - 40.0	.360 x .220	9⅝	2	120.00
R752C	10	26.5 - 40.0	.360 x .220	9⅛	2	120.00
R752D	20	26.5 - 40.0	.360 x .220	9⅛	2	120.00

Directivity: Better than 40 db over entire frequency range.

Coupling Accuracy: Mean coupling level is within 0.4 db (0.7 db for K and R) of specified value.

Coupling Variation: Not more than ± 0.5 db over frequency range.

Primary Guide VSWR: Less than 1.05 with "perfect" termination.

*J752 couplers operate to 5.2 KMC with reduced performance specifications. Directivity better than 40 db —5.85 to 5.5 KMC; better than 36 db —5.5 to 5.2 KMC. Coupling variation not more than —1.2 db at 5.5 KMC; —2 db at 5.2 KMC.

-hp- 750 Cross-Guide Couplers

Model	Coupling (db)	Frequency Range 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	$130.00
S750E	30	2.6 - 3.95	3 x 1½	9 x 9	18	130.00
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 x 6	7	120.00
J750D	20	*5.85 - 8.20	1½ x ¾	5 x 5	4	70.00
J750E	30	*5.85 - 8.20	1½ x ¾	5 x 5	4	70.00
H750D	20	7.05 - 10.0	1¼ x ⅝	4 x 4	3	60.00
H750E	30	7.05 - 10.0	1¼ x ⅝	4 x 4	3	60.00
X750D	20	8.2 - 12.4	1 x ½	3 x 3	2	50.00
X750E	30	8.2 - 12.4	1 x ½	3 x 3	2	50.00

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 KMC. Directivity same as above. Coupling within +3 ~~db~~ of nominal value.

Data subject to change without notice.

764D/767D DUAL DIRECTIONAL COUPLERS

Permit Reflectometer Measurements In Coaxial Systems

REFLECTOMETER systems save much engineering time in the development and manufacture of broad band apparatus; now the new *-hp-* dual directional couplers make reflectometer measurements practical in VHF-UHF coaxial systems.

The new couplers have a very flat frequency response and high directivity so that reflectometer accuracy is adequate for system checks and alignment. Their high power handling capacity and low insertion loss means they may be installed permanently in coaxial lines for power monitoring. They are dual devices; hence a power meter or detector may be connected to either "incident" or "reflected" secondary terminals to simplify maximizing forward power. Collectively, the four couplers cover all frequencies from 216 to 4,000 MC.

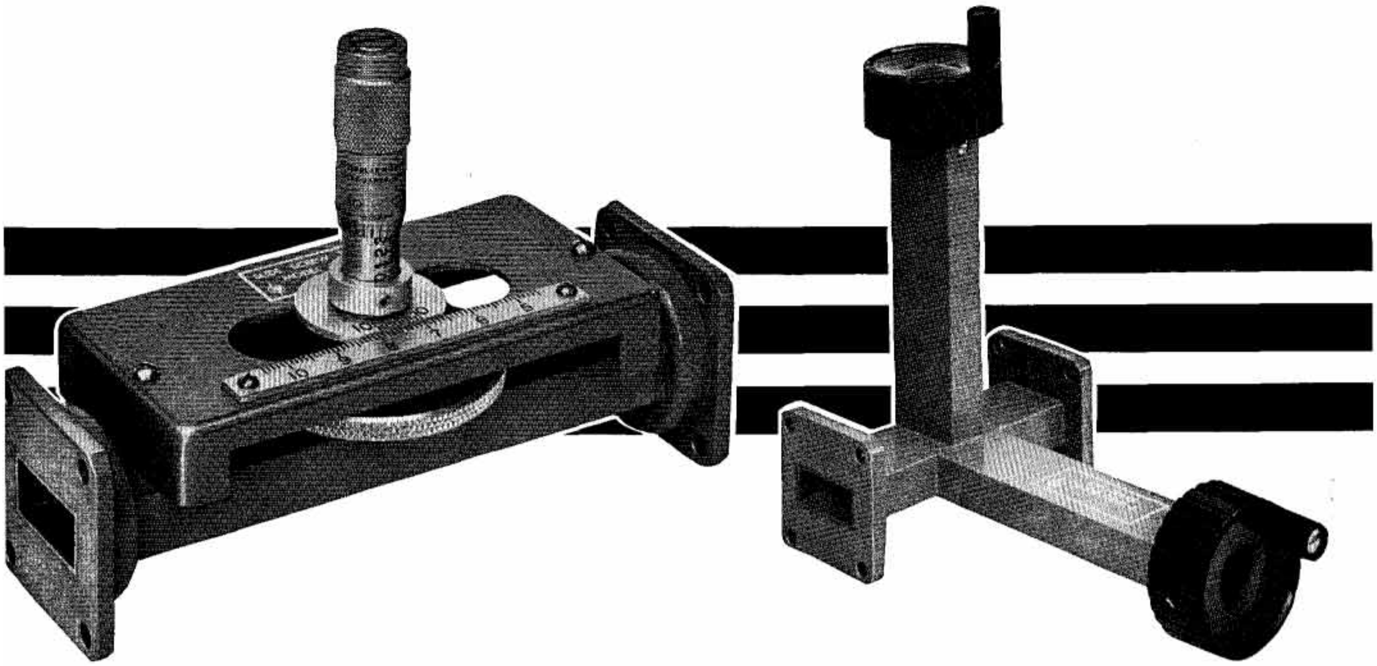
The instruments are compact, with a sturdy aluminum frame for unique ruggedness. Highly stable heat resistant materials are used to insure long term operating accuracy.

Specifications

Model	Coupling (db)	Frequency Range KMC	Primary SWR (max.)	Secondary SWR (max.)	Directivity (minimum)	Coupling Accuracy	Price
764D	20 db	216 - 450 MC	1.10	1.2	30 db	±1 db	$125.00
765D	20 db	450 - 945 MC	1.15	1.20	30 db	±1 db	125.00
766D	20 db	940 - 1975 MC	1.20	1.30	26 db	±1 db	125.00
767D	20 db	1900 - 4000 MC	1.25	1.50	26 db	±1 db	125.00
Power handling capacity, all couplers 50 watts CW, 10 kw peak. Type N connectors throughout. All couplers include -hp- 803A-76G Shorting Plug for reflectometer calibration.							

Data subject to change without notice.

870A/880A WAVEGUIDE TUNERS



-hp- 870A Slide-Screw Tuners

Waveguide slide-screw tuners are used primarily for correcting discontinuities or "flattening" waveguide systems. They are also used to match loads, terminations, bolometer mounts or antennas to the characteristic admittance of the waveguide. They are particularly valuable in determining experimentally the position and magnitude of matching structures required in waveguide systems.

The tuners consist of a waveguide slotted section with a precision-built carriage on which is mounted an adjustable probe. The position and penetration of the probe is adjusted to set up an SWR which is used to cancel out existing SWR in a system. Probe insertion may be varied by means of a calibrated micrometer screw (except on S870A). The position of the probe is adjusted by a thumb-operated knurled-wheel vernier drive. SWR values of 20 can be corrected with an accuracy of 1.02, and small SWR's may be exactly corrected. Insertion loss at SWR of 20 is less than 2 db.

-hp- 880A E-H Tuners

Tuners of the E-H configuration are used to tune out discontinuities in waveguide systems or adjust residual SWR of loads, antennas, bolometer and crystal mounts. They are particularly useful where power leakage is undesirable or where very high powers are employed. With *-hp-* 880A Tuners, SWR's as high as 20 may be reduced to a value of less than 1.02. The insertion loss is low—only slightly more than an equivalent length of waveguide when the SWR is at unity. The loss increases linearly with SWR; and is less than 3 db when a mis-match of 20 is corrected.

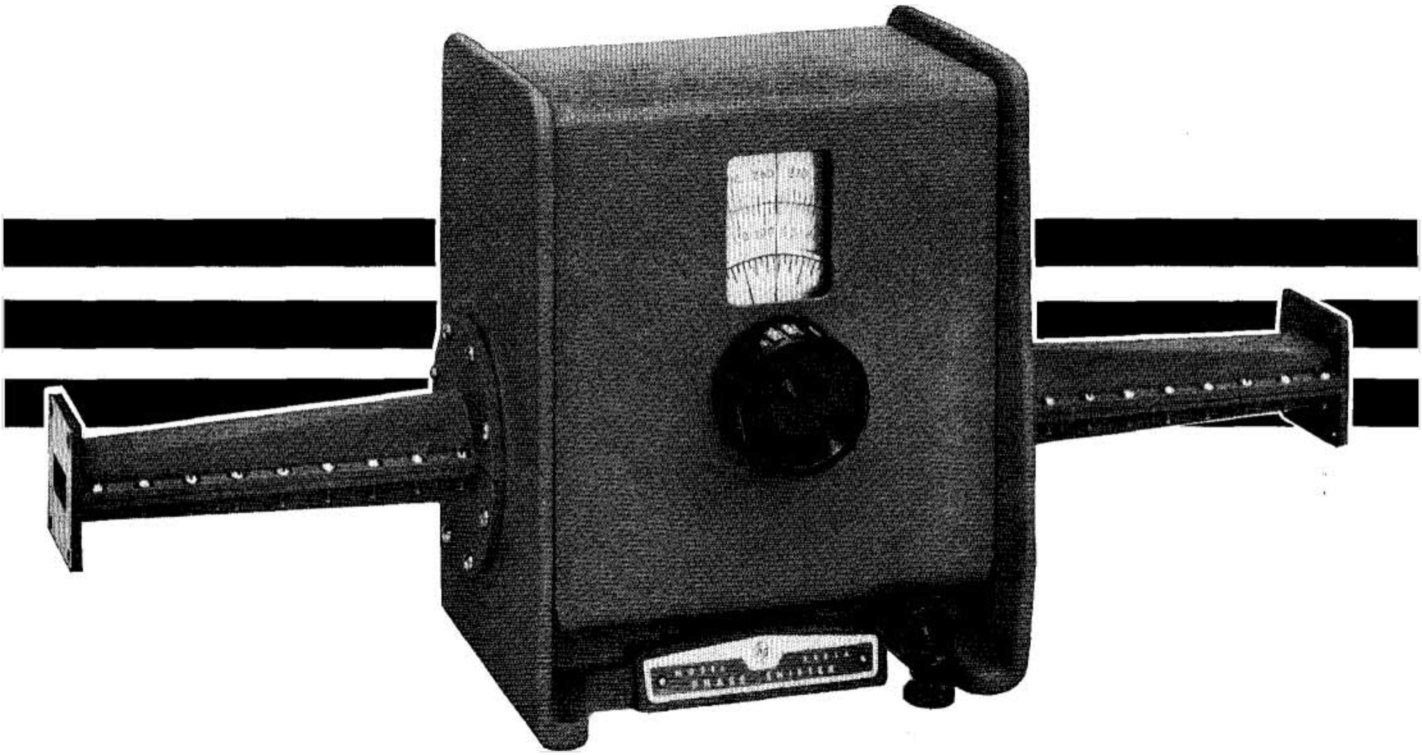
-hp- 880A Tuners consist of a straight section of wave guide to which series and shunt tuning arms are attached. Each arm has a movable short circuit which may be adjusted by a fine tuning control.

Data subject to change without notice.

Specifications

-hp- 870A Slide-Screw Tuner				-hp- 880A E-H Tuner				Frequency Range KMC	Waveguide Size (In.)
Model	Approx. Length (In.)	Shipping Weight (lbs.)	Price	Model	Approx. Length (In.)	Shipping Weight (lbs.)	Price		
S870A	9 7/8	15	$225.00	—	—	—	—	2.60 - 3.95	3 x 1 1/2
G870A	8 1/4	7	185.00	—	—	—	—	3.95 - 5.85	2 x 1
J870A	8 1/8	7	150.00	—	—	—	—	5.30 - 8.20	1 1/2 x 3/4
H870A	6	4	130.00	—	—	—	—	7.05 - 10.0	1 1/4 x 5/8
X870A	5 1/2	3	125.00	X880A	3 1/2	3	$130.00	8.20 - 12.4	1 x 1/2
P870A	5	3	130.00	P880A	2 1/4	3	135.00	12.4 - 18.0	.702 x .391
K870A	3 1/2	3	140.00	K880A	2	2	155.00	18.0 - 26.5	.500 x .250
R870A	2 7/8	3	140.00	R880A	1 7/8	2	170.00	26.5 - 40.0	.360 x .220

885A WAVEGUIDE PHASE SHIFTER



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.

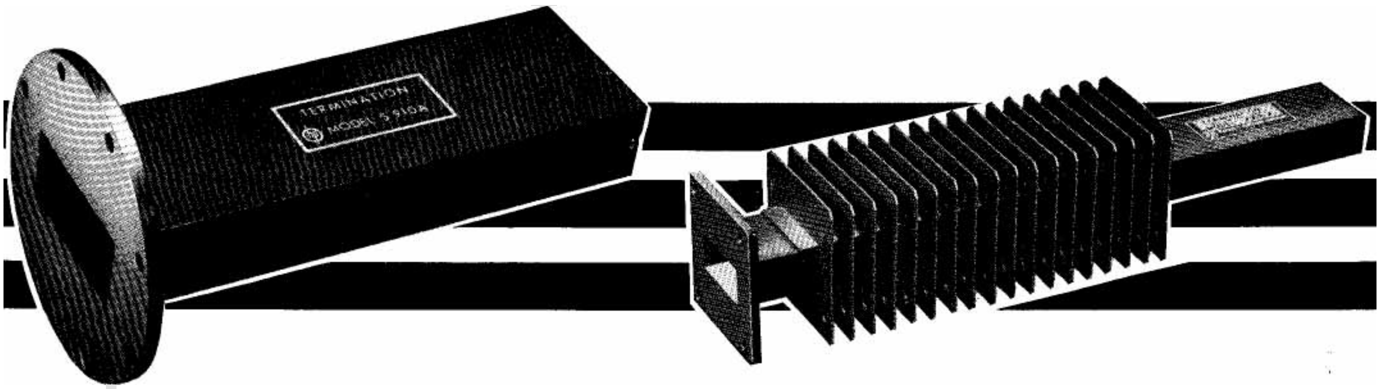
The instrument has a high accuracy over its entire phase range of −360 to +360 electrical degrees, has low power absorption, is simple to operate, and requires no charts or interpolation. It is sturdily built, comprising two rectangular-to-circular waveguide transitions with a dial-driven circular waveguide mid-section. The instrument is housed in a cast-aluminum container for rigidity and durability.

Specifications

Model	Frequency (KMC)	Accuracy	Insertion Loss	Loss Variation with Phase Setting	Approx. Length	Price
J885A	5.3 - 8.2	3°	2 db max.	0.4 db	25"	$400.00
X885A	8.2 - 12.4	2° 8.2 - 10 KMC 3° 10 - 12.4 KMC	2 db max.	0.4 db	15½"	300.00
P885A	12.4 - 18.0	3°	2.5 db max.	0.5 db	12¼	350.00

All models. SWR (maximum): 1.35. Accuracy (phase difference <30°): 10%. Power handling capacity: Approximately 10 watts.

Data subject to change without notice.



Model 910A Low Power Termination

Model 910A is designed for terminating waveguide systems operating at average powers of 1 watt or less. 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.

Mechanically, Model 910A consists of a waveguide section terminated in tapered lossy material which absorbs power in the waveguide. Careful design results in minimum reflection over the entire waveguide band.

Model 912A High Power Termination

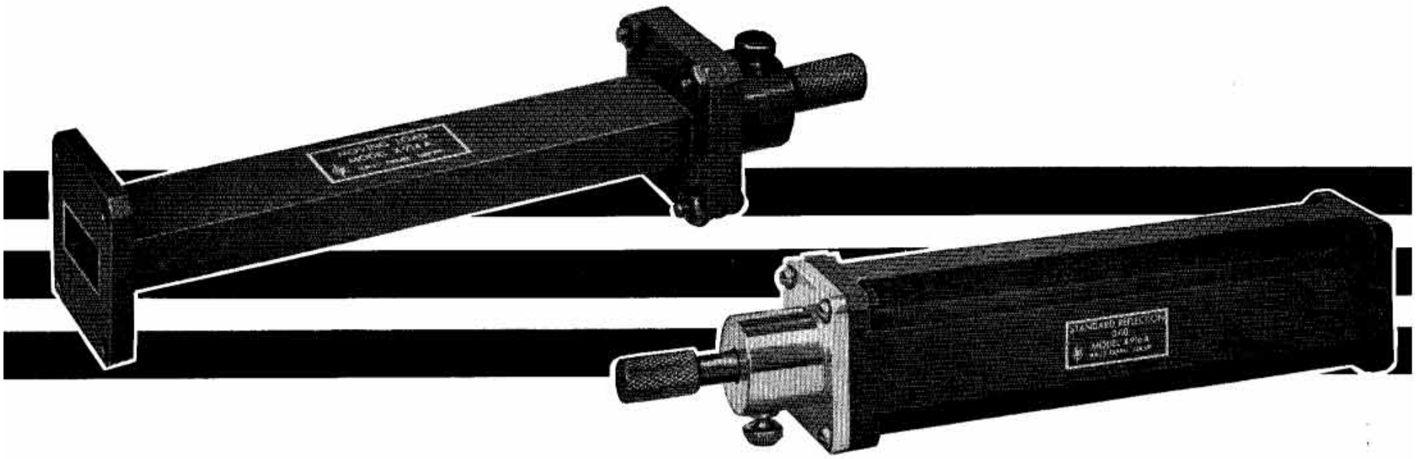
This termination is similar to Model 910A but is designed for waveguide systems operating at high powers. Since these terminations readily absorb large amounts of power, they are useful as dummy loads in testing vacuum tube characteristics, transmitter output, etc. Model 912A Terminations contain a high 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.

Specifications

-hp- 910A Low Power Termination					-hp- 912A High Power Termination						Frequency Range KMC	Waveguide Size (in.)
Model	Max. SWR	Average Power Watts	Length (in.)	Price	Model	Max. SWR	Average Power Watts	Peak Power kw	Length (in.)	Price		
S910A	1.06	1	10¼	$45.00	S912A	1.1	100	100	15¼	$160.00	2.60 - 3.95	3 x 1½
G910A	1.06	1	6⅝	35.00							3.95 - 5.85	2 x 1
J910A	1.02	1	6¼	30.00							5.30 - 8.20	1½ x ¾
H910A	1.02	1	4⅝	25.00							7.05 - 10.0	1¼ x ⅝
X910A	1.02	1	5½	20.00	X912A	1.1	50	50	8¼	50.00	8.20 - 12.4	1 x ½
P910A	1.02	½	4¼	25.00							12.4 - 18.0	.702 x .391
K910A	1.04	½	2¼	30.00							18.0 - 26.5	.500 x .250
R910A	1.04	½	2	35.00							26.5 - 40.0	.360 x .220

Data subject to change without notice.

WAVEGUIDE LOADS



-hp- 914A Moving Load

Model 914A 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.

Specifications

Model	Frequency Range KMC	Waveguide Size (in.)	Approx. Overall Length (in.)	Shipping Weight (lbs.)	Price
S914A	2.60 - 3.95	3 x 1½	24	21	$100.00
G914A	3.95 - 5.85	2 x 1	15¼	10	75.00
J914A	5.30 - 8.20	1½ x ¾	11¾	9	70.00
H914A	7.05 - 10.0	1¼ x ⅝	9½	4	60.00
X914A	8.20 - 12.4	1 x ½	8¼	3	50.00
P914A	12.4 - 18.0	.702 x .391	8	1	55.00
K914A	18.0 - 26.5	.500 x .250	6½	1	65.00
R914A	26.5 - 40.0	.360 x .220	5¼	1	75.00

-hp- 916A-E Standard Reflections

Model 916 Standard Reflections are precision loads used to set up exact reflections for standardizing SWR measuring setups. Specifically designed for measurements in the important X band, the loads are available in 5 reflection coefficient values ranging from 0.00 to 0.20.

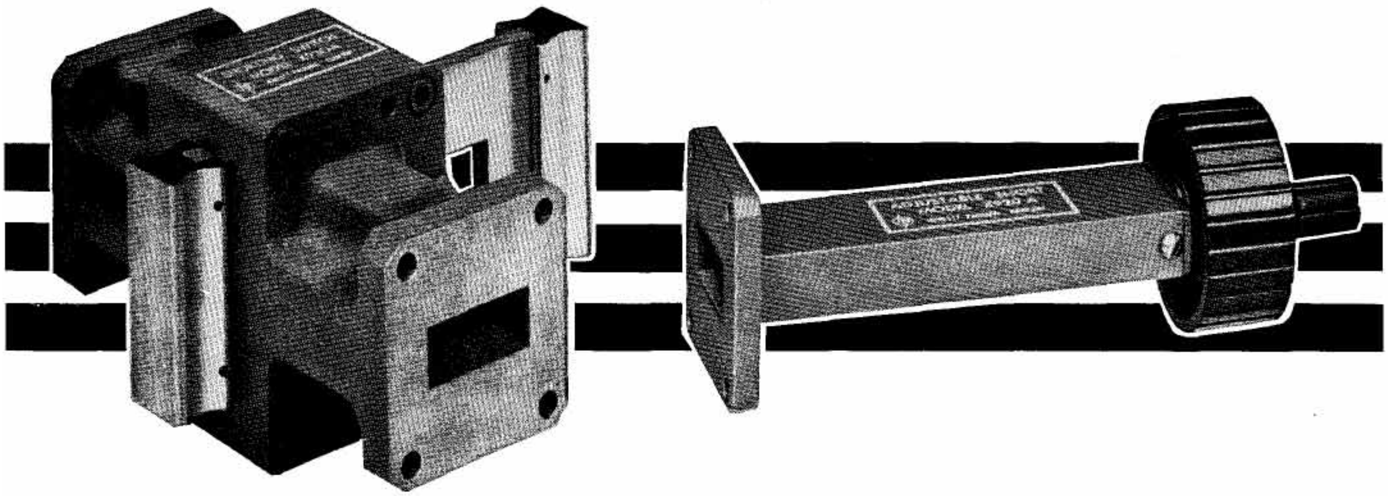
The instrument consists of a precision machined aluminum casting whose inside wide dimension is the same as that of a standard X band waveguide but whose inside narrow dimension is reduced by the exact amount necessary to establish the required power reflection at the junction of the waveguide. The precision taper load is movable so that small reflections which it causes can be isolated from the calibrated discontinuity.

Specifications

Model	Nominal Reflection Coefficient	Accuracy (Reflection Coefficient)	Price
X916A	0.00	±0.002	$100.00
X916B	0.05	±0.0025	100.00
X916C	0.10	±0.0035	100.00
X916D	0.15	±0.0045	100.00
X916E	0.20	±0.007	100.00

Waveguide Size: 1″ x ½″, flat cover flanges.
Frequency Range: 8.2 to 12.4 KMC.
Dimensions: 1⅝″ x 1⅝″ x 8⅜″ long.
Weight: Shipping 2 lbs.

Data subject to change without notice.



-hp- X930A Waveguide Shorting Switch

The *-hp-* 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 *-hp-* 430C. It can also be used to establish a reference reflection coefficient of 1.00 for calibrating Ratio Meters such as the *-hp-* 416A. The low insertion loss and SWR of the *-hp-* 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 KMC.

Length: 3 - 11/16".

Shipping Weight: Approximately 2 lbs.

Price: $60.00.

Data subject to change without notice.

-hp- 920A 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, *-hp-* 920A Shorts are a waveguide section in which a movable low loss contacting finger wiper* is mounted. Position of the short is varied by a fine tuning control.

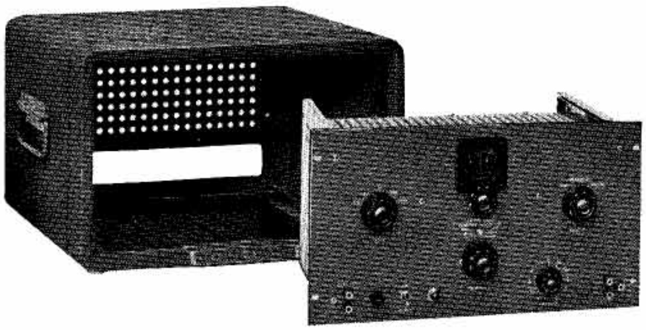
Specifications

Model	Approx. Length (in.)	Frequency Range KMC	Waveguide Size (in.)	Shipping Weight (lbs.)	Price
S920A	10½	2.60 - 3.95	3 x 1½	10	$90.00
G920A	7½	3.95 - 5.85	2 x 1	4	70.00
J920A	3¼	5.30 - 8.20	1½ x ¾	3	60.00
H920A	3½	7.05 - 10.0	1¼ x ⅝	2	50.00
X920A	4½	8.20 - 12.4	1 x ½	2	40.00
P920A	5½	12.4 - 18.0	.702 x .391	1	55.00
K920A	4½	18.0 - 26.5	.500 x .250	1	75.00
R920A	4	26.5 - 40.0	.360 x .220	1	85.00

*In the P, K, and R bands a choke-type short is employed. Position of the choke is varied by a micrometer adjustment.

METAL CABINETS, RACK MOUNT, END FRAMES

STANDARD -*hp*- instruments can be mounted any of three convenient ways—in new, streamlined all metal cabinets, with end frames, or in your relay rack and later remounted any other way quickly, conveniently with only minor modifications. This versatility means maximum usefulness from your -*hp*- equipment and increased flexibility of your entire instrument setup.



Cabinets. Hewlett-Packard instruments with standard 10½" x 19" panels are available in standardized -*hp*- AC-44 aluminum-and-steel cabinets. Equipped with sturdy carrying handles, AC-44 cabinets give your instruments greater protection, better ventilation, more convenience and a clean, rugged, modern appearance. The cabinets feature a separate back cover which may be removed individually. The cabinet itself may also be removed quickly and easily. Cabinets are finished in wrinkle grey, matching -*hp*- grey baked enamel panel faces.

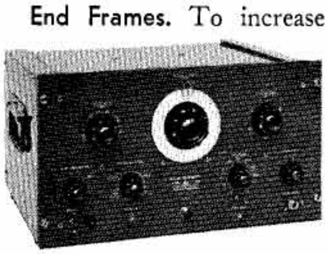
-*hp*- AC-44 cabinets are furnished with the following instruments when factory shipment of cabinet model instrument is made, but may be ordered separately to fit your present -*hp*- instrument.

AC-44A	*AC-44C*	*AC-44D*	*AC-44E*
100D	624C	522A/B	560A
202A	520A		686A
205AG	212A		
206A	540A		
330B/C/D			
650A			
712B			
416A			

-*hp*- AC-44 cabinets measure overall (outside dimensions) 20½" wide, 12½" high, 13¾" deep, except AC-44E, 17½" deep. Weight is approximately 15 pounds. When inquiring about cabinets for instruments you now have, please include model and serial number.

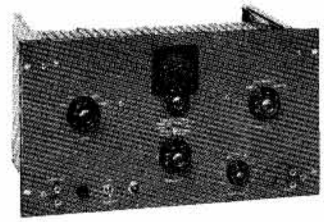
Cabinet, with instrument, $15.00; separately, $25.00.

End Frames. To increase flexibility and convenience of your -*hp*- instruments for bench use, -*hp*- AC-17 End Frames are offered. These frames are of heavy gauge aluminum, equipped with sturdy carrying handles and finished in -*hp*- grey baked enamel. They fit all late model -*hp*- instruments with panel size 10½" x 19" except -*hp*- Model 520A, and may be attached in a matter of moments.

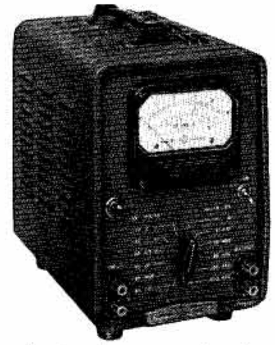


-*hp*- AC-17 End Frames, set, $7.50.

Rack Mounting. Many -*hp*- instruments are basically rack mounting, and can be installed directly into standard 19" relay racks. Many other -*hp*- instruments can be equipped for rack mounting at slight additional cost. A complete list of instruments available for rack mounting will be supplied on request; or make special inquiry concerning instruments you are interested in.

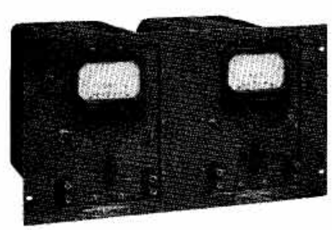


Smaller -*hp*- Instruments. Small -*hp*- instruments such as -*hp*- 400D Vacuum Tube Voltmeter (illustrated) are also supplied in streamlined all-metal cabinets. As with large size -*hp*- cabinets, the small cabinets provide greater protection, better ventilation, more convenience and a more pleasing appearance. Cabinets are finished in wrinkle grey matching the -*hp*- grey baked enamel panel faces, and are equipped with sturdy leather carrying handle. Instruments supplied with these cabinets as standard equipment include -*hp*- 400D, 400AB and 410B Vacuum Tube Voltmeters, 200AB and 200CD Audio Oscillators, 512A/B Frequency Convertors, 715A and 717A Klystron Power Supplies, and 490A and 491A Traveling-Wave Tube Amplifiers.



-hp- AC-2A/B Dual Rack Mounts

As a convenience to customers who wish to combine any two of the smaller -*hp*- instruments into one rack mounting, -*hp*- AC-2A Dual Mount is offered. Measuring 10½" x 19" overall, this mount is designed to accept any two of the following instruments, -*hp*- 200AB, 200CD, 200J, 201C, 202C, 400AB, 400D, 400H, 500B, 500C, 512A, 512B, 415B, 430C, 711A and 715A.



-*hp*- AC-2B Dual Mount is the same as the AC-2A except that it accepts an -*hp*- 410B and one of the instruments listed above. -*hp*- AC-2A or AC-2B, $25.00 ($35.00 if instruments are factory installed).

Data subject to change without notice.

-hp- AC-60A/B Line Matching Transformers

Model AC-60A

Model AC-60A is specifically designed to connect a balanced system to *-hp-* 200CD Audio Oscillators, 400D 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 *-hp-* 400D it provides voltage measurements on either a 135 or 600 ohm balanced line without grounding of one side, and permits bridging or terminated voltage measurements on both 135 and 600 ohm lines. Maximum level + 22 dbm. Shipping weight 2 lbs. $25.00.

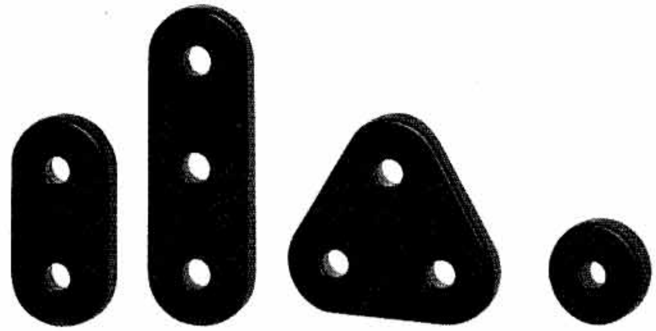
Model AC-60B is similar to the AC-60A except that it is for use in audio systems, being specifically designed for connecting *-hp-* 330B Noise and Distortion Analyzer to a balanced line. Frequency range is 20 cps to 60 KC; maximum level is + 15 dbm. Shipping weight 6 lbs. $35.00.

-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 with ¼" – 28. thread and the post body has a 10/32 thread. The insulated ferrule is ⅝" long and has an outside diameter of ½". AC-10C (black), $.30; AC-10D (red), $.30.

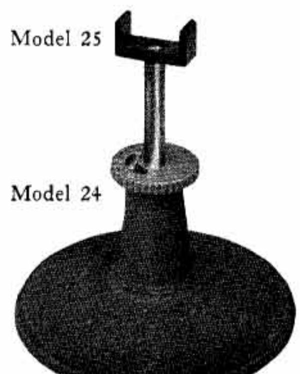
-hp- AC-54A/B/C/D Insulators

These binding post insulators are of four standard designs. All insulators are ¼" thick. Holes are spaced ¾" apart, have a minimum diameter of 0.190" and a 7° taper. AC-54C is made of nylon, others are polystyrene. Black only.



-hp- AC-54A $.15 *-hp-* AC-54B $.20 *-hp-* AC-54C $.20 *-hp-* AC-54D $.10

-hp- 24 Waveguide Stand



Model 25

Model 24

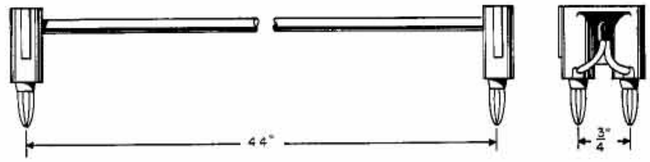
Model 24 Waveguide Stands are cast and machined from aluminum alloy. They are designed for *-hp-* 25 Waveguide Clamps and lock the clamps at any height from 2¾" to 5¼". Model 24 is 2½" high and its base measures 4¾" in diameter. $3.00 each.

-hp- 25 Waveguide Clamps

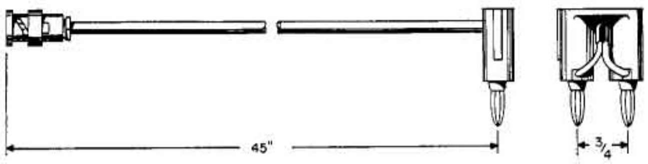
These clamps consist of a rubber molding with a steel insert. They are offered in 8 sizes to fit waveguide equipment covering frequencies from 2.6 to 40.0 KMC. They are designed for use with *-hp-* 24 Waveguide Stand, and when mounted in the Stand can be adjusted upward or downward to conform with a waveguide setup. When ordering, specify waveguide size. Model S25, 3" x 1½"; Model G25, 2" x 1"; Model J25, 1½" x ¾"; Model H25, 1¼" x ⅝"; Model X25, 1" x ½"; Model P25, .702" x .391"; Model K25, .500" x .250"; Model R25, .360" x .220". $2.50 each.

Data subject to change without notice. Prices f.o.b. factory.
Quantity discount prices on request.
Instruments finished in -hp- grey baked enamel.

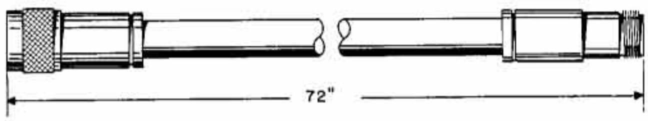
ACCESSORY CABLE ASSEMBLIES



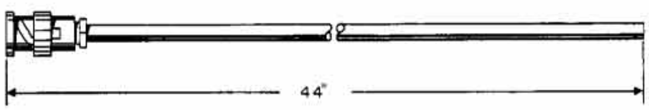
AC-16A Cable Assembly. Equipped with two dual banana plugs, this assembly is a section of RG-58/U 50 ohm coaxial cable measuring 44 inches overall. Plugs are for binding posts spaced ¾ inch between centers. Each, $4.00.



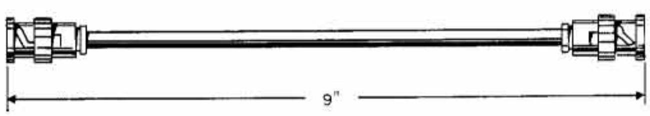
AC-16B Cable Assembly. Identical with AC-16A except has dual banana plug (¾ inch center) on one end and UG-88/U Type BNC male connector on other end. Length overall, 45 inches. Each, $4.25.



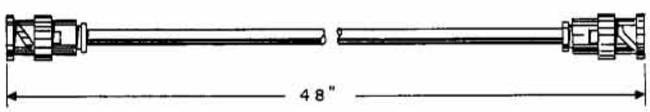
AC-16C Cable Assembly. This cable consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on one end with UG-21B/U Type N male connector and UG-23B/U Type N female connector at opposite end. For use at frequencies below 4,000 MC. Each, $7.50.



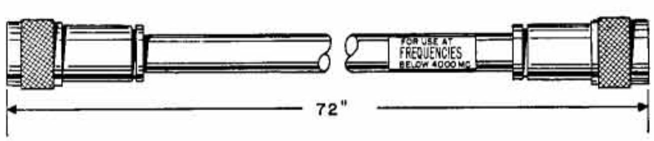
AC-16D Cable Assembly. This cable consists of 44 inches of RG-58/U 50 ohm coaxial cable terminated on one end only. Termination is UG-88/U Type BNC male connector. Each, $2.65.



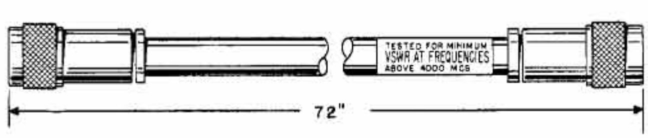
AC-16E Cable Assembly. A short cable of 9 inches length consisting of RG-58/U 50 ohm coaxial cable terminated on both ends with UG-88/U Type BNC male connectors. Each, $4.50.



AC-16K Cable Assembly. This cable consists of 4 feet of RG-58/U 50 ohm coaxial cable terminated on each end with UG-88/U Type BNC male connectors. Each, $5.00.



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, $7.50.



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. Each cable tested and selected for minimum SWR at frequencies above 4,000 MC. Each, $12.00.

Prices f.o.b. factory.

Data subject to change without notice.

WARRANTY

Hewlett-Packard Company warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this Warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to making good at our factory any part or parts thereof except tubes, fuses or batteries which shall, within one year after making delivery to the original purchaser, be returned to us with transportation charges prepaid, and which on our examination shall disclose to our satisfaction to have been thus defective.

Hewlett-Packard reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is expressly in lieu of all other obligations or liabilities on the part of Hewlett-Packard, and Hewlett-Packard neither assumes nor authorizes any other person to assume for them any other liability in connection with the sales of Hewlett-Packard instruments.

STANDARD WAVEGUIDE AND FLANGE SPECIFICATIONS

-hp- designations	WAVEGUIDE		Material	Frequency Range (KMC) for Dominant (TE_{10}) Mode	DIMENSIONS, IN INCHES			
					Inner Dimensions		Outer Dimensions	
	RETMA Designation	JAN Type			Width	Height	Width	Height
S	WR284	RG-48/U RG-75/U	Brass Aluminum	2.60 - 3.95	2.840	1.340	3.000	1.500
G	WR187	RG-49/U RG-95/U	Brass Aluminum	3.95 - 5.85	1.872	0.872	2.000	1.000
C	WR159		Brass Aluminum	4.9 - 7.05	1.590	0.795	1.718	0.923
J	WR137	RG-50/U RG-106/U	Brass Aluminum	5.3 - 8.20	1.372	0.622	1.500	0.750
H	WR112	RG-51/U RG-68/U	Brass Aluminum	7.05 - 10.00	1.122	0.497	1.250	0.625
X	WR90	RG-52/U RG-67/U	Brass Aluminum	8.20 - 12.40	0.900	0.400	1.000	0.50[illegible]
M	WR75		Brass Aluminum	10.00 - 15.00	0.750	0.375	0.850	0.475
P	WR62	RG-91/U RF-107/U	Brass Silver	12.40 - 18.00	0.622	0.311	0.702	0.391
N	WR51		Brass Silver	15.00 - 22.00	0.510	0.255	0.590	0.335
K	WR42	RG-53/U RG-66/U	Brass Silver	18.00 - 26.50	0.420	0.170	0.500	0.250
Q	WR34		Brass Silver	22.00 - 33.00	0.340	0.170	0.420	0.250
R	WR28	RG-96/U	Silver	26.50 - 40.00	0.280	0.140	0.360	0.220

NOTES:

(1) Resistivity of Brass—7.0×10^{-6} ohm - cm.
Resistivity of Aluminum—2.83×10^{-6} ohm - cm.
Resistivity of Silver—1.62×10^{-6} ohm - cm.

(2) All *-hp-* flanges are plain contact type. Where choke type connection is required, use *-hp-* 290A Cover to Choke Flange Adapter.

Wall Thick-ness Nominal	Cut-Off Frequency of TE_{10} Mode (KMC)	Theoretical Attenuation Lowest to Highest Freq. (db/100 Ft.) (1)	WAVEGUIDE FLANGES (2) Aluminum		WAVEGUIDE FLANGES (2) Bronze	
			Cover Type JAN No.	Choke Type & Gasket JAN No.	Cover Type JAN No.	Choke Type & Gasket JAN No.
0.080	2.080	1.478 - 1.008 0.940 - 0.641	UG-584/U	UG-585/U	UG-53/U	UG-54A/U
0.064	3.155	2.79 - 1.93 1.77 - 1.22	UG-407/U	UG-406A/U	UG-149A/U	UG-148B/U
0.064	3.714	2.89 - 2.24 1.84 - 1.42				
0.064	4.285	4.61 - 3.08 2.93 - 1.94	UG-441/U	UG-440A/U	UG-344/U	UG-343A/U
0.064	5.260	5.51 - 4.31 3.50 - 2.74	UG-138/U	UG-137A/U	UG-51/U	UG-52A/U
0.050	6.560	8.64 - 6.02 5.49 - 3.83	UG-135/U	UG-136A/U	UG-39/U	UG-40A/U
0.050	7.880	10.1 - 7.12 6.42 - 4.52				
0.040	9.490	12.76 - 11.15 6.14 - 5.36			UG-419/U	UG-541/U
0.040	11.590	17.5 - 12.7 8.43 - 6.12				
0.040	14.080	27.7 - 19.8 13.3 - 9.5			UG-595/U	UG-596/U
0.040	17.37	33.3 - 23.2 16.1 - 11.2				
0.040	21.100	21.9 - 15.0			UG-599/U	UG-600/U

INDEX BY INSTRUMENT TITLE

INDEX BY INSTRUMENT MODEL NUMBERS

COMPLETE COVERAGE . . .

In electronic test instruments, Hewlett-Packard gives you complete coverage several different ways.

In development—*-hp-* engineer teams are continually at work designing and producing accurate, helpful new instruments that meet and anticipate the demands of electronics.

In instrumentation—the *-hp-* line is the world's largest and most complete. You choose from over 300 instruments the ones that provide exactly the measuring coverage you require.

In frequency coverage—*-hp-* makes nearly every kind of useful electronic test instrument. And, for almost all useful frequencies, too. For example, *-hp-* signal generators offer solid frequency coverage from 10 to 21,000 MC; *-hp-* voltmeters from 10 to 700,000,000 cps, oscillators from 0.008 to 10,000,000 cps.

In personnel service—*-hp-* has selected the best independent organizations to give you personal help with measuring problems. Electronics specialists—men trained by Hewlett-Packard—save you time by helping select the exact *-hp-* instrumentation you need—and following through to be sure the equipment is properly utilized to serve you best. These men are located in major business centers—as near as your telephone. Call them when you need personal help, in your plant, today.

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