ELECTRONIC TEST INSTRUMENTS 1960

HEWLETT-PACKARD COMPANY

INDEX BY INSTRUMENT TYPE AND FUNCTION

Oscilloscopes—DC to 500 MC

Instrument	Primary Uses	Characteristics	Price	Page
-hp- 120A	General laboratory and production measuring	Dc to 200 KC	$ 435.00	12, 13
-hp- 122A	General laboratory and production measuring	Dc to 200 KC—Dual trace	625.00	14, 15
-hp- 130B	General laboratory and production testing	Dc to 300 KC—High sensitivity	650.00	16, 17
-hp- 150A	General laboratory high frequency and TV work	Dc to 10 MC—Plug-in vertical amplifiers	1100.00	18, 19, 20, 21
-hp- 151B	High sensitivity—Plug-in for 150A	Dc to 10 MC—High sensitivity	200.00	20
-hp- 152B	Dual trace plug-in for 150A	Dc to 10 MC—Presents two phenomena for simultaneous viewing	250.00	21
-hp- 153A	High sensitivity—Plug-in for 150A	1 mv/cm, dc to 500 KC	125.00	21
-hp- 154A	Dual trace plug-in for 150A	Voltage and current observation	430.00	21
-hp- 160B	Militarized general duty oscilloscope	Dc to 15 KC; plug-in versatility	1850.00	22, 23
-hp- 162A	Dual trace plug-in for 160B	20 mv/cm, high stability	350.00	23
-hp- 185A	Sampling oscilloscope for very fast circuits	Dc to 500 MC; 5" CRT	2000.00	24, 25
-hp- 187A	Dual trace plug-in for 185A	10 mv/cm to 200 mv/cm	1000.00	25
-hp- 196A	Oscilloscope camera for all -hp- scopes	Prints, transparencies on Polaroid® films	425.00	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	$150.00	30
-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	170.00	30
-hp- 200J	Interpolation, frequency measurements	6 cps to 6 KC	160 mw/10 v	300.00	31
-hp- 200SR	Driving -hp- 739AR Frequency Response Test Set	5 cps to 600 KC	3 v rms into 50 ohms	180.00	29
-hp- 200T	Telemetry, carrier current tests	250 cps to 100 KC	160 mw or 10 v/600 ohms; 20 v open circuit	450.00	30
-hp- 201C	High quality audio tests	20 cps to 20 KC	3 w or 42.5 v/600 ohms	225.00	31
-hp- 202A	Low frequency measurements	0.008 to 1200 cps	28 mw or 30 v p-p/4000 ohms	525.00	32, 33
-hp- 202C	Servo equipment tests, measurements	1 cps to 100 KC	160 mw or 10 v/600 ohms	300.00	30
-hp- 205AG	High power audio tests, gain measurements	20 cps to 20 KC	5 watts	500.00	40, 41
-hp- 206A	High quality, high accuracy audio tests	20 cps to 20 KC	+ 15 dbm	750.00	42, 43
-hp- 207A	Audio sweep generation	20 cps to 20 KC	160 mw or 10 v/600 ohms	325.00	35
-hp- 233A	Carrier oscillator—current tests	50 cps to 500 KC	3 w/600 ohms	500.00	34
-hp- 650A	Wide range video tests	10 cps to 10 MC	15 mw/3 v	490.00	36, 37

Voltmeters and Ammeters—DC to 700 MC

Instrument	Primary Uses	Frequency Range	Range	Input Impedance	Price	Page
-hp- 400D	Wide range ac measurements High sensitivity	10 cps to 4 MC	0.1 mv to 300 v 12 ranges	10 megohms 15 $\mu\mu f$ shunt	$225.00	56
-hp- 400H	High accuracy wide range ac measurements	10 cps to 4 MC	0.1 mv to 300 v 12 ranges	10 megohms 15 $\mu\mu f$ shunt	325.00	58
-hp- 400L	High resolution, wide range ac measurements	10 cps to 4 MC	0.3 mv to 300 v 12 ranges	10 megohms 15 $\mu\mu f$ shunt	325.00	57
-hp- 403A	Battery operated portable; fast, accurate, hum-free	1 cps to 1 MC	0.001 to 300 v 12 ranges	2 megohms 40, 20 $\mu\mu f$ shunt	250.00	59
-hp- 405AR	Digital display of dc voltages	Dc	0.001 to 999 v automatic range	11 megohms	825.00	60
-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	61
-hp- 412A	Dc voltage, dc current; ohms	Dc	0.1 mv to 1,000 v 13 ranges	10 to 200 megohms depending on range	375.00	62
-hp- 425A	Low dc voltages and current	Dc	1 μv to 1 v 11 ranges	1 megohm ±3%	500.00	64, 65
-hp- 428A	Dc current measurements	Dc	1 ma to 1 amp 6 ranges	—	475.00	63
-hp- 456A	AC Current Probe	Converts amps to v for direct current readings on scope, VTVM			190.00	66
-hp- Voltmeter Accessories, Including Dividers, Multipliers, Shunt Resistors and Connectors						67
-hp- 738AR	Voltmeter Calibrator	Dc + or —; 400cps sine wave	300 μv to 300 v	Works into 3 to 10 megohms	875.00	55
-hp- 739AR	Frequency Response Test Set	5* cps to 10 MC (* with 200SR)	3 v output	—	450.00	55

Distortion, Wave Form Analyzers—20 cps to 20 KC

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 302A	Wave form analyzer	20 cps to 50 KC	Measuring range 30 μv to 300 v oscillator-tuned voltmeter	$1,750.00△	50, 51
-hp- 330B	Measures total audio distortion	20 cps to 20 KC	Includes input amplifier, VTVM	410.00△	52, 53
-hp- 330C	For FM broadcast measurements	20 cps to 20 KC	Special VU meter to meet F.C.C. requirements	440.00△	52, 53
-hp- 330D	For AM, FM broadcast measurements	20 cps to 20 KC	AM detector and VU meter to meet F.C.C. requirements	500.00△	52, 53

△ Rack mounted instrument available for $15.00 less.

Frequency Measuring, Monitoring Equipment

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 100ER Frequency Standard	Establish standard frequencies; calibrate, measure time	6 sine 10 cps to 1 MC; 4 pulse, 10 cps to 10 KC	Stability 5/10⁸ per week Timing comb	$ 900.00	81
-hp -113AR Frequency Divider and Clock	Adjust freq. standards; comparisons	——	100 KC input	2,500.00	82
-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	78, 79
-hp- 500C Electronic Frequency Meter	Rpm measurements	180 to 6,000,000 rpm	Similar to 500B but calibrated in rpm	285.00	78, 79
-hp- 506A Optical Tachometer Pickup	Rps and rpm measurement	300 to 300,000 rpm	Phototube and light source; output 1 v rms	125.00	80
-hp- 508A Tachometer Generator	Shaft speed measurement	15 to 40,000 rpm	Output 60 cycles per revolution	100.00	80
-hp- 508B Tachometer Generator	Shaft speed measurement	15 to 30,000 rpm	Output 100 cycles per revolution	100.00	80
-hp- 508C Tachometer Generator	Shaft speed measurement	15 to 25,000 rpm	Output 120 cycles per revolution	100.00	80
-hp- 508D Tachometer Generator	Shaft speed measurement	15 to 5,000 rpm	Output 360 cycles per revolution	100.00	80
-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△	83
-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	84, 85
-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	84, 85
-hp- 521D Electronic Counter	Measure frequency, speed, time interval	1 cps to 120 KC	Same as 521A except 4-place inline registration	675.00	84, 85
-hp- 521E Electronic Counter	Measure frequency, speed time interval	1 cps to 120 KC	Same as 521C except 5-place inline registration	875.00	84, 85
-hp- 521G Electronic Counter	Measure frequency, speed, elapsed time	1 cps to 1.2 MC	Direct reading, accuracy ±1 count ±0.1%. 5-place registration	650.00	84
-hp- 522B Electronic Counter	Frequency, period, time interval measurements	10 cps to 120 KC	Direct reading, accuracy ±1 count ±0.001%	915.00△	86, 87
-hp- 523B Electronic Counter	Frequency, period, time interval	10 cps to 1.1 MC	Direct reading, accuracy ±1 count ±2/1,000,000	1,245.00	88, 89
-hp- 523CR Electronic Counter	Frequency, period, time interval	10 cps to 1.2 MC	Rack mount, similar to -hp- 523D, inline registration	1,485.00	88, 89
-hp- 523DR Electronic Counter	Frequency, period, time interval	10 cps to 1.2 MC	Similar to -hp- 523CR; standard presentation	1,285.00	88, 89
-hp- 524B Frequency Counter	Frequency, period measurements	10 cps to 10.1 MC (Freq.) 0 cps to 10 KC (Period)	Direct reading, no interpolation, accuracy about 2/1,000,000/week	2,150.00	92
-hp- 524C Frequency Counter	Frequency, period measurements	10 cps to 10.1 MC (Freq.) 0 cps to 10 KC (Period)	5/10⁸ stability; digital display tube readout	2,300.00■	90, 91, 92
-hp- 524D Frequency Counter	Frequency, period measurements	10 cps to 10.1 MC (Freq.) 0 cps to 10 KC (Period)	5/10⁸ stability; decade counter readout	2,150.00■	90, 91, 92
-hp- 525A Frequency Converter	Extends 524'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	91, 92
-hp- 525B Frequency Converter	Extends 524'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	91, 92
-hp- 526A Video Amplifier	Increases 524's sensitivity to 10 millivolts	10 cps to 10.1 MC	Accuracy same as basic counter; 10 mv rms min. input	175.00	91, 92
-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	91, 92
-hp- 526C Period Multiplier	Period measurement	Extends range of 524B to measure 10,000 periods	Greater accuracy in period measurement	225.00	91, 92
-hp- 540A Transfer Oscillator	Frequency measurements	10 MC to 5 KMC	Extends range of 524 to 5 KMC	615.00△	95
-hp- 540B Transfer Oscillator	Frequency measurements	10 MC to 12.4 KMC	Extends range of 524 to 12.4 KMC	750.00△	94, 95
-hp- 560A Digital Recorder	Record counter measurements	Slave of counter	5 counts per second; 11 digit parallel entry; analog output	1,265.00△	96, 97
-hp- 561B Digital Recorder	Record counter measurements	Slave of counter or voltmeter	10-line decimal code input	1,065.00△	96, 97
-hp- 570A Digital Clock	Adds time of day information to -hp- 560A	Slave of counter	Inline, 6-place numeric readout; also can control measuring rate	1,050.00	97
-hp- 571B Digital Clock	Adds time of day information to -hp- 561B	Slave of counter or voltmeter	Inline, 6-place numeric readout; also can control measuring rate	950.00	97

Square Wave, Pulse, and Digital Delay Generators

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 211A	Square wave generator	1 cps to 1 MC	Output 7 v p-p across 75 ohms and 55 v p-p across 600 ohms	$ 300.00	44
-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	585.00△	45
-hp- 218AR	Digital delay generator	——	Time interval 1 to 10,000 μsec; adjustable in 1 μsec steps	2,000.00	46, 47
-hp- 219A	Dual trigger unit	——	Two trigger pulses, approx. 50 v amplitude	100.00	47
-hp- 219B	Dual pulse unit	——	Two high power pulses	450.00	47
-hp- 219C	Digital pulse-duration unit	——	Digital delay, digital duration pulses	350.00	47

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

Signal Generators — 50 KC to 21,000 MC

Instrument	Frequency Range	Characteristics	Price	Page
-hp- 606A	50 KC to 65 MC	Output 0.1 μv to 3 v into 50 ohm load. Constant output impedance, versatile modulation.	$1,200.00△	102, 103
-hp- 608C	10 to 480 MC	Output 0.1 μv to 1 v into 50 ohm load. AM, pulse, or CW modulation. Direct calibration.	1,000.00	104, 105
-hp- 608D	10 to 420 MC	Output 0.1 μv to 0.5 v. Incidental FM 0.002 entire range.	1,100.00	104, 105
-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	106, 107
-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	108, 109
-hp- 616B	1,800 to 4,200 MC	Output 0.1 μv to 0.223 v into 50 ohm load. Pulse, CW or FM modulation. Direct calibration.	1,950.00	108, 109
-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	110, 111
-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	110, 111
-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.	1,900.00	112, 113
-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△	112, 113
-hp- 626A	10 to 15.5 KMC	Output 10 dbm to—90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,250.00	114, 115
-hp- 628A	15 to 21 KMC	Output 10 dbm to —90 dbm. Pulse, FM, or square wave modulation. Direct calibration.	3,250.00	114, 115

Swept Frequency Oscillators

Instrument	Frequency Range	Characteristics	Price	Page
-hp- 683A	2 to 4 KMC	Electronically swept; variable sweep width and rate. Output 10 mw to 0. Pulse, square wave, FM and AM modulation.	$3,000.00△	116, 117
-hp- 684B	4 to 8.1 KMC		2,900.00△	116, 117
H01686A	7.0 to 11.0 KMC		3,000.00△	116, 117
-hp- 686A	8.2 to 12.4 KMC		2,900.00△	116, 117
-hp- 687A	12.4 to 18.0 KMC		3,400.00△	116, 117

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	$ 85.00	49
-hp- 355A/B Precision Attenuator	Measurement of gain, attenuation	Dc to 500 MC	Bilateral: 50 ohm impedance; 1 and 10 db steps	125.00	49
-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	126
-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	69
-hp- 460AR Amplifier, Wide Band	Wide band, pulse amplification	100 KC to 120 MC	20 db gain, rise time 0.003 μsec	185.00	70, 71
-hp- 460BR Amplifier, Fast Pulse	Pulse amplification, high output	100 KC to 120 MC	15 db gain, 125 peak volts	225.00	70, 71
-hp- 466A AC Amplifier	Transistorized, general-purpose instrument	10 cps to 1 MC	20, 40 db gain; response ±0.5 db	150.00	69
-hp- 46A Accessories	Apply and connect 460A/B amplifiers				71
-hp- 711A Laboratory Power Supply	General purpose regulated supply, metered output		0 to 500 volts @ 100 ma	250.00	119
-hp-712B Power Supply	Same as 711A		0 to 500 volts @ 200 ma	365.00△	120
-hp- 715A Klystron Power Supply	Regulated beam, reflector source for low power klystrons		250 to 400 volts @ 50 ma	300.00	121
-hp- 721A Transistor Power Supply	Dc voltages for transistor work		0 to 30 v dc, 150 ma	145.00	118
Binding Posts, Insulators, Support Pedestals					163
-hp- AC-2A/B Dual Rack Mount				25.00	162
-hp- AC-4 Decade Counters					93
-hp- AC-16 Cable Assemblies					164
-hp- AC-17 End Frames				17.00 pr.	162
-hp- AC-44 Cabinets					162
-hp- AC-60A Line Matching Transformers	Connect balanced system to VTVM, oscillators	5 to 600 KC	Max. level +22 dbm	45.00	163
-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	60.00	163
-hp- AC-60K Matching Transformer	Match barretters to -hp- 416A			80.00	145

△ 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" .702 x .391" 12.4 - 18.0 KMC	"K" .500 x .250" 18.0 - 26.5 KMC	"R" .360 x .220" 26.5 - 40.0 KMC	Page
Adapter, Waveguide to Coax		S281A $50	G281A $40	J281A $35	H281A $30	X281A $25				125
Cover to choke flange		S290A $65	G290A $50	J290A $35	H290A $30	X290A $15	P290A $25			125
Waveguide to waveguide		-hp- 292A Series								125
Waveguide Noise Source		S347A $250	G347A $190	J347A $190	H347A $190	X347A $190	P347A $250			129
Attenuators, Fixed 3, 6, 10, 20 db		S370A $75	G370A $75	J370A $65	H370A $60	X370A $55	P370A $60	K370A $100	R370A $100	130
Precision, Fixed		372 Series								122
Flap, 25 db max.		S375A $120	G375A $110	J375A $100	H375A $90	X375A $90	P375A $100	K375A $140	R375A $180	130
Calibrated, precision		S380A $260	G382A $500	J382A $350	H382A $350	X382A $275	P382A $275	K382A $425	R382A $450	130
Detector Mounts	420A $50				H421A $95	X421A $75	P421A $95			152
	420B $75									152
	440A† $85									152
		S485D° $170	G485D $170	J485D° $170						139
		S485A‡ $140	G485B† $95	J485B† $90	H485B† $85	X485B† $75				139
Thermistor Mounts (Fixed tuned) ■	477B $75		G487B $95	J487B $90	H487B $80	X487B $75	P487B $110	K487B $150	R487B $225	137, 140
Frequency Meters, Reaction				J530A/B**	H530A $120		P530A $150			153
Direct Reading					H532A $195	X532B $150	P532A $210	K532A $230	R532A $250	153
Directional Couplers, Cross Guide: 20, 30 db		S750 $150	G750 $120	J750 $80	H750 $70	X750 $50				154, 155
Directional Couplers, Multi Hole: 3, 10, 20 db		S752 $375	G752 $250	J752 $140	H752 $120	X752 $100	P752 $115	K752 $175	R752 $200	154, 155
Slotted Sections, Waveguide		S810A* $450	G810B§ $110	J810B§ $110	H810B§ $110	X810B§ $90	P810B§ $110			151
Slotted Sections, Waveguide								K815B $265	R815B $265	151
Tuners, Slide Screw		S870A $225	G870A $185	J870A $150	H870A $130	X870A $125	P870A $130	K870A $250	R870A $300	157
E - H						X880A $130	P880A $150			157
Waveguide Phase Shifter				J885A $500		X885A $400	P885 $550			158
Terminations, Low Power		S910A $60	G910A $50	J910A $35	H910A $30	X910B $25	P910A $30			159
Terminations, High Power		S912A $200				X912A $75				159
Moving Load		S914A $100	G914A $75	J914A $70	H914A $60	X914B $50	P914A $55	K914B $250	R914B $250	160
Standard Reflections						X916B-E $100				160
Adjustable Shorts		S920A $150	G920A $125	J920A $100	H920A $75	X920A $75	P920A $75	K920A $140	R920A $150	161
Waveguide Shorting Switch						X930 $100				161
Broad Band Probe	442B§ $40	All Frequencies								152
Broad Band Probe, Untuned			444A $40 2.6 to 18.0 KMC				446B $145 18.0 to 40 KMC			152
Waveguide Clamps, Stands										163

† For use with barretter or crystal.
■ Includes Thermistor, installed.
‡ For use with barretter only.
** J530A, 5.85 to 8.2 KMC, $120; J530B, 5.20 to 7.05 KMC, $150.
* Complete assembly including carriage.
§ Mounts in 809B Carriage.
° Includes barretter; checked for square law characteristics.

Microwave Test Instruments—for coaxial and waveguide systems

Instrument	Primary Uses	Frequency Range	Characteristics	Price	Page
-hp- 340B Noise Figure Meter	Noise figure measurement, alignment	30 and 60 MC	Fast, simple, adaptable to your specific equipment	$ 715.00△	128, 129
-hp- 342A Noise Figure Meter	Noise figure measurement, alignment	30 MC plus any 4 frequencies 38 to 200 MC	Versatile, accurate, new convenience	815.00△	128, 129
-hp- 343A VHF Noise Source	IF and rf amplifier measurement	10 to 600 MC	Broad band, 50 ohm impedance	100.00	129
-hp -345B IF Noise Source	IF and rf amplifier measurement	30/60 MC	Selectable impedance 50, 100, 200 and 400 ohms	75.00	129
-hp- 415B Standing Wave Indicator	SWR indicator or null indicator	315 to 2020 cps. Normal freq. 1,000 cps	0 to 70 db attn. Max. sensitivity 0.3 μv	200.00	149
-hp- 416A Ratio Meter	Reflection coefficient measurements	1,000 cps ±40 cps	Continuous swept frequency presentation; accuracy ±3%	475.00△	144, 145
-hp- 417A VHF Detector	vhf bridge detector (for -hp- 803A)	10 to 500 MC	Approx. 5 μv sensitivity	350.00	147
-hp- 430C Microwave Power Meter	Measurement of rf power	Depends on bolometer mount	0.02 to 10 mw ±5% accuracy	250.00	136, 137
-hp- 434A Calorimetric Power Meter	Measurement of rf power	Dc to 12.4 KMC	10 mw to 10 watts	1,400.00△	134, 135
-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	300.00	138
-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	138
-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	137
-hp- 490B Traveling-Wave Tube Amplifier	Amplification throughout "S" band	2 to 4 KMC	30 db gain; millimicrosec rise time; 10 mw output	1,400.00	72, 73
-hp- 491A Traveling-Wave Tube Amplifier	High power "S" band amplification	2 to 4 KMC	30 db gain; millimicrosec rise time; 1 watt output	1,400.00	72, 73
-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	72, 73
-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	72, 73
-hp-764D-767D Dual Directional Coupler	Reflectometer	216 to 4000 MC	26 db directivity	150.00 to 160.00	156
-hp- 803A VHF Bridge	Measurement of vhf impedance, SWR	50 to 500 MC	2 to 2,000 ohms impedance −90° to +90° phase angle	800.00	146, 147
-hp- 805A Coaxial Slotted Section	Measurement of SWR	500 to 4,000 MC	For Type N Connectors flexible cables	450.00	148
-hp- 805B Coaxial Slotted Section	Same as above	Same as above	For rigid ⅞" RG44/U line	450.00	148
-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	151
-hp- 809B Universal Probe Carriage	G, J, H, X and P 810 Waveguide Sections Supports 806B section, also		Accepts 442B, 444A probes	160.00	150, 151
-hp- 814B Universal Probe Carriage	Supports K and R 815B Waveguide Slotted Sections		Accepts Untuned Probe 446B	200.00	150, 151

△ 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, 1501 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

In most cases, repairs to Hewlett-Packard instruments can be made quickly and locally at field repair stations maintained by hp representatives. normally, having instruments serviced by these field stations saves time since shipping to the hp factory is not involved.

Field service by factory-trained technicians is available at the following locations: (See inside back cover of this Catalog for complete names, addresses and telephone numbers of the representatives involved.) Albuquerque, Boston (Burlington), Bridgeport, Conn.; Chicago, Cleveland, Dallas, Dayton, Denver, Detroit, High Point, N. C.; Houston, Indianapolis, Los Angeles (North Hollywood), New York City, Orlando, Fla.; Philadelphia (Upper Darby), Phoenix, Rochester, Sacramento, San Diego, San Francisco (San Carlos), Seattle, St. Paul, Washington, D. C. (Rockville, Md.). In other areas field repairs are available in Bromma, Sweden; London, England; Koniz/Bern, Switzerland; Melbourne, Australia; Milan, Italy; Paris, France; Rijswijk (Z. H.), The Netherlands; Toronto, Ontario.

Hewlett-Packard respectfully suggests you contact your hp representative first concerning repairs to your hp instruments. Should you ultimately wish to return an instrument to the hp factory for repairs, recalibration or any other reason, please contact the Hewlett-Packard Company for shipping instructions. Please give model number, name, type number, 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.

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 CO.

Mail: 1501 Page Mill Road, Palo Alto, California, U. S. A.

Telephone: DAvenport 6-7000 after May 20, 1960

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.

TO COMMUNICATE WITH HEWLETT-PACKARD S. A.

Mail: Rue du Vieux Billard No. 1 Geneva, Switzerland

Telephone: No. (022) 26. 43. 36

Telex: No. 2. 24. 86

Cable: "HEWPACKSA."

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:

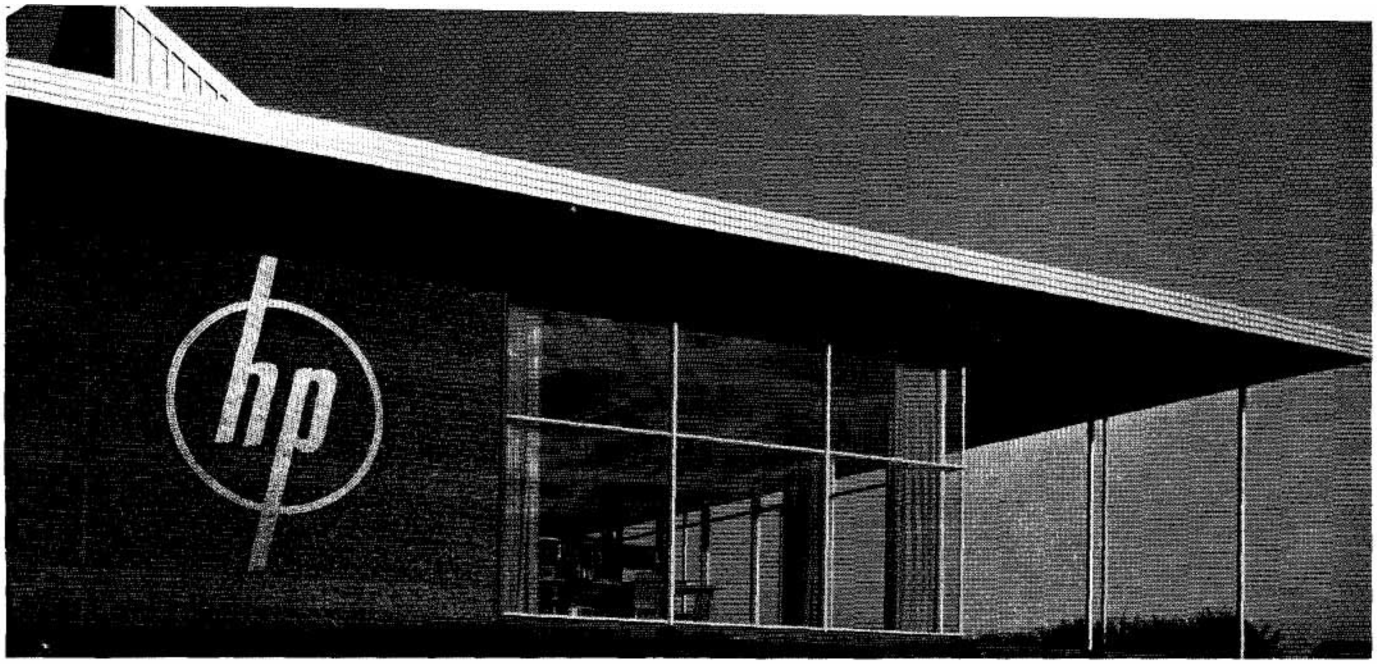
Essential ordering information, terms and shipping and repair data are listed on the previous page.

Prices:

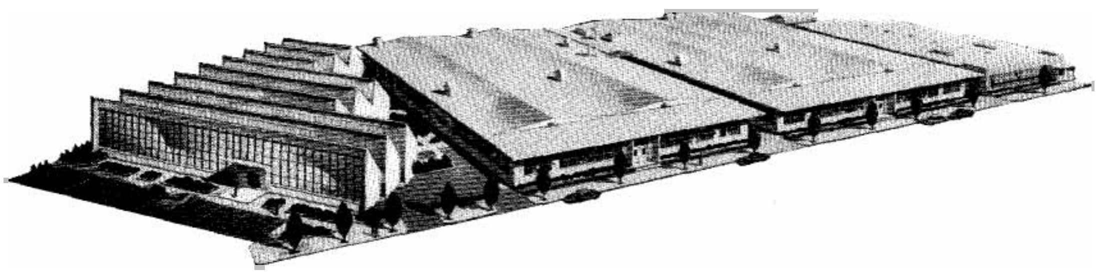
Prices of major hp instruments are listed on individual pages and also in the tables at the beginning of the catalog. Prices of certain small components and accessories are listed on pages where such equipment is catalogued. Prices are subject to change without notice, and are f.o.b. factory.

Warranty:

All hp instruments are warranted free from defects in materials and workmanship. For details see page 165.



The new Hewlett-Packard plant at Stanford Industrial Park is engineered to be the most efficient yet thoroughly "livable" electronic manufacturing facility known. Ultimately to become Hewlett-Packard's administrative as well as engineering and manufacturing headquarters, the Stanford plant will consist of 6 basic units—over 500,000 square feet of space under roof. While the "new plant" is under construction the "old" ⓗⓟ facilities (shown below; last unit finished in 1954) will house Hewlett-Packard's offices and much of manufacturing.



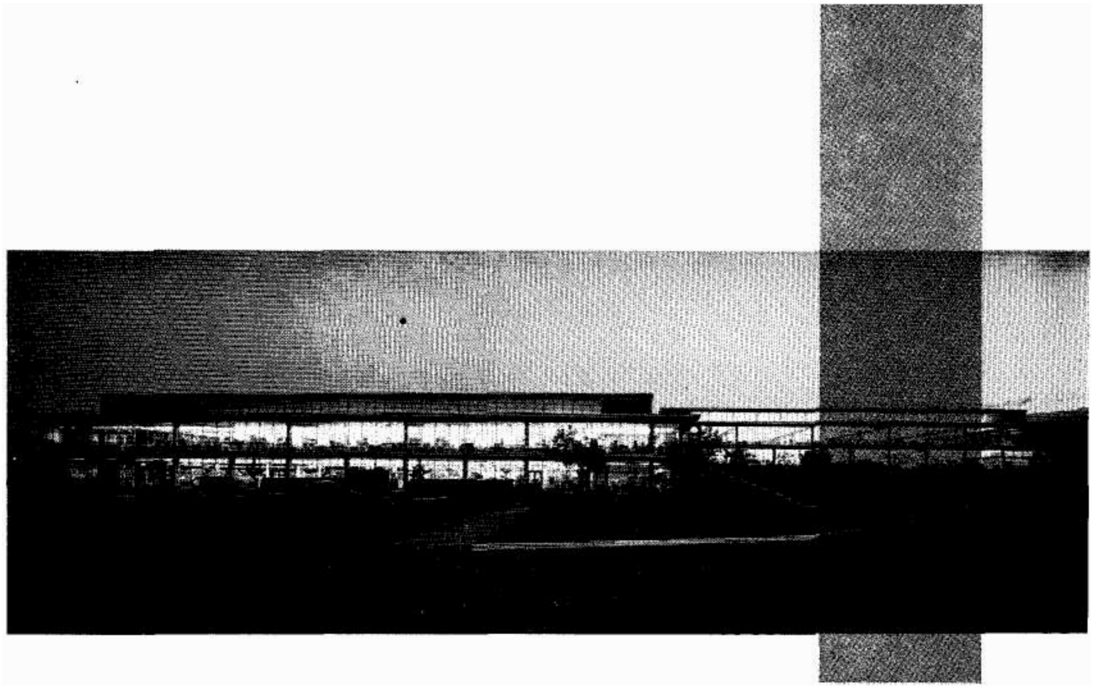
ABOUT HEWLETT-PACKARD

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

During the past 2 decades, 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. Approximately 1800 men and women are now regularly employed, and over 150 field representatives sell and service ⓗⓟ instruments in the United States, Canada and overseas.

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

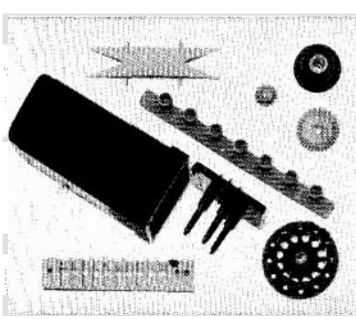
Consistently, Hewlett-Packard insures that these standards are met. Every effort is made to provide the best engineering staff possible, and to pursue the most up-to-date manufacturing methods.



This means not only modern techniques, but modern machinery. Hewlett-Packard's manufacturing departments are equipped with the newest and finest machinery obtainable for the job. Typical of this equipment is a 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-.

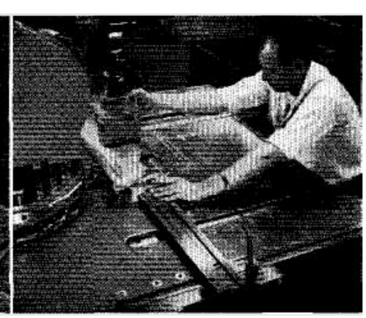
In addition to the different types of commercial machinery, a number of special devices developed by -hp- engineers are in daily use. Some of these were developed to meet unusual manufacturing problems; others were "imagineered" to make some special part better, faster, or at lower cost. They include 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.

Still other unique devices developed by -hp- to speed or simplify manufacturing include a semi-automatic reticule scriber reducing reticule scribing time from 45 to 2 minutes and a jumper-twister machine twisting up to 4 pre-cut wires at once. The jumper-twister even handles pre-stripped wires.

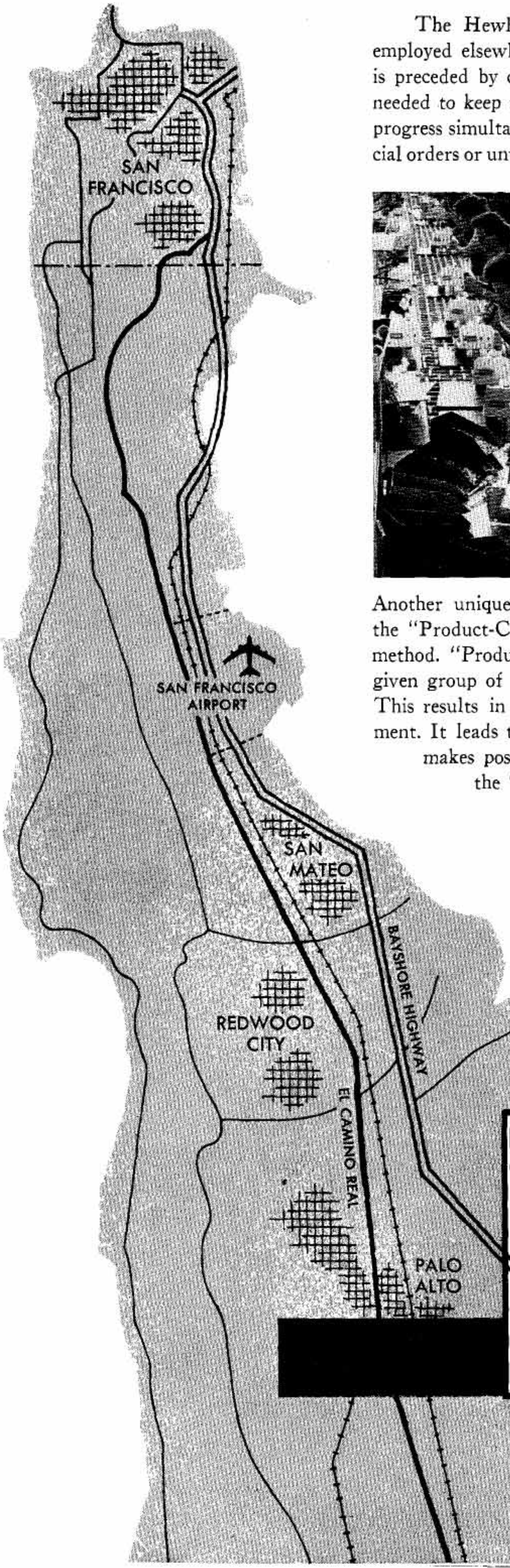


In electronics, special or unusual parts are often hard to find, or prohibitive in cost. To avoid this roadblock to progress, -*hp*- has its own plastics and molding shop, which turns out knobs, escutcheons, Nylon gears, etc.

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.



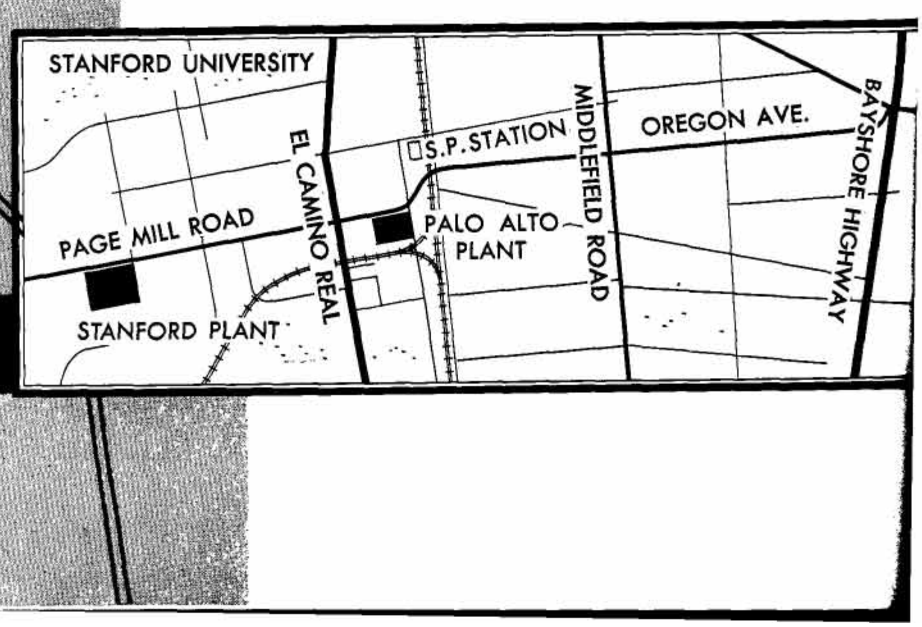
Another unit typical of the modern machinery in daily use at -*hp*- is this turret press~~, a~~ precision equipment which punches many sizes of perforations on instrument chassis with a single set-up.



The Hewlett-Packard production policy is also somewhat different from that employed elsewhere. Instruments are manufactured in "runs," and actual fabrication is preceded by careful planning to insure that all parts are available and supplied as needed to keep the runs progressing smoothly. As many as thirty runs are normally in progress simultaneously, yet production schedules are kept flexible to permit meeting special orders or unusual delivery requirements involving substantial numbers of instruments.

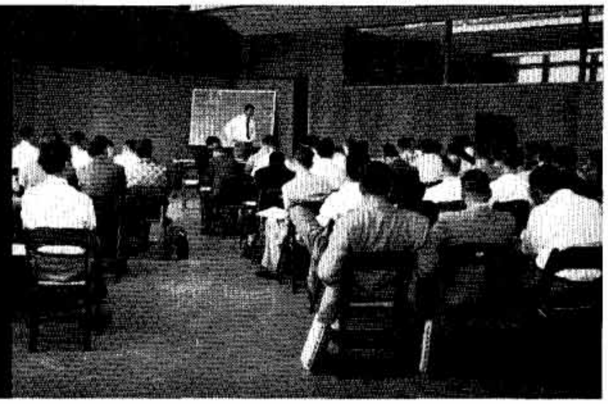
Another unique aspect of the Hewlett-Packard manufacturing process is the use of the "Product-Centered" approach as opposed to the conventional "Process-Centered" method. "Product-Centered" means that a group of people and equipment produce a given group of instruments from prefabricating through assembly, wiring and testing. This results in intimate familiarity on the part of employees with the finished instrument. It leads to a more critical self-inspection of work, a greater desire to excel, and makes possible a "hand-crafted" operation combining the best quality aspects of the "small company" approach with "big-company" economies to the user.

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

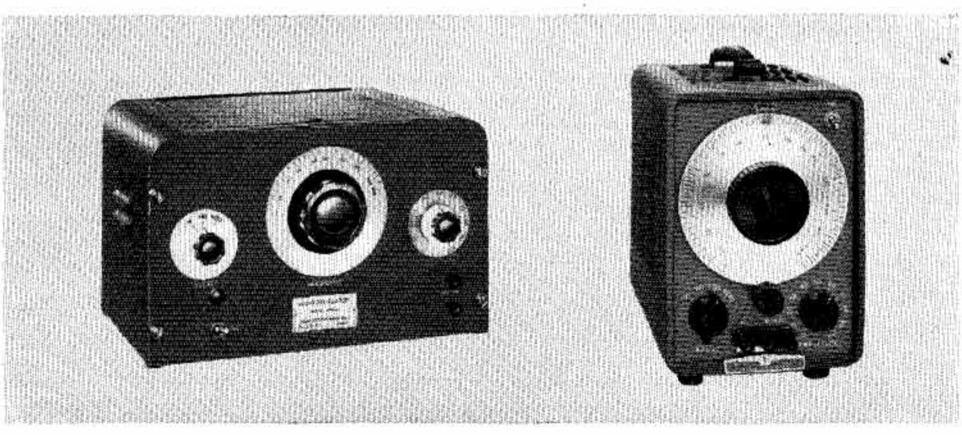


In sales and service, Hewlett-Packard makes a particular effort to provide customers with every assistance that will make the use of hp instruments more efficient and productive. Factory-trained field engineering representatives provide prompt, on-the-job consultation as well as operating and repair 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 retraining 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.

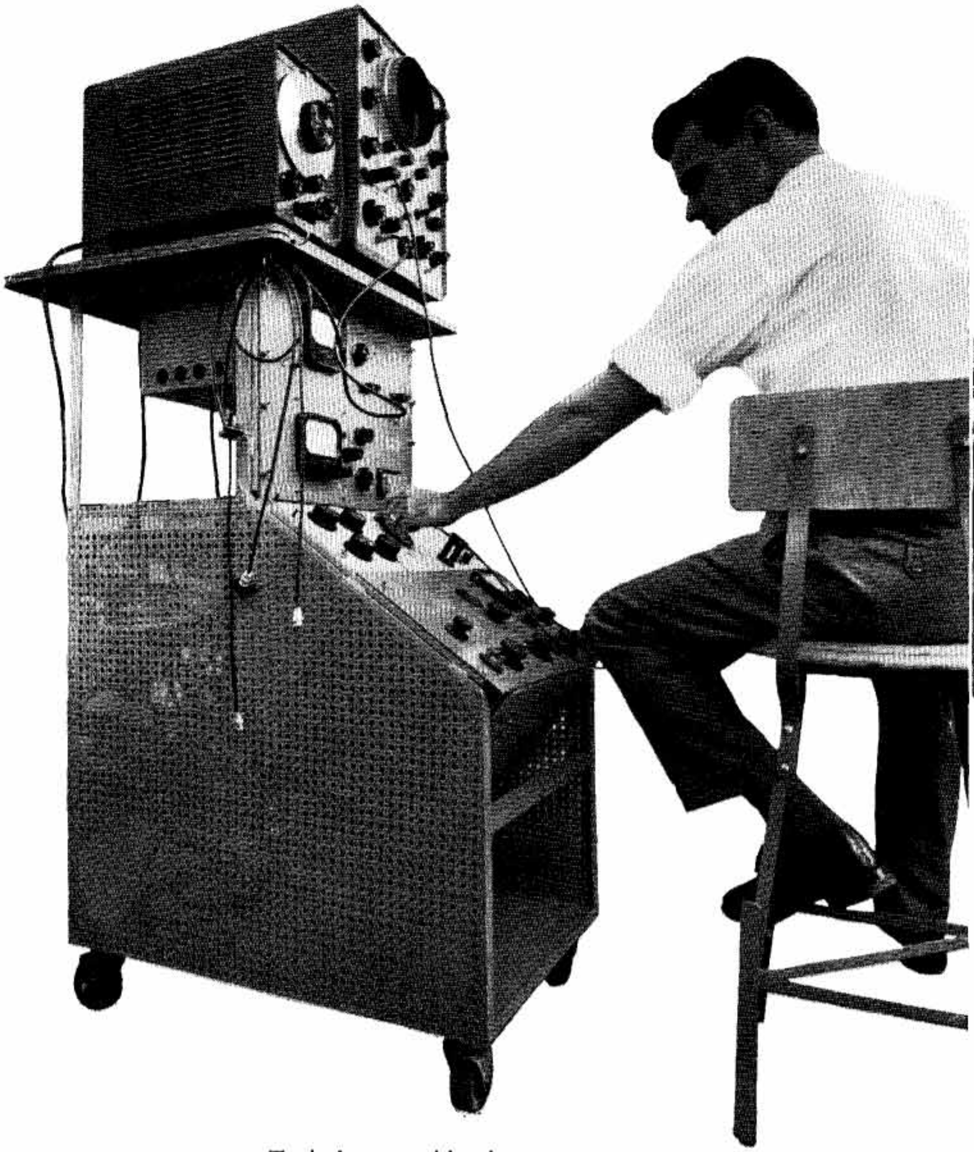
A basic part of the frequent re-training seminars are actual measuring operations duplicating field testing and research problems. By performing each measurement themselves under expert guidance, hp field engineers are even more familiar with the instruments they offer.



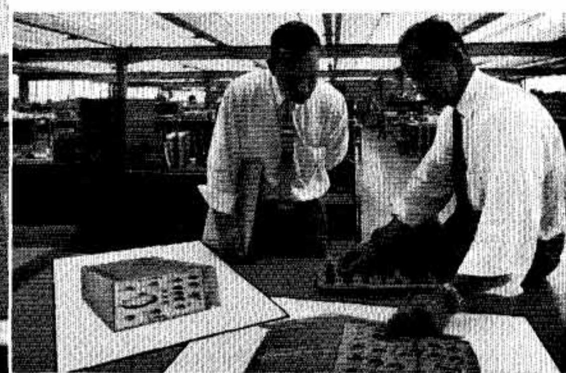
Lectures covering problems ranging from practical applications to pure theory are another fundamental part of the hp re-training seminars. Field engineers are brought up to date on the most advanced engineering thinking as well as the latest applications known for hp instruments.



Old and New. Pictured above are two hp audio oscillators—the very first instrument (left) and the modern 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.



Typical test position in Hewlett-Packard plant.



"Human engineering" is vital in making an instrument convenient and logical to operate. At hp, human engineering includes panel arrangement, even shape and size of knobs.

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.

OSCILLOSCOPES

An oscilloscope is designed to display a wide variety of electrical signals on the face of a cathode ray tube. An electron beam in the CRT precisely controlled by horizontal and vertical deflection plates activates the phosphor on the tube face, and thus traces a visible signal. Since an oscilloscope will display a variety of signals, it is useful for many different measurements.

Types of Measurements

General

Time interval, frequency and amplitude measurements are usually made by sweeping the oscilloscope internally to measure the time or to measure the amplitude in volts. The oscilloscope, however, may be swept externally to provide Lissajous patterns for frequency, time, and phase relation of two signals.[1]

Dual Trace Measurements

The dual trace feature of some oscilloscopes permits two quantities to be observed simultaneously. Hence, the input and output of an amplifier or filter, for example, or the driving-source and output of a servo-mechanism could easily be observed and compared. Also, the dual trace permits comparison of phase or time relationships of two separate waveforms.

Pulse Testing

A straightforward method of determining the transient response of a system consists of applying a squarewave or pulse to the system input and observing the output on an oscilloscope. A typical arrangement for using pulses to test systems is shown below. A dual channel oscilloscope is particularly useful for pulse testing since the system output can easily be compared with the input.

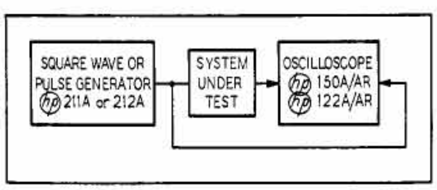


Figure 1. Testing system response to step functions.

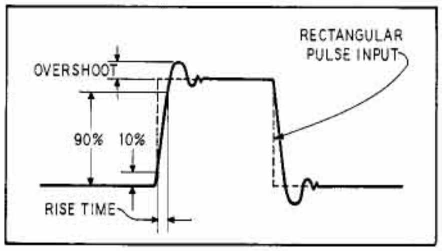


Figure 2. Typical amplifier response to a rectangular pulse input.

The response of a system to a pulse input can be viewed in terms of rise time, and overshoot. Rise time is the time required for the response to increase from 10 to 90% in amplitude.

ABOUT CRT PHOSPHORS

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

Each of these phosphors has specific characteristics which render it, and hence the oscilloscope, maximumly useful in a given application.

The four phosphors and their basic characteristics are:

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

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

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

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

The rise time is important since it can be used to determine amplifier bandwidth, for overshoots less than 5%,

$$B \cong \frac{0.35}{RT},$$

where RT is the rise time of the amplifier in microseconds and B is defined as the upper frequency at which the amplifier response is 3 db below mid-frequency response. For example, if an amplifier output has a rise time of 0.035 μsec with a pulse input, the amplifier bandwidth is approximately 10 megacycles.

In general, an oscilloscope is used to observe the response of a system to a step function provided that the rise time of the oscilloscope is faster than the rise time to be measured. If it is not, the system rise time may be calculated from the formula.

$$RT_{obs} = \sqrt{\underset{\text{input pulse}}{(RT)^2} + \underset{\text{system}}{(RT)^2} + \underset{\text{oscilloscope amplifier}}{(RT)^2}}$$

Oscilloscope bandwidth may be increased by using an external wide band amplifier such as the ⓗⓟ460A/B connected directly to the oscilloscope deflection plates.

Pulse testing is especially convenient in testing systems which are to handle signals characterized by having step-like transitions (such as TV signals).[2]

Selecting an Oscilloscope

General

Two important considerations in selecting an oscilloscope are the bandwidth and sensitivity. The bandwidth must be large enough to display the highest anticipated frequency. For pulse work, the necessary oscilloscope bandwidth may be estimated by using the relationship between bandwidth and rise time, where the rise time is

Notes: 1. Phase shift may be read directly by using a Webb mask available from -hp- engineering representatives. 2. More information on pulse testing is contained in Hewlett-Packard Applications Note 17, available from -hp- engineering representatives.

that necessary to view the fastest anticipated pulse. Oscilloscope sweep speeds should be commensurate with bandwidth for viewing the fastest signals.

The sensitivity must also be sufficient to display all of the anticipated signals on the cathode ray tube. Otherwise, an additional amplifier may be required.

In addition, there are several features normally found on ⓗⓟ oscilloscopes which contribute to ease of use and reliability. For example, differential amplifiers insure stable gain and low distortion throughout the entire life of the instrument. Oscilloscope power supplies are regulated so that calibration is not affected by power line fluctuation. Hard tube Miller Integrator sweep circuits assure accurate sweep times. Automatic synchronization gives jitterless signal display and a mono accelerator cathode ray tube presents a sharp, halo-free trace.

Hewlett-Packard offers oscilloscopes to meet a wide variety of applications. There are presently four different oscilloscopes available in either rack or cabinet mounting.

High Frequency Oscilloscopes

Model 185A (pages 24, 25) is a revolutionary new 500 MC sampling oscilloscope which is essentially as straightforward to use as a low frequency oscilloscope, but which provides fast-circuit information. It permits fatigue-free viewing on a big, bright 5″ cathode ray tube, of repetitive short pulses requiring a bandwidth of 500 MC. The rise time of less than 0.7 millimicroseconds permits direct measurement and observation of extremely fast phenomenon. Trace brightness is independent of duty cycle. Horizontal sweep speeds range from 0.1 millimicrosecond/cm to 100 millimicroseconds/cm, vertical sensitivity from 10 to 200 millivolts/cm with vernier increase to 3 mv/cm.

Model 185A operates with ⓗⓟ 187A Dual Trace Amplifier, a plug-in unit permitting observation and comparison of two high speed signals simultaneously, or comparisons of time, duration and spacing. The amplifier has a wide dynamic range of 3 mv to 2 volt peak; each channel has an independent sensitivity control calibrated to $\pm 5\%$.

Model 160B/BR (pages 22, 23) is a reliable, extra rugged, general duty 15 MC oscilloscope meeting MIL standards for shock, vibration, humidity, and temperature. Available as either a cabinet or rack mount model (ⓗⓟ 160B and 160BR respectively), this new instrument is a commercial version of a premier ⓗⓟ military oscilloscope. It offers 24 calibrated sweep times, 0.1 μsec/cm to 5 sec/cm, with accuracy of $\pm 3\%$. A 7-range magnifier increases the fastest sweep to 0.02 μsec/cm. Triggering is by internal, line or external voltages; horizontal sensitivity is 0.1 v/cm to 10 v/cm.

Model 160B/BR operates with ⓗⓟ 162A Dual Trace Amplifier, a plug-in unit of 20 mv/cm maximum sensitivity which offers the convenience of dual trace with 1 MC chopping and differential input. High stability is achieved through the use of unique new tube-transistor circuitry, regulated dc filament voltages, and improved etched circuitry. Model 162A is described on page 23.

Model 150A (pages 18-21) is a dc to 10 MC instrument for sophisticated laboratory use. In addition to ⓗⓟ automatic triggering, the 150A offers a single shot sweep which may be reset electrically or manually. There are 24 direct reading calibrated sweeps providing sweep times from 0.1 μsec/cm to 5 sec/cm.

A series of plug-in amplifiers extend the versatility of the 150A. Briefly, these include a High Gain Amplifier providing sensitivity from 5 mv/cm to 50 v/cm, a Dual Trace Amplifier providing differential input and dual traces, a very High Gain Amplifier providing sensitivity from 1 mv/cm to 125 v/cm, and a Current Probe plug-in. Details of these plug-ins appear on pages 18 through 21.

Low Frequency Oscilloscopes

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

Model 120A (pages 12, 13 for details) is a dc to 200 KC instrument with a maximum sensitivity of 10 mv/cm.

Model 122A (pages 14, 15) is a dc to 200 KC *dual trace* instrument that permits the viewing of two phenomena simultaneously. The 122A has 10 mv/cm maximum sensitivity.

Model 130B (pages 16, 17) is a dc to 300 KC oscilloscope. The 130B has a maximum sensitivity of 1 mv/cm permitting the viewing of phenomena from many transducers without pre-amplification.

Oscilloscope Camera

Full-size, distortion free, *flat and scalable* photographs of oscilloscope traces may be made quickly and in an amazingly simple manner with the new ⓗⓟ 196A Oscilloscope Camera. This new instrument, employing a Polaroid® Land Camera back, takes sharp pictures in which an 8 x10 cm graticule fills the full film area. The camera may be mounted on the oscilloscope by a "one-hand" clamp mount with quick-lock tab; thereafter, it is not necessary to remove the camera to change the shutter or *f*-setting.

Multiple exposures are simple; a one-hand adjustment moves the lens through 11 detented positions. Use of a professional camera bellows prevents light leaks. Tab pulling is simple due to the sturdy construction and mounting. In addition to conventional Polaroid Land Camera prints, Model 196A also permits the "instantaneous" making of transparencies for slides and reproduction.

For complete details of Model 196A Oscilloscope Camera, see next page.

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

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

Results are as sharp and clear as the cathode ray tube trace itself; the camera's new *f*/1.9 lens has imperceptible distortion which means pictures may be scaled accurately. A 10 cm graticule fills the full film area, and multiple exposures are easily achieved by a one-hand adjustment moving the lens through 11 detented positions.

Mount, Unmount In Seconds

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

Specifications

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

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

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

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

Print Size: 2-7/8″ x 3-13/16″ (7.3 cm x 9.6 cm).

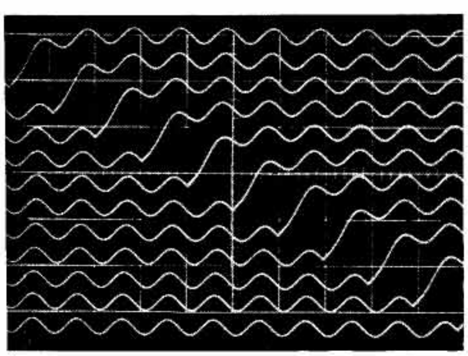
Film: Polaroid® Land types 42, 44, 46, 46-L, 47.

Size: 13-1/2″ long, 9 1/4″ high, 10″ wide. Weight 9 lbs.

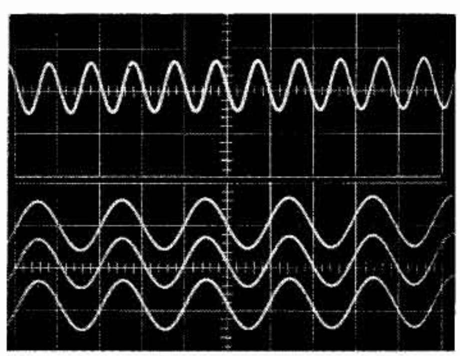
Accessories Available: hp 196A-45 Carrying Case, $35.00; hp 196A-20 Tektronix Adapter, $4.50.

Price: $425.00.

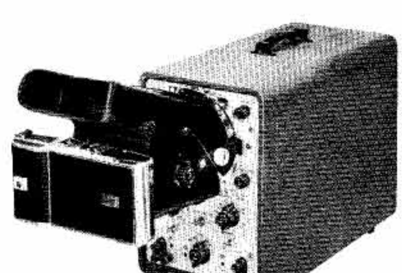
Data subject to change without notice.



Up to 11 equally spaced exposures available.

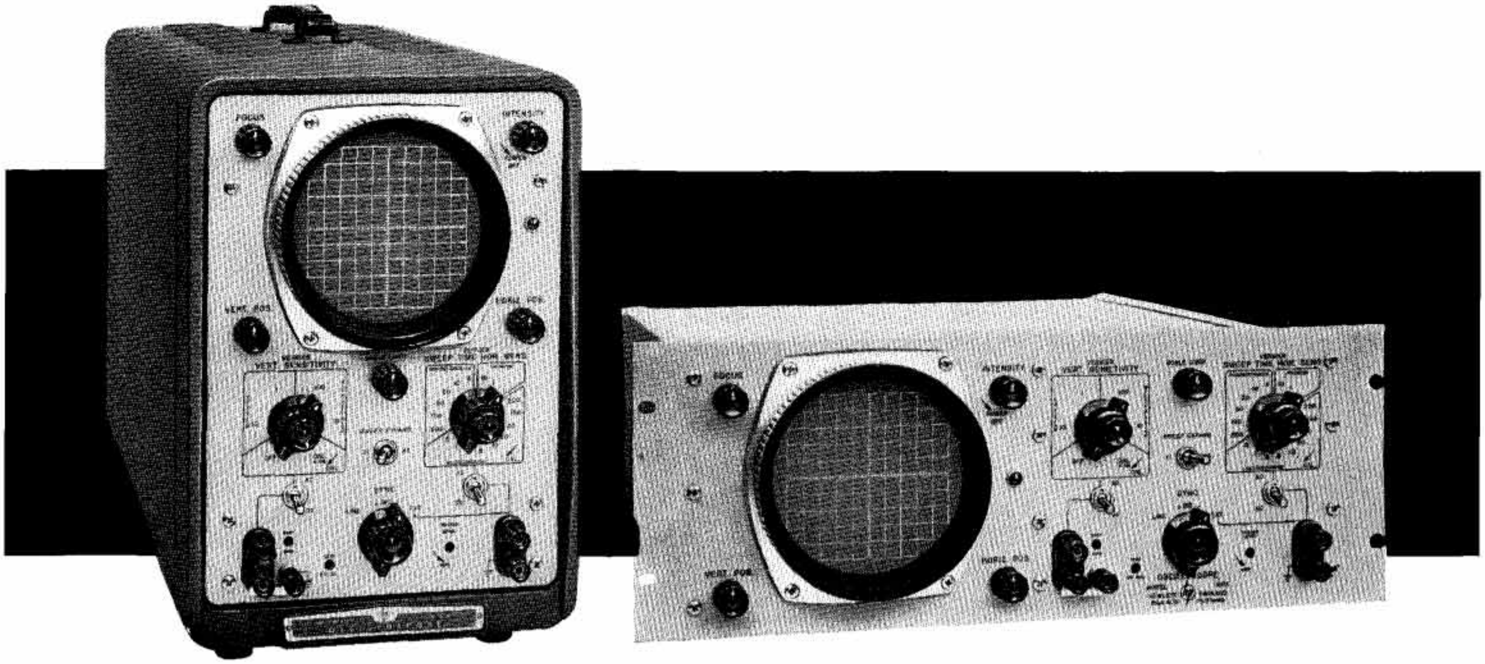


Two 4 x 10 cm field exposures note no overlapping



New hp 196A Camera on hp 120A Oscilloscope.

120A/AR INDUSTRIAL OSCILLOSCOPE



Multi-use Deluxe 200 KC Scope at Low Price

THE POPULAR 120A oscilloscope is deliberately engineered for simple operation, rugged production-line service, and low price. Yet, it remains a precision instrument; there is no compromise with quality to bring you broad usefulness and the attractive price of $435. The 120A gives you calibrated performance plus simplicity readily understandable by production-line personnel.

Automatic Triggering

For example, there are no trigger controls to mis-set. Just connect the synchronizing signal and a stable, steady trace appears automatically. This same universal automatic trigger eliminates "hunting" for the spot; always establishes a baseline when the sync signal is disconnected. This automatic baseline provision, however, may be locked out by a front panel screwdriver adjustment and an external trigger level adjustable from −10 to +10 volts established.

An important quality feature of the 120A is the 5AQP1 mono-accelerator cathode ray tube. This type of tube requires no astigmatism adjustment and is always in sharp focus over the entire face. Such tubes are characteristic of high quality equipment.

Advantages:

Simple to use—automatic trigger, automatic baseline

No computation—read sweep times directly

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

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

Built-in amplifier calibrator assures accurate voltage measurements

Auto baseline "locks out" for photographic work

Uses:

Ideal production tool for measuring complex voltages, stress, strain and vibration analysis, pressure, flow, displacement and other phenomena through proper transducers

Slow sweep speeds for medical or mechanical work

Fast sweep speeds for measuring transients

"Times-5" Sweep Expander

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

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

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

ⓗ 120A oscilloscope is available in a portable cabinet or as a standard 19" relay rack mount instrument. This rack-mount version, Model 120AR, measures only 7" high, and can be supported in the rack by the sturdy front panel or on slides (special order) permitting easy withdrawal.

Specifications

Sweep Range: 1 μsec/cm to at least 0.5 sec/cm. 15 calibrated sweeps, accurate to within ±5%, in a 1–2–5–10 sequence, 5 μsec/cm to 200 msec/cm. Vernier permits continuous adjustment of sweep time between calibrated steps and extends the 200 msec/cm step to at least 0.5 sec/cm.

Sweep Expand: X5 sweep expansion, for all ranges, expands fastest sweep to 1 μsec/cm. Expansion is about the center of the CRT; expanded sweep accuracy is ±10%.

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

Trigger Point: Zero crossing, negative slope of external sync signals, zero crossing, positive or negative slope of vertical deflection signals. Screwdriver control overrides automatic and permits the trigger point to be set between −10 to +10 v. Turning fully counter-clockwise into AUTO restores automatic operation.

Vertical Amplifier

Bandwidth: Dc coupled: dc to 200 KC. Ac coupled: 2 cps to 200 KC. Bandwidth independent of sensitivity setting.

Sensitivity: 10 mv/cm to 100 v/cm. 4 calibrated steps accurate within ±5%, 10 mv/cm, 100 mv/cm, 1 v/cm, and 10 v/cm. Vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

Internal Calibrator: Calibrating signal automatically connected to vertical amplifier for standardizing gain, accuracy ±2%.

Input Impedance: 1 megohm, approx. 50 μμf shunt.

Balanced Input: On 10 mv/cm range. Input impedance, 2 megohms shunted by approximately 25 μμf.

Common Signal Rejection: Rejection at least 40 db. Common signal must not exceed ±3 v peak.

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

Horizontal Amplifier

Bandwidth: Dc coupled: dc to 200 KC. Ac coupled: 2 cps to 200 KC. Bandwidth independent of attenuator setting.

Sensitivity: 0.1 v/cm to 100 v/cm. 3 calibrated steps, accurate within ±5%, 0.1 v/cm, 1 v/cm, and 10 v/cm. Vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

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

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

General

Cathode Ray Tube: 5AQP1 5" mono-accelerator normally supplied; 2500 v accelerating potential. P2, P7 and P11 phosphors also available.

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

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

Intensity Modulated: Terminals on rear. 20 v positive signal blanks trace at normal intensity.

Filter Supplied: Color of filter compatible with screen phosphor supplied.

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

Dimensions: Cabinet Mount: 9¾" wide, 15" high, 21¼" deep. Rack Mount: 19" wide, 7" high, 21¼" deep. 19½" deep behind panel.

Weight: Cabinet Mount: Net 34 lbs. Shipping 50 lbs. Rack Mount: Net 32 lbs. Shipping 47 lbs.

Power: 115/230 v ±10%, 50/1000 cps; 130 watts.

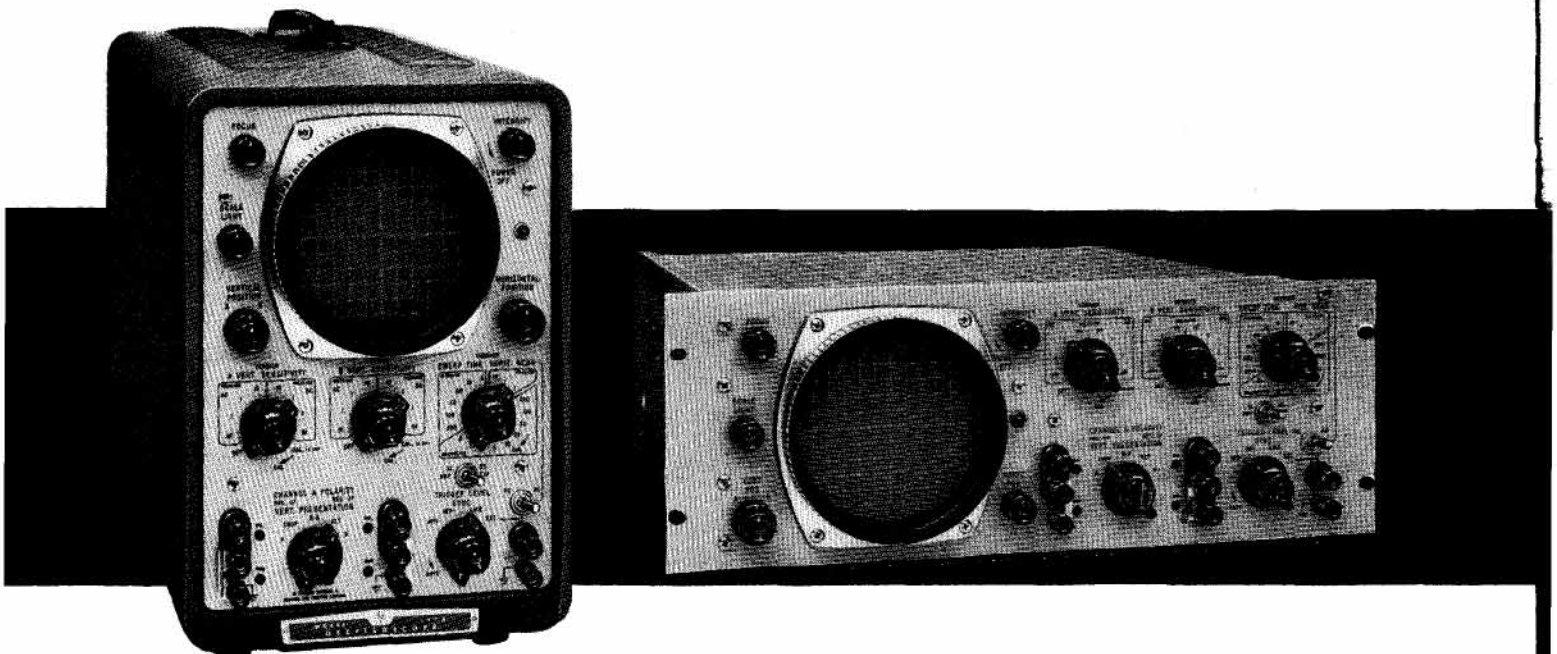
Equipment Slides: Installed at factory on special order for easy withdrawal of rack mount. Specification No. CO1120A, $87.50 extra.

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

Price: (Cabinet or rack model), $435.00.

Data subject to change without notice.

ⓗ 122A/AR 200 KC OSCILLOSCOPE



Advantages:

- Dual trace, compares two signals simultaneously
- Direct reading calibration, automatic trigger, automatic base line
- Easily understood and used by non-technical personnel
- Twin vertical amplifiers; each usable simultaneously
- Alternate and chopped presentation; differential input
- "Times-5" sweep expander; linear integrator for accurate sweeps
- Built-in amplifier calibrator assures accurate voltage measurements

Uses:

- Compare output directly with input of filters, amplifiers, etc.
- Use with vibration testing apparatus, study filter and amplifier characteristics
- Ideal production tool for measuring complex voltages; stress and strain analysis, pressure, flow, displacement and other phenomena through proper transducers
- Slow sweep speeds for medical or mechanical work
- Fast sweep speeds for measuring many transients

Big Scope Dual-Trace Versatility at Moderate Cost!

HERE at last is a 200 KC oscilloscope—priced at just $625—giving you "big scope" utility plus the time-saving convenience of simultaneous two-phenomena observation.

Engineered to speed industrial, mechanical, medical and geophysical measurements in the dc to 200 KC range, the new ⓗ 122A has two identical vertical amplifiers and a vertical function selector.

The amplifiers may be operated independently, (in many ways like having two separate oscilloscopes), differentially on all ranges, alternately on successive sweeps or chopped at a 40 KC rate.

Automatic Triggering

Non-technical personnel can quickly learn the simple operation of the 122A and will use it with confidence since it has a guaranteed calibration on both its sweep or time axis and its voltage amplitude measurement circuitry. In addition, the 122A has the Hewlett-Packard universal automatic triggering arrangement which means there are no trigger controls to mis-set, no "hunting" for the "spot" and a base line is present even when the sync signal is disconnected. (This automatic baseline, however, may be over-ridden by a front panel control and an external trigger level adjustable between −10 to +10 volts established.)

A further convenience and simplicity feature is the use of a high quality 5AQP1 mono-accelerator cathode ray tube. This tube requires no astigmatism adjustment and is always in sharp focus over the entire face.

AC or DC Coupling

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

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

"Times-5" Sweep Expander

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

Model 122A is available in a convenient portable cabinet, or in rack mount configuration as Model 122AR. The rack mount version measures only 7" high and can be supported on a standard 19" relay rack by the sturdy front panel or on slides (special order) permitting easy withdrawal.

Specifications

Sweep

Sweep Range: 15 calibrated sweeps, accurate to within ±5%, in a 1–2–5–10, . . . sequence, 5 μsec/cm to 200 millisec/cm. Vernier permits continuous adjustment of sweep time between calibrated steps and extends the 200 millisec/cm step to at least 0.5 sec/cm.

Sweep Expand: X5 sweep expansion may be used on all ranges and expands fastest sweep to 1 μsec/cm. Expansion is about the center of the CRT and expanded sweep accuracy is ±10%.

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

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

Vertical Amplifiers

Bandwidth: Dc coupled: dc to 200 KC. Ac coupled: 2 cps to 200 KC. Bandwidth is independent of calibrated sensitivity setting.

Sensitivity: 10 millivolts/cm to 100 volts/cm. 4 calibrated steps accurate within ±5%, 10 mv/cm, 100 mv/cm, 1 v/cm and 10 v/cm. Vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

Internal Calibrator: Calibrating signal automatically connected to vertical amplifier for standardizing of gain, accuracy ±2%.

Input Impedance: 1 megohm, approximately 60 μμf shunt capacitance.

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

Balanced Input: On 10 mv/cm range on both amplifiers. Input impedance, 2 megohms shunted by approximately 30 μμf. Common signal rejection is at least 40 db. Common signal must not exceed ±3 volts peak.

Difference Input: Both input signals may be switched to one channel to give differential input on all vertical sensitivity ranges. The sensitivity switches may be set separately to allow mixing signals of different levels. Common signal rejection is at least 40 db with both switches on most sensitive range, 30 db on other ranges.

Vertical Presentation: Switch selects: A ONLY, B ONLY, B-A, ALTERNATE or CHOPPED.

Horizontal Amplifier

Bandwidth: Dc coupled: dc to 200 KC. Ac coupled: 2 cps to 200 KC. Bandwidth is independent of calibrated sensitivity setting.

Sensitivity: 0.1 v/cm to 100 v/cm. 3 calibrated steps, accurate within ±5%, 0.1 v/cm, 1 v/cm, and 10 v/cm. Vernier permits continuous adjustment of sensitivity between steps and extends 10 v/cm step to at least 100 v/cm.

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

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

General

Cathode Ray Tube: 5AQP1 mono-accelerator normally supplied; 2500 volt accelerating potential. P7 and P11 phosphors are also available. P2 is available if desired for special applications.

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

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

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

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

Dimensions: Cabinet Mount: 9¾" wide, 15" high, 21¼" deep. Rack Mount: 19" wide, 7" high, 21¼" deep. 19½" deep behind panel.

Weight: Cabinet Mount: Net 35 lbs. Shipping 51 lbs. Rack Mount: Net 33 lbs. Shipping 48 lbs.

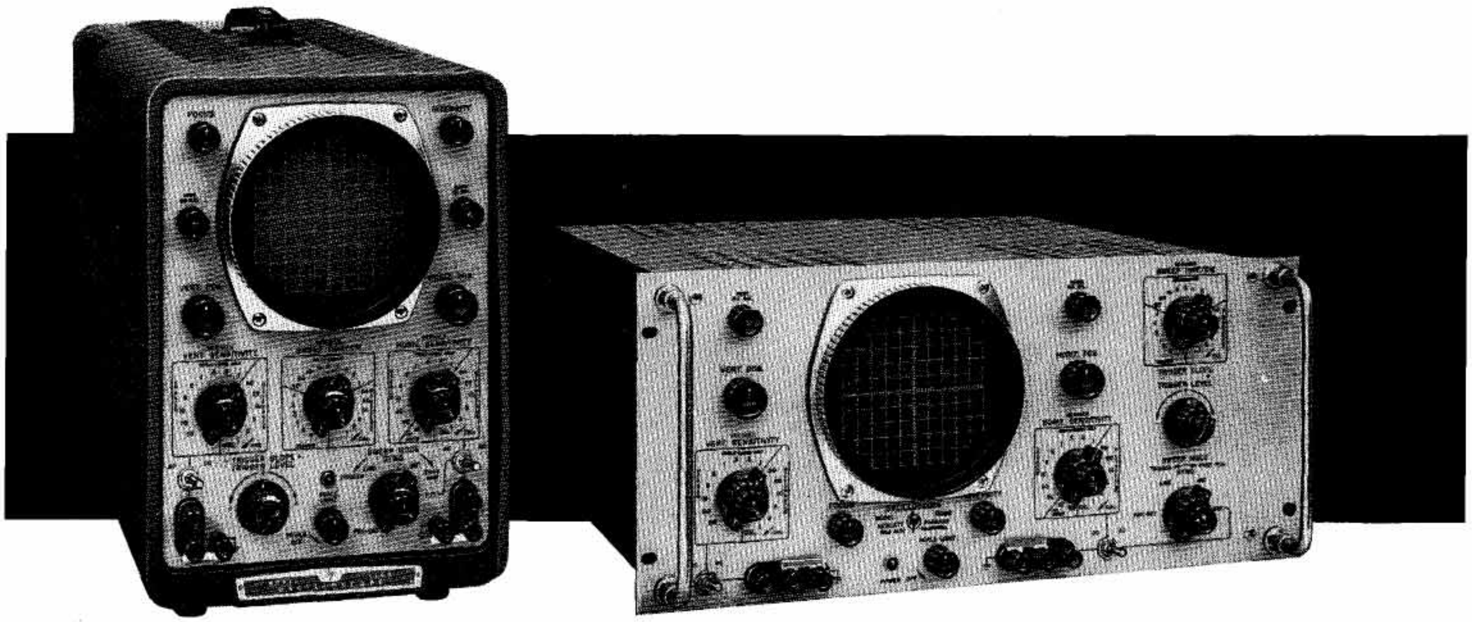
Power: 115/230 v ±10%, 50/1000 cps; approximately 150 watts.

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

Price: (Cabinet or Rack Mount): $625.00. Normally supplied with P1 phosphor. When ordering P2, P7 or P11, specify by adding phosphor number after model. P2 is not recommended for general purposes.

Data subject to change without notice.

ⓗⓟ 130B/BR 300 KC OSCILLOSCOPE



Truly Dependable Laboratory, Production Oscilloscope

Advantages:

Extreme operating dependability
Brilliant, high resolution trace
Automatic triggering system
Sensitivity 1 mv per centimeter
High stability, unique versatility
High gain, balanced input
21 calibrated sweeps; direct reading
Wide pass band, dc to 300 KC
Similar vertical, horizontal amplifiers

Uses:

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

HERE is a unique 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 ⓗⓟ instruments. ⓗⓟ 130B provides each of these advantages, and sets new standards for oscilloscope usefulness, simplicity and reliability.

Covering frequencies from dc to 300 KC, ⓗⓟ 130B is a versatile, all-purpose tool for laboratory, production line and industrial processing measurements. In addition to its versatility as an oscilloscope, ⓗⓟ 130B 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. A "times-5" magnifier, for all ranges, expands the fastest sweep to 0.2 μsec/cm.

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 Vertical, Horizontal Amplifiers

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

Use as Voltmeter

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

Quick CRT Interchange

ⓗ 130B 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 easily to simplify changing 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.

Specifications

Sweep

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

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

Synchronization: Internally from line voltage or from signals causing ½ centimeter or more vertical deflection. Externally from 0.5 volts peak-to-peak or more.

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

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

Input Amplifiers

Vertical and horizontal amplifiers have same characteristics.

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

Stability: 1 mv/hr after warm up.

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

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

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

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

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

General

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

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

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

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

Dimensions: Cabinet Mount: 9¾″ wide, 15″ high, 21¼″ deep. Rack Mount: 19″ wide, 8¾″ high, 22″ deep, depth behind panel 19¾″.

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

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

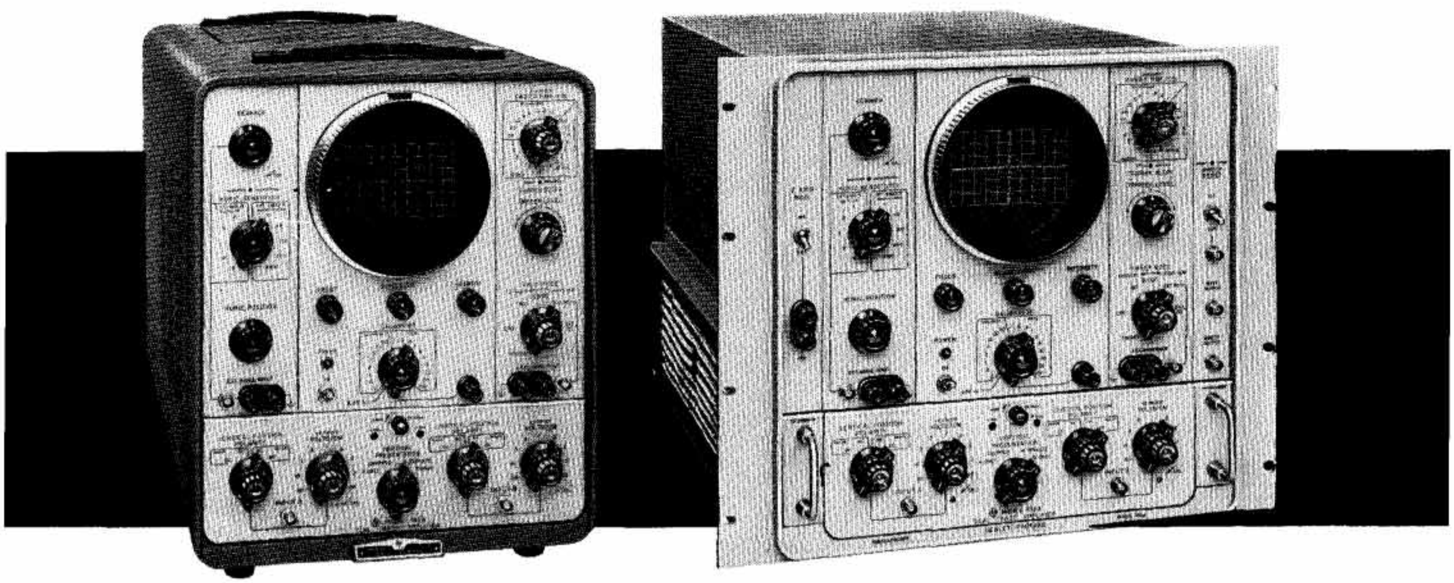
Filter Supplied: Color of filter compatible with screen phosphor: green for P1 and P2, amber for P7, blue for P11.

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

Price: (cabinet or rack mount) $650.00. Normally supplied with P1 screen. When ordering with P2, P7 or P11 ~~sereen~~, specify model and phosphor number.

Data subject to change without notice.

ⓗ 150A/AR 10 MC 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 probes
- Sweep magnification of 5, 10, 50 and 100 x
- Single shot sweep with lock-out
- Twist-off bezel; CRT access door
- Quick CRT interchange
- Unitized construction
- Color-coded, concentric controls, simplified and functionally grouped

Uses:

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

High Sensitivity, Dual Trace, Outstanding Scope Value

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

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.

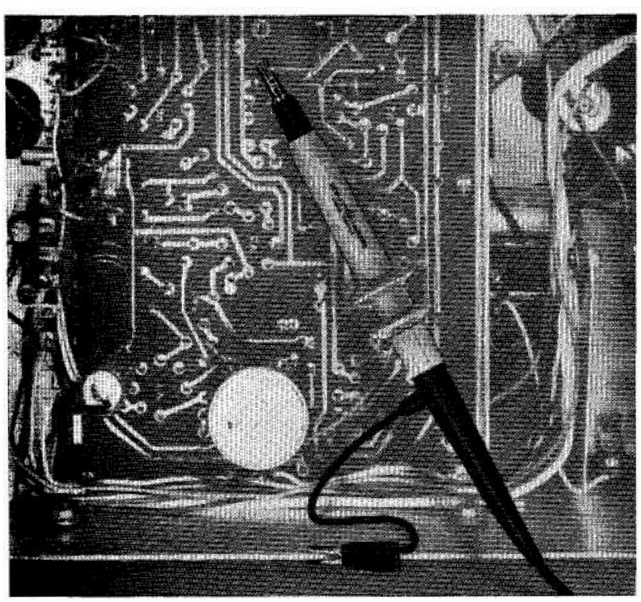
Sweep Magnification

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.

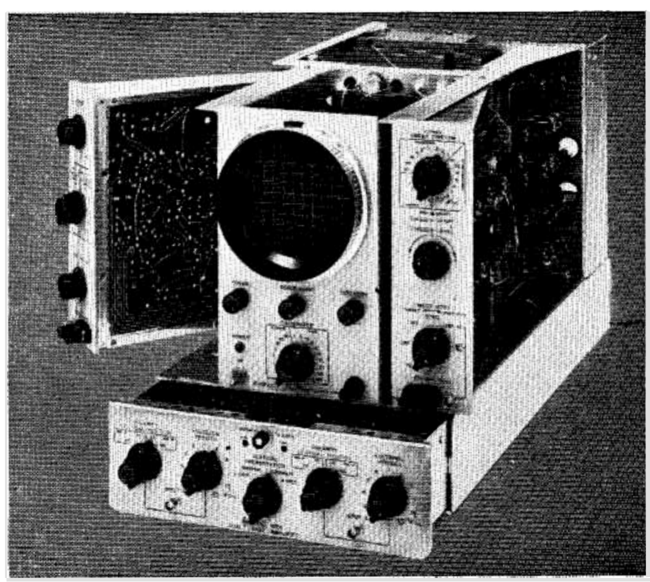
Two New Low Capacity Probes

For use with Models 150A/AR, hp has developed two highly convenient, pen-sized test probes with miniature alligator jaws. One of these probes, Model AC-21A (pictured) has a 10 $\mu\mu$f capacitance, 10 megohm impedance and provides a 10:1 voltage division. The other probe, Model AC-21C, is identical in appearance but has a 2.5 $\mu\mu$f capacitance, 9 megohm impedance and provides a 50:1 voltage division. Compensating capacity is adjustable by rotating one portion of the Nylon barrel of the probes. Two Model AC-21A probes are supplied as standard accessories with hp 150A or 150AR oscilloscopes, or are available separately at $25.00. Model AC-21C probe is offered as a separate accessory, also at $25.00. Either grey or black leads may be supplied.



Highly Convenient

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 unitized and may be isolated from the instrument by unplugging. Many 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.



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%.

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.

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

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 5 v/cm. Five calibrated ranges plus vernier.

Input Impedance: 1 megohm shunted by 27 $\mu\mu$f.

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 approximately 1 μsec.

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

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

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

CRT Bezel: 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 610 watts.

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

Dimensions: Cabinet Mount: 13½" wide, 17¼" high, 25" deep. Rack Mount: 19" wide, 15½" high, 23 - 5/16" deep behind panel.

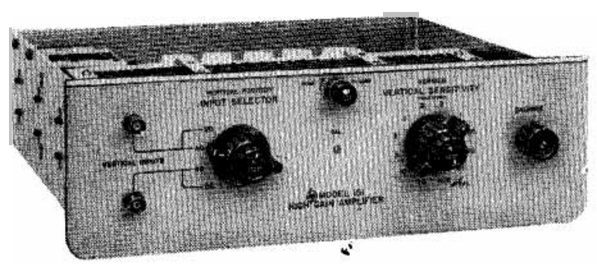
Weight: Net 83 lbs. Shipping 125 lbs. (cabinet mount). Net 97 lbs. Shipping 198 lbs. (rack mount).

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

Accessories Available: AC-21A 10:1 Low Capacity Probes (specify grey or black lead), $25.00; AC-21C 50:1 Low Capacity Probe, $25.00. AC-76A BNC Male to Binding Post Adapter, $5.00; AC-83A Viewing Hood, $5.00; AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00; AC-16K Cable Assembly, $5.00.

Price: $1,100.00 (cabinet); $1,200.00 (rack mount). (Normally supplied with P2 screen. For P1 screen, specify 150A-1; for P7 screen, specify 150A-7; for P11 screen, specify 150A-11.)

151B High Gain Amplifier



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

Input Attenuator: 12 calibrated ranges, in 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 27 $\mu\mu$f.

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

Coupling: ac or dc.

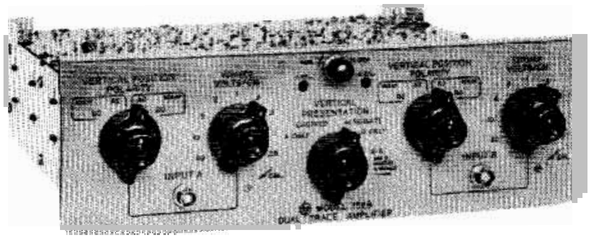
Dual Inputs: Two signal inputs with Type BNC. Selection of either input by panel switch.

Weight: Net 4 lbs. Shipping 9 lbs.

Price: $200.00.

Data subject to change without notice

ⓗⓟ 152B Dual Channel Amplifier



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

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

Input Impedance: 1 megohm shunted with 30 $\mu\mu f$.

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

Coupling: Ac or dc.

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

Vertical Positioning: Individually adjustable.

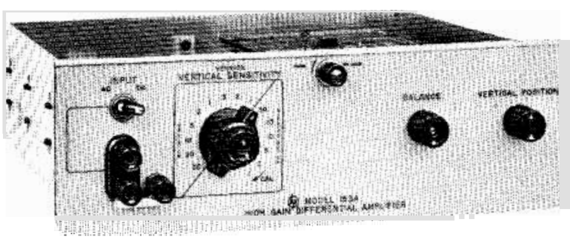
Polarity of Presentation: Input signal as applied or inverted.

Input Connectors: Type BNC both channels.

Weight: Net 4 lbs. Shipping 10 lbs.

Price: $250.00.

ⓗⓟ 153A Differential Amplifier



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

Input Attenuator: 15 calibrated ranges, in 1-2-5-10 sequence, from 1 mv/cm to 50 v/cm. Vernier permits continuous adjustment between ranges.

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

Coupling: Ac or dc.

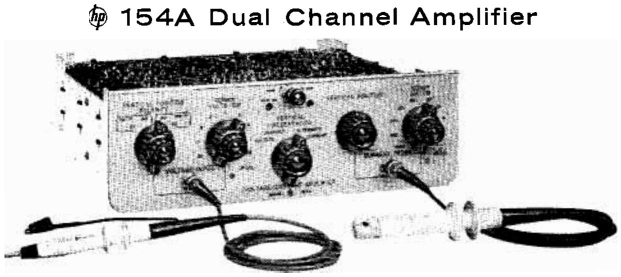
Input Impedance: 2 megohms shunted with 17 $\mu\mu f$ (balanced). 1 megohm shunted with 35 $\mu\mu f$ (single-ended).

Common Signal Rejection: (Balanced input only.) At least 40 db on 1 mv/cm range when signal does not exceed 1.5 volts.

Weight: Net 4 lbs. Shipping 9 lbs.

Price: $125.00.

ⓗⓟ 154A Dual Channel Amplifier



Sensitivity Range: 1 ma/cm to 1,000 ma/cm (current). 0.05 v/cm to 20 v/cm (voltage).

Pass Band: 50 cps to 8 MC (current). Dc to 10 MC, dc coupled (voltage). 2 cps to 10 MC, ac coupled (voltage).

Input Impedance: Current channel: probe adds approx. 0.01 ohm with 1 μh shunt to test circuit. Voltage channel: 1 megohm, 30 μf shunt.

Maximum Current: Ac - 10 amps rms, 20 KC and above; dc up to 0.5 amp has no appreciable effect.

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

Weight: Net 5 lbs. Shipping 10 lbs.

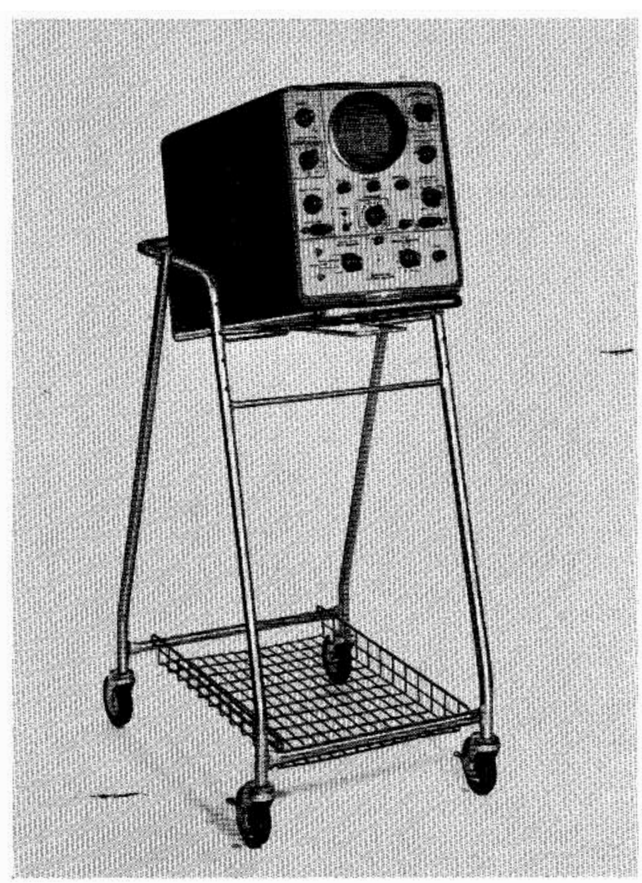
Price: $430.00 (includes AC-21F Current Probe).

New Oscilloscope Cart

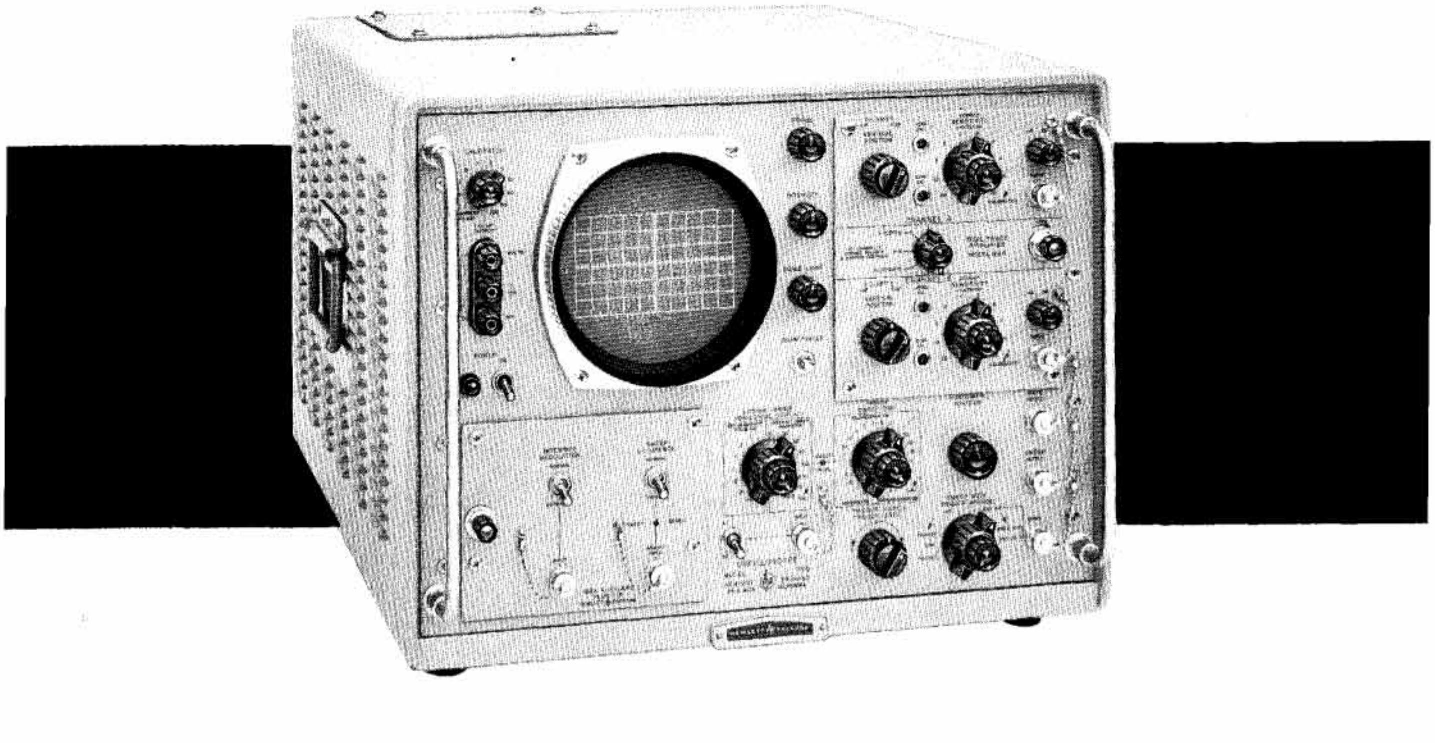
ⓗⓟ AC-115B Oscilloscope Testmobile

Here is a sturdy, attractive and highly convenient cart that makes it easy to move your oscilloscope, or to tilt the scope up to 30° in 7½° increments for better viewing.

Specifically designed for ⓗⓟ cabinet mount Oscilloscopes, the 115B Testmobile is also usable with other instruments. The unit rolls easily on large, 4″ rubber-tired wheels. Construction is of rugged ⅞″ tube stock, highly chromed. Overall size of the cart (less oscilloscope) is 40″ high x 25-7/16″ wide x 29″ deep. The unit weighs only 28 pounds, and folds compactly for shipment or storage. Price, $85.00.



hp 160B 15 MC OSCILLOSCOPE



Advantages:

Extra rugged, militarized instrument

Dual channel plug-in unit

Premium components for unique dependability

24 calibrated sweeps, 0.1 μsec/cm to 5 sec/cm

Magnifier increases fast sweep to 0.02 μsec/cm

Reliable operation in extreme environments

Simplified layout for easy maintenance

Tube-transistor circuits increase stability, lengthen tube life.

Uses:

Aircraft, missile check-out systems

Field locations

Test installations in adverse environment

General-purpose laboratory measurements involving fast circuit pulse applications including radar, TV, nucleonics and guidance systems

High Sensitivity, Militarized Multi-Purpose Oscilloscope

THE NEW hp 160B is a premier instrument in every respect—perhaps the most convenient, dependable and versatile 15 MC oscilloscope ever offered.

Maximum accuracy and reliability are possible since Model 160B is designed to military specifications to withstand shock, vibration, humidity and temperature variations—using MIL-E-16400B as design guide.

High stability is contributed to the 160B by hp-developed tube-transistor circuitry, and regulated dc filament voltages throughout. Power transistors are mounted in efficient heat sinks to insure adequate cooling even at high ambient temperatures.

Printed circuit boards are translucent glass-epoxy for convenient viewing of components on opposite sides. Of 42 tubes, 32 are of the same type; solid state components are three transistor and one rectifier type; thus, parts inventory is streamlined.

Dual Channel Amplifier

hp 162A Dual Channel Amplifier, plugged in to Model 160B, provides maximum sensitivity of 20 mv/cm with dual channel operation featuring electronic switching on either an alternate sweep or 1 MC chopping basis; or, a differential presentation is available.

Each amplifier of Model 162A has its individual attenuator and positioning controls so baselines or waveforms can be positioned for ready comparison. This also means that in differential mode, signals of different amplitude may be compared or undesirable common mode signals (such as hum) attenuated.

Specifications

ⓗⓟ 160B 15 MC Oscilloscope

(with ⓗⓟ 166A Auxiliary Unit plugged in. Model 166A, essential for operation of 160B and supplied with 160B, provides trigger input, Z-axis input and single sweep arming input connections.)

Sweep Generator:

Internal Sweep: 24 calibrated ranges, 0.1 μsec/cm to 5 sec/cm, accuracy within 3%. Vernier extends slowest sweep to 15 sec/cm.

Magnification: 7 calibrated ranges expanding sweep 1, 2, 5, 10, 20, 50 and 100 times. Increases fastest sweep speed to 0.02 μsec/cm.

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

Trigger Point: Positive or negative going voltage, +30 to −30 v external trigger level.

Single Sweep: Provided by switch with manual or electrical re-set.

Sawtooth Output: −50 to +50 v concurrent with sweep.

Gate Output: 50 v pulse for duration of sweep.

Horizontal Amplifier:

Bandwidth: Dc to 1 MC.

Sensitivity: 0.1 v/cm to 10 v/cm, 7 ranges; vernier extends minimum sensitivity to 25 v/cm.

Input Impedance: 1 megohm shunted by 30 μμf.

Calibrator:

1,000 cps square wave with approx. 1 μsec rise and decay time. 9 calibrated ranges, 0.2 mv to 100 v peak-to-peak. 5 ma current peak-to-peak, accuracy within ±3%.

Cathode Ray Tube:

Type: 5 AMP-mono accelerator, flat face, P1, P2, P7, or P11 screen. 5000-volt accelerating potential.

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

Graticule: 10 cm long x 6 cm high marked in centimeter squares; 2 mm subdivisions on horizontal and vertical axes. Controlled edge lighting.

Deflection Plate Connection: Pin type terminals.

Deflection Sensitivity: 20 volts/cm approximately.

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

General:

Power Requirements: 115/230 v ± 10%, 50/60 cps, 50/440 cps on special order, approx. 480 watts.

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

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

Plug-in Vertical Amplifier: Model 162A Dual Trace Amplifier, dc to 14 mc, differential input.

Accessories Available: AC-83A Viewing Hood, AC-21A Probe, 10:1 voltage division, AC-21C Probe, 50:1 voltage division, AC-76A BNC to binding post adapter.

Accessories Furnished: Two AC-21A Probes.

Price: $1850.00.

ⓗⓟ 162A Dual Channel Amplifier (When used with ⓗⓟ 160B)

Each Channel:

Sensitivity Range: 0.02 v/cm to 50 v/cm.

Input Attenuator: 10 calibrated ranges, 1, 2, 5, 10 sequence, 0.02 v/cm to 20 v/cm; accuracy ±5%.

Pass band: Dc coupled: dc to 14 MC, 0.025 μsec risetime. Ac coupled: 2 cps to 14 MC.

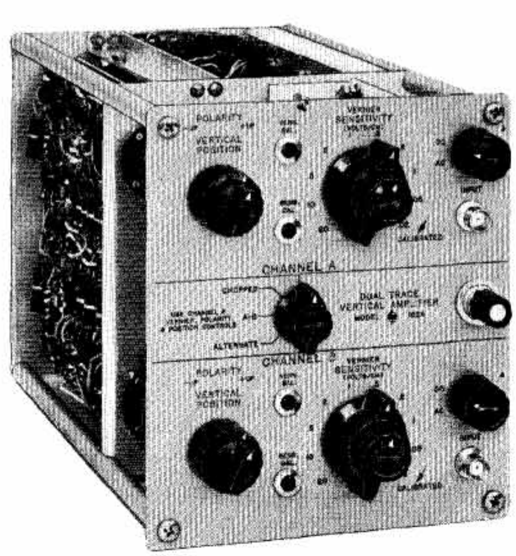
Input Impedance: 1 megohm with 30 μμf shunt.

Electronic Switching: Alternate sweep or 1 MC chopping.

Differential Input: Both inputs may be switched to one channel to give differential input. Input attenuators adjustable separately.

Common Mode Rejection: At least 40 db (max. sensitivity) or 30 db (with attenuators). Differential input only.

Price: $350.00.



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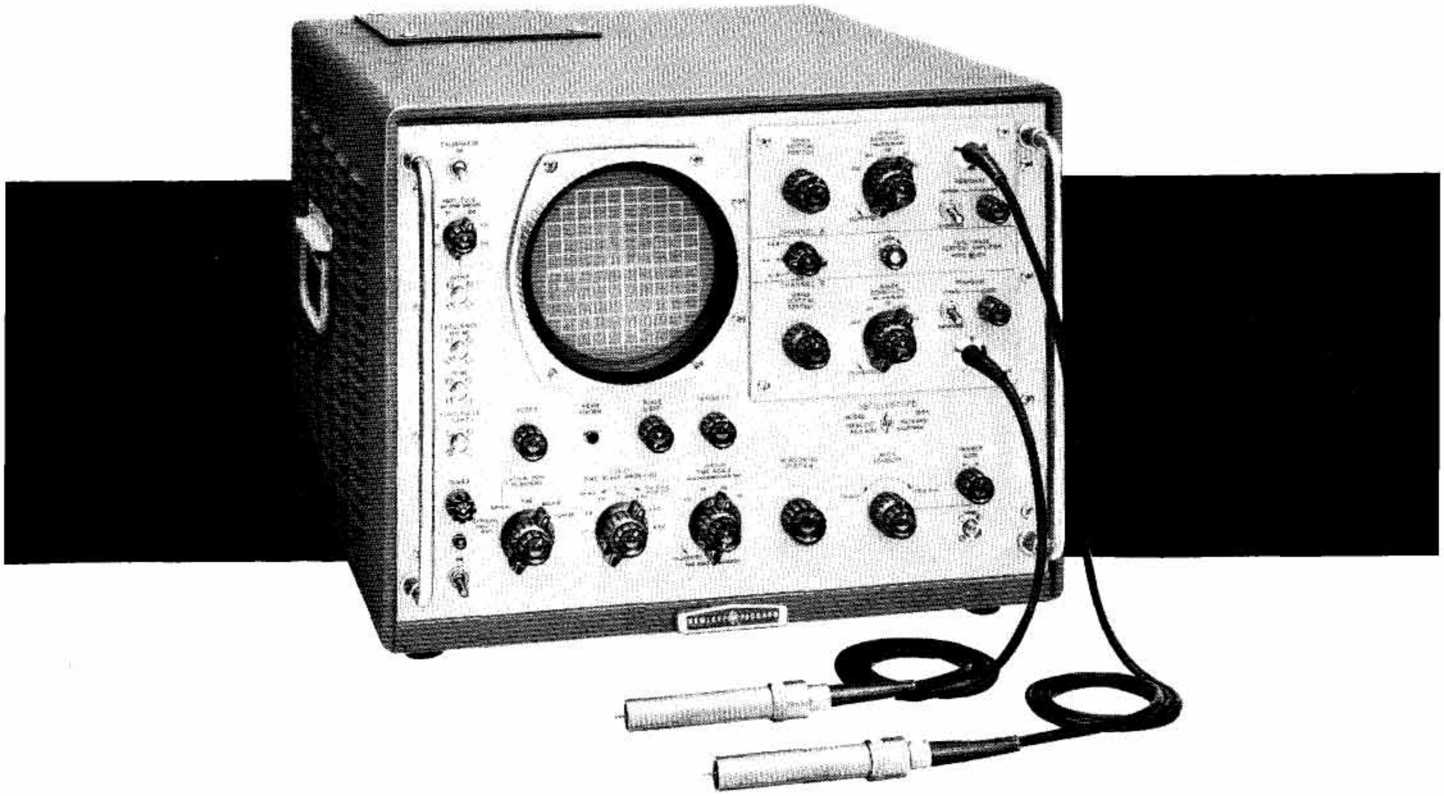
185A 500 MC OSCILLOSCOPE



Advantages:

- Bright, clear, 5″ scope presentation of repetitive short pulses requiring 500 MC and greater bandwidth
- Bright, steady traces even at repetition rates down to 50 cps
- Less than 0.7 millimicrosecond rise time for brilliant picture of millimicrosecond pulses
- Dual channel, differential input permits study of two high speed signals, or time vs. duration, spacing
- X-100 expander provides 0.1 millimicrosecond/cm sweep speed
- High sensitivity for viewing small signals; wide dynamic range for viewing small voltages on high voltage plateaus
- X-Y recorder output; time, amplitude calibrators, beam finder, conventional oscilloscope controls

Uses:

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

Conventional Measuring Ease in Millimicrosecond Region

THE hp 185A 500 MC Oscilloscope is a completely new instrument essentially as easy to use and easy to read as a conventional broadband oscilloscope—yet providing a wealth of fast-circuit information.

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

The 185A provides brilliant, steady 5″ scope traces that are totally comparable in information, clarity and usefulness with the presentations you expect at much lower frequencies.

Sampling Oscilloscope

Whereas most previous oscilloscopes have been broadband instruments, the new hp 185A is a sampling oscilloscope.

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

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

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

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

Built-In Delay Feature

Model 185A syncs with external triggers to 50 MC, and also provides a front panel delayed sync pulse which may be used to trigger the circuit under test. In situations where the circuit will respond to this trigger, a delay line is unnecessary.

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

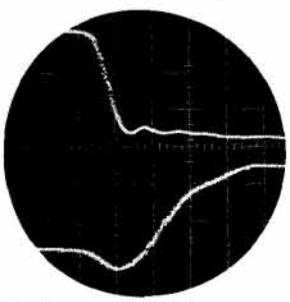
Dual or Differential Input

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

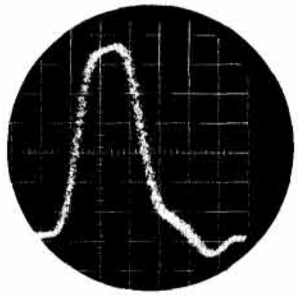
Special, Easy-to-Use Probes

An outstanding feature of the hp 187A is the pair of compact, new-concept probes arranged for easy application to the test circuit. The probes provide a high 100,000 ohm input resistance shunted by 3 $\mu\mu$f to virtually eliminate loading of the test circuit. For maximum versatility, the probes may be used with Type N, BNC or other fittings.

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



Simultaneous dual pulse presentation. Top is pulse from mercury pulser, applied to 2N1383 mesa transistor. Bottom is responding turn-on of transistor. Scope sweep speed 1 mμsec/cm.



2 millimicrosecond pulse on the big, clear 5" cathode ray tube of -hp- 185A. Trace is brilliant, unflickering, does not cause eye fatigue.

Specifications

hp Model 187A Dual Trace Amplifier

(When plugged into Model 185A Oscilloscope)

Vertical (Dual Channel):

Bandwidth: Greater than 500 MC at 3 db point. Less than 0.7 mμsec rise time.

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

Voltage Calibrator: 10 mv to 500 mv, accuracy $\pm 3\%$.

Input: By means of input probe for each channel.

Noise: Less than 2 mv peak-to-peak; reduced by approximately 3:1 in smoothed (noise compensation) position of input switch.

Input Impedance: 100,000 ohms shunted by 3 $\mu\mu$f.

Price: $1,000.00.

hp Model 185A Oscilloscope

Horizontal:

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

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

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

Jitter: Less than 0.1 mμsec peak-to-peak; reduced by approximately 3:1 in smoothed (noise compensation) position of vertical input switch.

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

Manual Scan: Permits making X-Y pen-recordings.

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

Minimum Delay: Less than 120 mμsec.

Variable Delay Range: Ten times the Time Scale setting less the display time. (Time Scale magnified.)

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

"Sampling" Repetition Rate: 100 KC maximum.

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

Trigger Input Impedance: With Sync Probe, greater than 500 ohms; without probe, 50 ohms at panel. Capacitive coupling.

Sync Pulse Output:

Amplitude: Negative 1.5 volts into 50 ohms.

Rise Time: Approximately 2 mμsec.

Timing: Approximately 20 mμsec after start of undelayed trace.

Repetition Rate: Approximately 100 KC or rate may be controlled by a fast-rise generator.

General:

X-Y Recorder Output: Available in Manual Scan for making pen-recording of waveforms:

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

Cathode Ray Tube: 5 in. type 5AQP.

Useful Deflection: 10 cm x 10 cm.

Power: 115/230 volts $\pm 10\%$, 50/60 cps, approx. 250 w.

Dimensions:

Cabinet Mount: 14⅝" high, 19" wide, 22⅛" deep.

Weight: Net 75 lbs.

Accessories Furnished: 187A-76A BNC Adapter, 2 supplied. 185A-21A Sync Probe.

Accessories Available: 187A-76B Type N Adapter. 187A-76C 10:1 Divider. 187A-76D Blocking Capacitor. 187A-76E 50 ohm T Connector. AC-16V 120 mμsec Delay Line.

Price: $2,000.00 (cabinet).

Data subject to change without notice.

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)*.

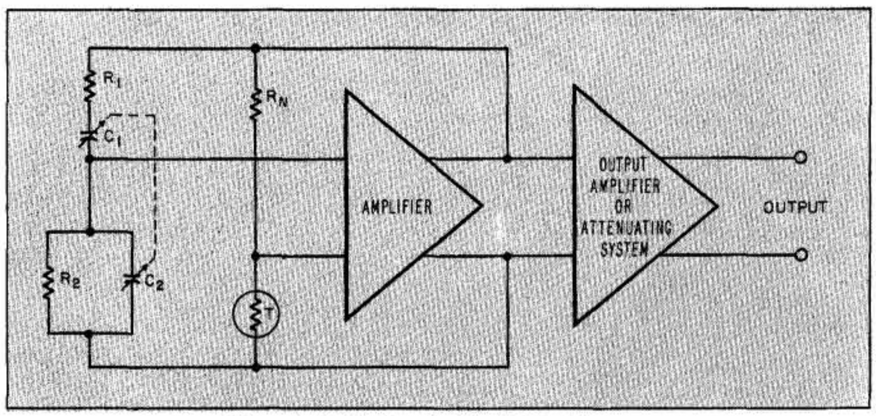


Figure 1. Basic Circuit, *-hp-* RC Oscillator.

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.

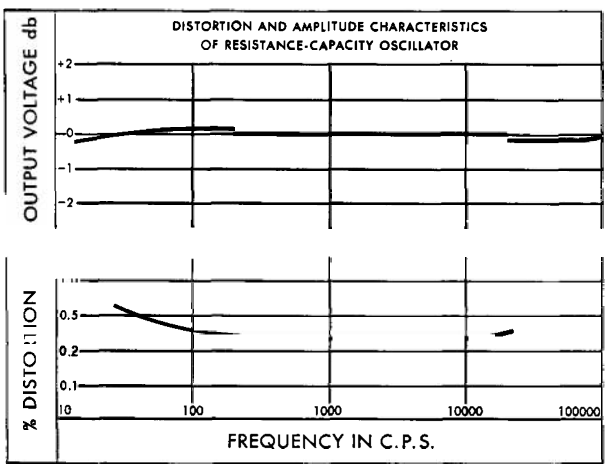


Figure 2. Distortion and Amplitude Characteristics, RC Oscillator.

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.

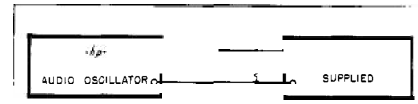
Distortion

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-



tory for most applications. Other values of resistance may be used to obtain different voltage division, but the total load presented to the oscillator should be less than the rated load to prevent distortion of the signal due to saturation of the oscillator output stages.

Accuracy

"Overall accuracy" as applied to a variable-frequency oscillator is a general term including factors such as inherent circuit stability, mechanical stability, resettability of the tuning system, readability of the tuning dial, dial calibration, component aging, power supply variations and temperature changes. Some of these factors affect short time stability; others affect long time stability. The accuracy specification of within 2% usually given for RC oscillators 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 pages 29, 30, 31) 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

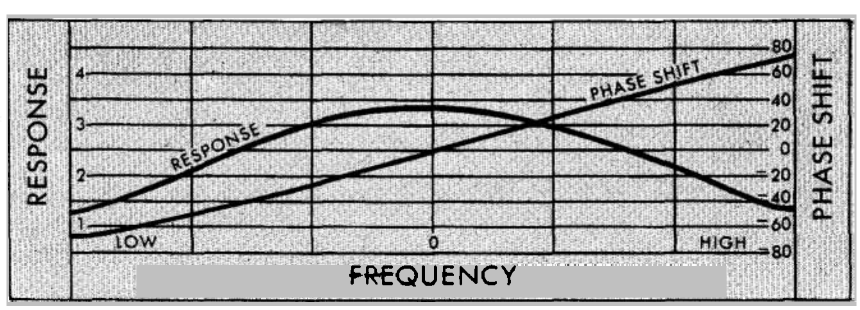


Figure 3. Characteristics of Frequency Determining Network.

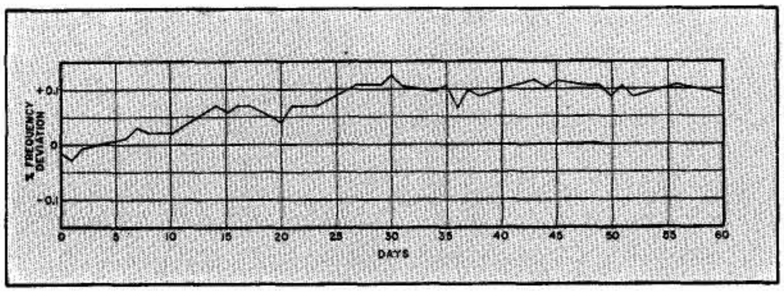


Figure 5. Long-time stability curve of circuit using wire-wound resistors and temperature compensation.

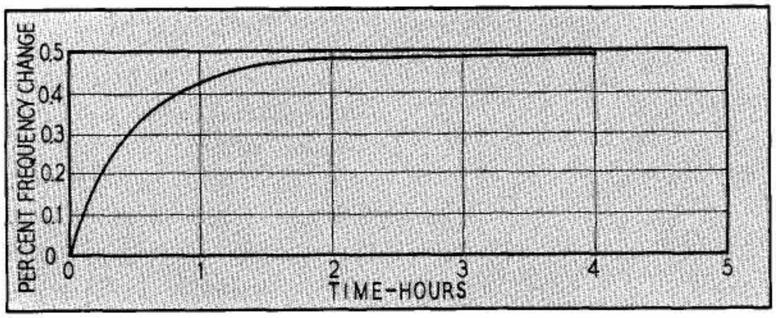


Figure 6. Typical short-term stability of RC oscillator.

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 36, 37) 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 32, 33) 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 31) 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 31) 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 34) 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*- 200S is a version of -*hp*- 200CD Oscillator designed to provide low frequency signals required by -*hp*- 739AR Frequency Response Test Set. Together Models 200S and 739AR quickly and accurately determine frequency response of ac vacuum tube voltmeters between 5 cps to 10 MC. In addition, these instruments in combination may be used to measure frequency response of oscilloscopes, amplifiers and filters. -*hp*- 200S is also part of the 3-instrument Hewlett-Packard Voltmeter Calibration System which provides both frequency response and voltage calibration. Further details of this system appear on page 55.

Waveform distortion and output impedance of Model 200S have been made low to insure reliable measurements. For further information, see "Specifications", page 29, opposite.

-*hp*- Model 200T is a precision telemetering test oscillator specifically designed to provide the highest possible frequency stability in a commercial wide range, audio oscillator. It covers the frequency range from 250 cps to 100 KC. The band spread is arranged to provide wide overlap so that the entire IRIG spectrum for FM-FM telemetering is covered without splitting a single telemetering channel (see page 30).

The latest -*hp*- RC oscillator is Model 207A Audio Sweep Oscillator (page 35). 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 ±3% 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 163.

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

Exceptional Value, Highest Quality Throughout

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 is available on order.

Specifications

Model	Frequency Range	Calibration Accuracy	Output to 600 Ohms	Recommended Load	Maximum Distortion	Max. Hum & Noise ¶	Input Power	Weight—Lbs. Net	Ship	Size (Inches) W H D	Price
200AB	20 cps to 40 KC (4 bands)	±2%	1 watt (24.5 v)	600 ohms	1% 20 cps to 20 KC 2% 20 KC to 40 KC	0.05%	65 watts	15	22	7½ x 11½ x 12¼	$150.00
200CD	5 cps to 600 KC (5 bands)	±2%	160 mw 10 volts	600 ohms*	0.5% below 500 KC 1% 500 KC and above	0.1%	75 watts	23	29	7½ x 11½ x 14¼	$170.00
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	$300.00
200S	5 cps to 600 KC (5 bands)	±2%	3 v rms (50 ohms)	50 ohms	0.5% below 500 KC. 1%, 500 KC and above	0.1%	75 watts	23	29	7½ x 11½ x 14¼	$180.00
200T	250 cps to 100 KC (5 bands)	±1%†	160 mw 10 volts	600 ohms*	0.5%	0.03%	160 watts	27	42	18¾ x 9¼ x 11¾	$450.00
201C	20 cps to 20 KC (3 bands)	±1%†	3 watts (42.5 v)	600 ohms**	0.5%‡	0.03%	75 watts	16	23	7½ x 11½ x 12½	$225.00
202C	1 cps to 100 KC (5 bands)	±2%	160 mw 10 volts	600 ohms*	0.5%§	0.1%	75 watts	27	33	7½ x 11½ x 14¼	$300.00

*Internal impedance is 600 ohms. Frequency and distortion unaffected by load resistance. Balanced output with amplitude control at 100. Use line matching transformer for other control settings. **Internal impedance approximately 600 ohms with output attenuator at 10 db or more. Approximately 75 ohms below 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.

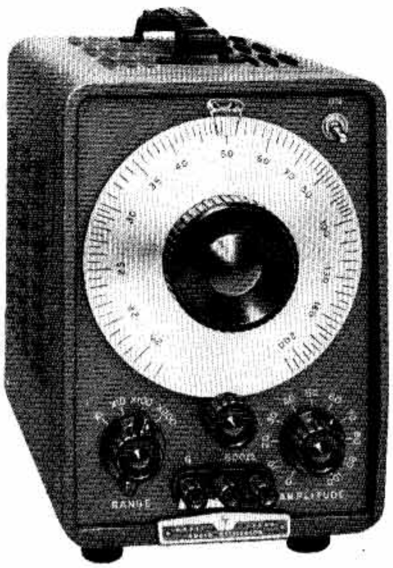
Size and Weight: Maximum overall size and weights are given for cabinet models. 19″ rack models also available.

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, $5.00; AC-60A Line Matching Transformer, $45.00.

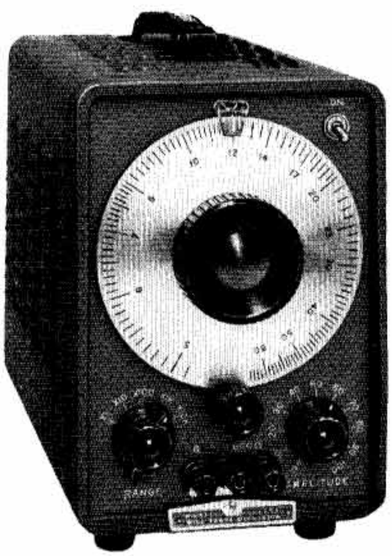
Data subject to change without notice.

200AB/200CD/200T OSCILLATORS



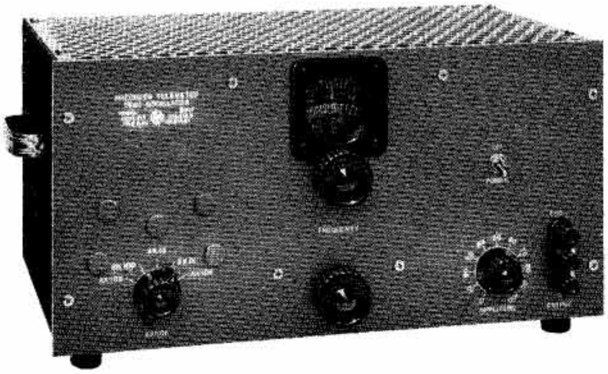
200AB Audio Oscillator

This basic and widely used oscillator is a compact, convenient source of precision audio test voltages at extremely low price. Frequency coverage is 20 cps to 40 KC, covered in four overlapping bands. The 63″ effective scale length and 72 dial divisions insure accurate direct frequency setting on the large, easily read logarithmic dial. Output is 1 watt or 24.5 volts into 600 ohms, and output is balanced full range for dependable driving of transmission systems. Distortion is less than 1% to 20 KC, and hum is at least 66 db below rated output. The 200AB is ideal for amplifier testing, as a bridge voltage source, for testing transmitter modulator response, modulating signal generators, syncing-pulse generators, making loudspeaker resonance tests and powering mechanical systems. $150.00 (cabinet); $155.00 (rack mount).



200CD Wide Range Oscillator

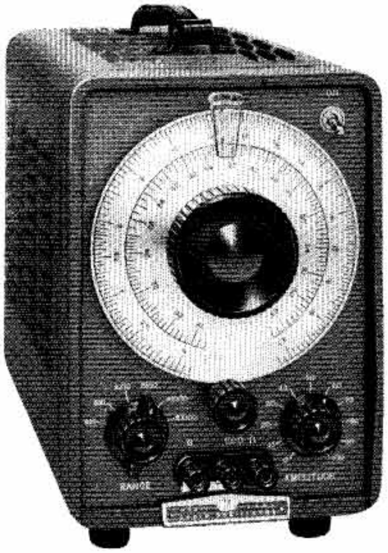
One of the most popular of all oscillators, Model 200CD covers the range 5 cps to 600 KC and is particularly useful for testing servo and vibration systems, medical and geophysical equipment, audio amplifiers, sonar and supersonic apparatus, carrier telephone systems, video frequency circuits, etc. The instrument provides at least 160 mw or 10 volts across 600 ohms, or 20 volts open circuit. Distortion is less than 0.5% below 500 KC. Waveform purity is maintained with extremely low loads. Frequency is covered in 5 decade ranges, and accuracy is ±2% including warmup, aging, tube changes, etc. Frequency response is ±1 db full range. $170.00 (cabinet); $175.00 (rack mount).



200T Telemetry Oscillator

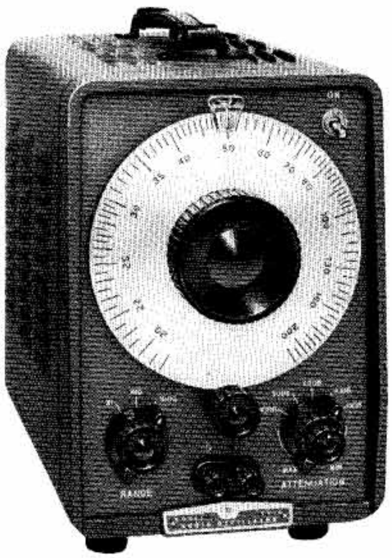
Model 200T is designed to provide the highest possible frequency stability in a wide range, convenient commercial audio oscillator. It is particularly useful for precise, high resolution frequency checking applications such as the evaluating of telemetering circuits, determination of carrier current equipment operation, and measurement of characteristics of sharply tuned filters. Model 200T covers frequencies 250 cps to 100 KC with good overlap between bands; output is 160 mw or 10 volts into 600 ohms, or 20 volts open circuit. The instrument is compact, versatile, simple to operate and available in either cabinet or rack mounting. It covers RDB channels 1 through 18 and no channel is split by band-switching. $450.00 (cabinet); $455.00 (rack mount).

ⓗⓟ 200J, 201C, 202C OSCILLATORS



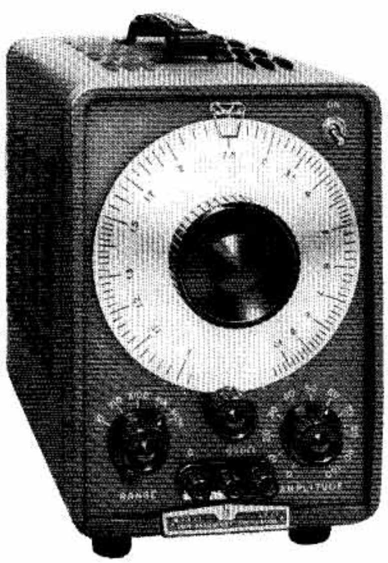
ⓗⓟ 200J Interpolation Oscillator

THIS ultra-precision instrument replaces the well-known ⓗⓟ 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. $300.00 (cabinet); $305.00 (rack mount).



ⓗⓟ 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 ⓗⓟ 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 (cabinet); $230.00 (rack mount).



ⓗⓟ 202C Low Frequency Oscillator

Replacing the established ⓗⓟ 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 (cabinet); $305.00 (rack mount).

hp 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

⊕ 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 ⊕ exclusively for this equipment. In this circuit, 12 crystal diodes 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 ⊕ 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.

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

Output System: Output is isolated from ground and either side may be grounded. Output system is direct coupled; dc level of output remains stable over long periods of time and can be adjusted to zero by a front panel control.

Frequency Response: Constant within 0.2 db.

Hum Level: Less than 0.01% 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 ±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 ⊕ AC-17 End Frames.

Weight: Net 43 lbs. Shipping 63 lbs. (cabinet mount). Net 36 lbs. Shipping 74 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00.

Price: $525.00 (cabinet); $510.00 (rack mount).

Data subject to change without notice.

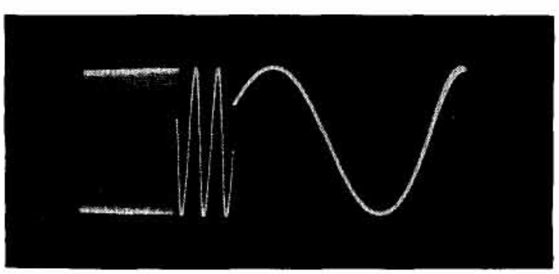


Figure 1. Oscillogram shows freedom from transients as output frequency is rapidly changed.

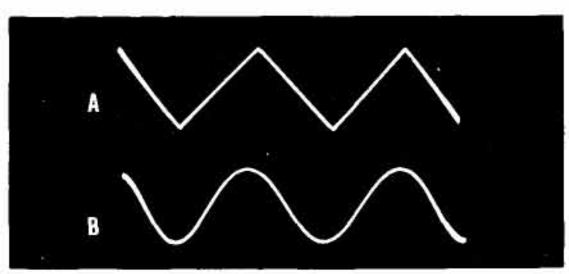


Figure 2. Oscillogram of (A) triangular wave applied to special ⊕ developed shaping circuit and (B) resulting true sine wave.

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 maximum 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. Less than 3% distortion, 100 KC to 500 KC.

Modulation: No. 1 output modulated at voice frequencies 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, 185 watts.

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

Weight: Net 39 lbs. Shipping 59 lbs. (cabinet mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00.

Price: $500.00.

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.

207A AUDIO SWEEP OSCILLATOR

Continuous Coverage 20 cps to 20 KC For Swept Audio Tests

THE 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 either 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 sweeps the instrument through its full frequency range with 150° of rotation.

Since 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 warm-up, aging, tubes, etc.

Frequency Response: ±3% entire frequency range.

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

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, 90 watts.

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

Weight: Net 21 lbs. Shipping 26 lbs. (cabinet mount). Net 27 lbs. Shipping 42 lbs. (rack mount).

Optional Motor Drive: Supplies an output voltage proportional to logarithm of frequency. Permits true logarithmic presentation on an oscilloscope or X-Y recorder. Specify H02-207A (cabinet mount) $625.00; (rack) $630.00.

Price: $325.00 (cabinet); $330.00 (rack mount).

Data subject to change without notice.

ⓗⓟ 650A TEST OSCILLATOR

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 ⓗⓟ Model 650A Oscillator is another of the famous ⓗⓟ 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 ⓗⓟ 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.

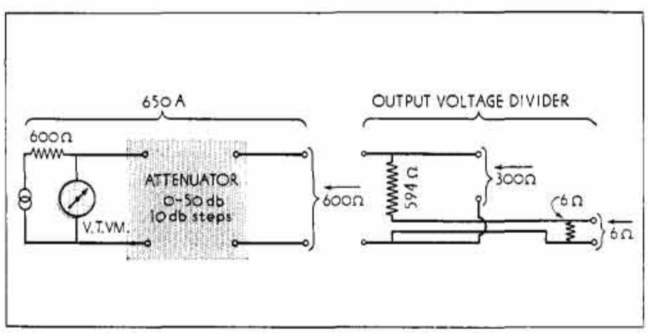


Figure 1

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 26, 27, 28 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. Less than 2% from 100 KC to 1 MC, approximately 5% at 10 MC.

Output Monitor: Vacuum tube voltmeter monitors level at input to attenuator, in volts or db at 600 ohm level. Zero db=1 mw in 600 ohms. Accuracy ±5% of full scale reading.

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

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

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

Dimensions: Cabinet Mount: 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). Net 39 lbs. Shipping 80 lbs. (rack mount).

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

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00.

Price: $490.00 (cabinet); $475.00 (rack mount).

Data subject to change without notice.

AUDIO SIGNAL, SQUARE WAVE, PULSE AND DIGITAL DELAY GENERATORS

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

The discussion on this page considers use and application techniques of *-hp-* audio signal generators. A similar presentation concerning *-hp-* square wave, pulse and digital delay generators appears on the opposite page.

Audio Signal Generators

One of the basic instruments for audio research development, production and maintenance is an Audio Signal Generator.

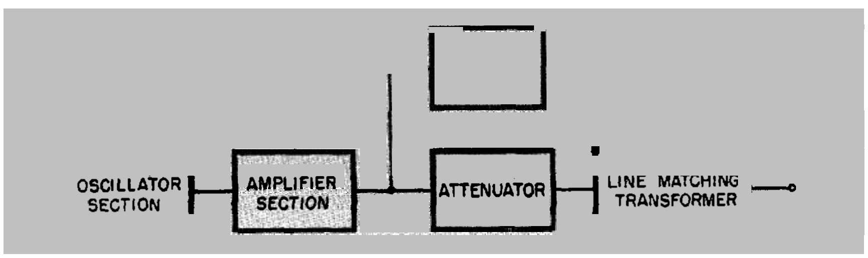


Figure 1. Elements of a signal generator.

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

-hp- Audio Signal Generators are useful in making amplifier gain measurements, determining network or transmitter frequency response; as signal sources for distortion measurements, in production testing or general laboratory work and in other applications where an accurate, 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 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 be-

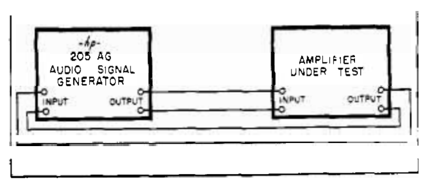


Figure 2. Typical test set-up.

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.

Square Wave Generator

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

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

The 211A (page 44) provides complete coverage of all frequencies from 1 cps to 1MC, and has a rise time of 0.02 μsec. It offers two separate outputs—a 7 volt peak-to-peak 75 ohm impedance circuit for television measurement, and a 55 volt peak-to-peak 600 ohm output for high level work. Full amplitude variation is available on either output. This instrument may be operated free-running or externally synchronized with either a positive going pulse or a sine wave signal of at least 5 volts.

Pulse Generator

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

The widely-used *-hp-* Model 212A Pulse Generator (page 45) is deliberately designed for speeding and simplifying all of these measurements. It offers continuously variable pulses from 0.07 to 10 μsec. It has a direct-reading pulse length control, and 50 watts of pulse power. Rise time is 0.02 μsec, pulses have a "flat" top with minimum overshoot. Either positive or negative pulses may be synchronized to other equipment through built-in delay and advance sync-out circuits; accurate pulses may also be delivered at the end of a long transmission line. Where lines are correctly terminated, the pulse shape is unaffected by pulse rate frequency, line length, input sync voltage or the output attenuator setting.

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

Digital Delay Generator

Delay generators—instruments providing a pulse at a known and selectable time after a trigger signal—provide the engineer with a laboratory and production tool of unique utility in generating and measuring precise time intervals in the microsecond to millisecond area. Such an instrument is of unusual service in checking radar, loran, Tacan, DME and other fast circuits, simulating or measuring fast gates, and generating and measuring delays in such circuits and devices.

New Model 218AR Digital Delay Generator and associated *-hp-* 219A series plug-ins (pages 46, 47) represent an important advance in precision digital techniques.

The *-hp-* 218AR provides an initial time zero reference pulse and two positionable pulses, all of which are precisely known in time with respect to a start trigger pulse. Accuracy is 0.1 μsec $\pm 0.001\%$ for time measurements when the internal crystal oscillator is the time base: the inherent "plus-or-minus-one count" ambiguity once associated with such equipment has been eliminated. In the 218AR, counting *always* begins at zero phase and ends at zero phase. No "part phases" are included at the beginning or end of the counting period; there is no unknown increment to impair accuracy.

Model 218AR is also distinguished by the fact that it is a perfect slave to the start trigger, whose rate can be random. The 218AR generates selectable delays directly from its crystal controlled oscillator or from external signals, periodic or random. It will trigger from an internal rate circuit over the range 10 cps to 10 KC, also from external triggers or from a manual start button.

The basic circuitry of *-hp-* 218AR is shown in Figure 3.

When the crystal oscillator is turned on, a pulse, T_0, is generated which marks the beginning of the time intervals. The crystal oscillator signal is counted by the dual preset counter which opens a gate just prior to the preset number. Opening this gate allows a pulse from the crystal oscillator to trigger an interpolation multivibrator which then forms an output pulse marking the end of one time interval. Oscillation continues until the preset counter opens the second gate, allowing a pulse from the oscillator to trigger the second interpolation multivibrator which generates a pulse marking the end of the second time interval. The oscillator pulses which are gated to the interpolation multivibrators occur 1 to 2 microseconds before the ends of the prescribed delays. Pulse duration of the interpolation multivibrators is variable from 1 to 2 microseconds so that the trailing edges of the multivibrator pulses mark the ends of the prescribed time intervals. A reset circuit (not shown in Figure 3), then turns off the oscillator and resets the counter to await another input trigger. Until reset circuit operates, a lockout circuit prevents any external signal from restarting the cycle.

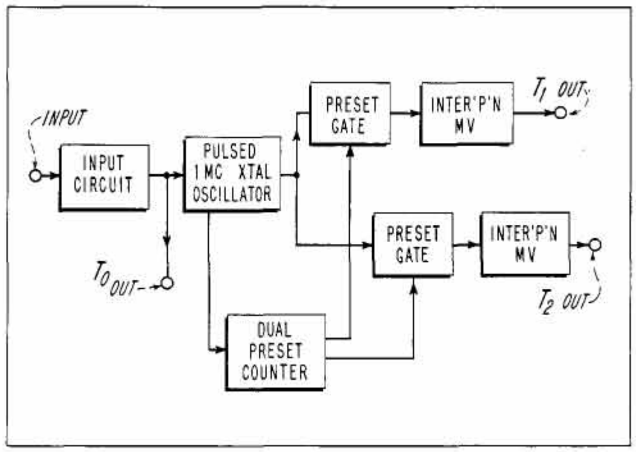


Figure 3. Basic circuit arrangement of *-hp-* 218AR Digital Delay Generator.

218AR Plug-Ins

A plug-in unit is essential to operate Model 218AR Digital Delay Generator. Three such units are currently offered. These include *-hp-* 219A Dual Trigger Unit, *-hp-* 219B Dual Pulse Unit and *-hp-* 219C Digital Pulse Duration Unit. A more complete description of these plug-ins and Model 218AR itself appears on pages 46, 47.

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

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 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.

Frequency Response: ± 1db, 20 cps to 20 KC at output levels up to + 30 dbm with output meter reading held at + 37 db; ± 1.5 db, 20 cps to 20 KC at output levels above + 30 dbm with output meter reading held at + 37 db (reference 1,000 cps).

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.

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: Calibrated directly in volts at 600 ohms and dbm (0 dbm = 1 mw in 600 ohms).

Voltage Scale: 0-65 volts, db scale +20 to +37 dbm.

Input Meter: Calibrated in dbm (0 db = 1 mw, 600 ohms) from −5 to 18 dbm and in volts from 0 to 2 volts rms. Voltage accuracy is ± 5% of full scale.

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

Output Attenuator: 110 db in 1 db steps. 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 56 lbs. Shipping 78 lbs. (cabinet mount). Net 49 lbs. Shipping 71 lbs.(rack mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00.

Price: $500.00 (cabinet); $485.00 (rack mount).

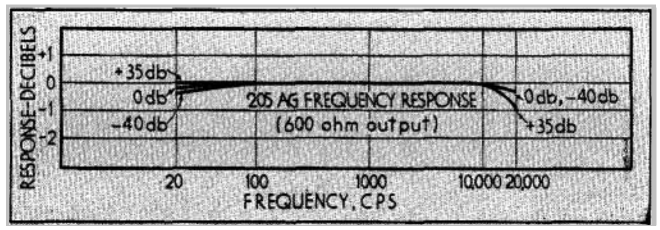
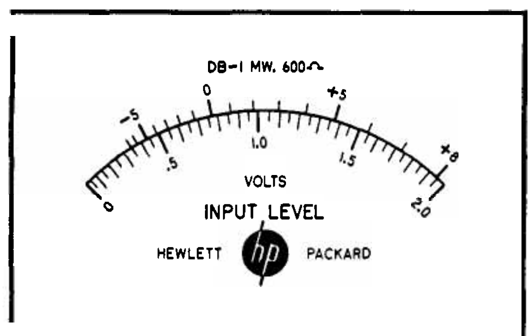


Figure 1. **Typical** frequency response of ***-hp-* 205AG** output section. (Response of attenuator **and line matching transformer.**)



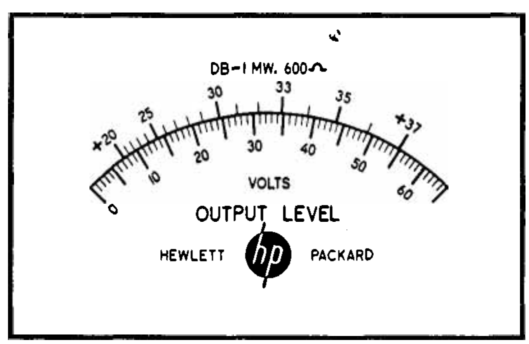


Figure 2. Input and Output Meters, *-hp-* 205AG. Input meter (top) is directly calibrated in dbm based on level in a 600 ohm circuit. Attenuator extends range by 40 db in 5 db steps. Output meter is directly calibrated in volts and dbm for operating into 600 ohm circuits.

Data subject to change without notice.

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 ⓗⓟ 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 ⓗⓟ 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 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 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 ⓗⓟ 206A generator includes an output matching transformer which allows it to be matched to resistive

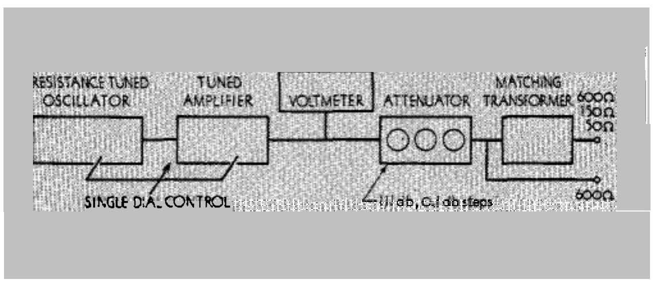


Figure 1. Circuit arrangement, Model 206A.

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 75 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: 20¾″ wide, 12¾″ high, 14″ deep. Rack Mount: 19″ wide, 10½″ high, 13½″ deep. Also can be used with ⓗⓟ AC-17 End Frames.

Weight: Net 56 lbs. Shipping 77 lbs. (cabinet mount). Net: 50 lbs. Shipping 72 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00.

Price: $750.00 (cabinet); $735,00 (rack mount).

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, 225 watts.
Dimensions: Cabinet Mount: 9¾" wide, 15" high, 14⅜" deep. Rack Mount: 19" wide, 8¾" high, 13⅜" deep behind panel.
Weight: Net 25 lbs. Shipping 40 lbs. (cabinet mount). Net 25 lbs. Shipping 33 lbs. (rack mount).
Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00; AC-16D Cable Assembly, $2.65.
Price: $300.00 (cabinet); $305.00 (rack mount).

Data subject to change without notice.

Convenient Audio, Video Testing 1 cps to 1 MC

THE Ⓗ 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 miscroseconds. 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 5 volts peak minimum amplitude.

Uses

Model 211A is ideal for testing amplifiers and networks and modulating signal generators. It will measure time constants, check 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.

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

POPULAR hp 212A Pulse Generator provides positive or negative pulses, and may be synchronized to other equipment through built-in delay and advance sync out circuits. It offers pulse lengths continuously variable from 0.07 to 10 microseconds, has a direct reading pulse length control, and provides pulses of 50 watts peak power. Pulses are of high quality, with very fast 0.02 microsecond rise and decay, "flat" top and minimum overshoot. The instrument permits accurate pulses to be delivered to the end of a long transmission line. If the line is correctly terminated, pulse shape is independent of line length, sync conditions, input voltage or output attenuator setting.

Double pulses can be obtained by connecting a stub line across the output of the generator.

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

Data subject to change without notice.

Specifications

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

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

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

Jitter: Less than 0.01 microsecond.

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

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

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

Sync Out: 25 v pos, 15 v neg into 2,000 ohms load. Approx. 1 μsec duration at half voltage. Rise time approx. 0.25 μsec.

Pulse Position: Delay, 0 to 100 μsec (rep rates up to 2,500 pps) 0 to 50 μsec (rep rates up to 5,000 pps). Advance, 0 to 10 μsec.

Power: 115/230 v ±10%, 50/60 cps, 380 watts.

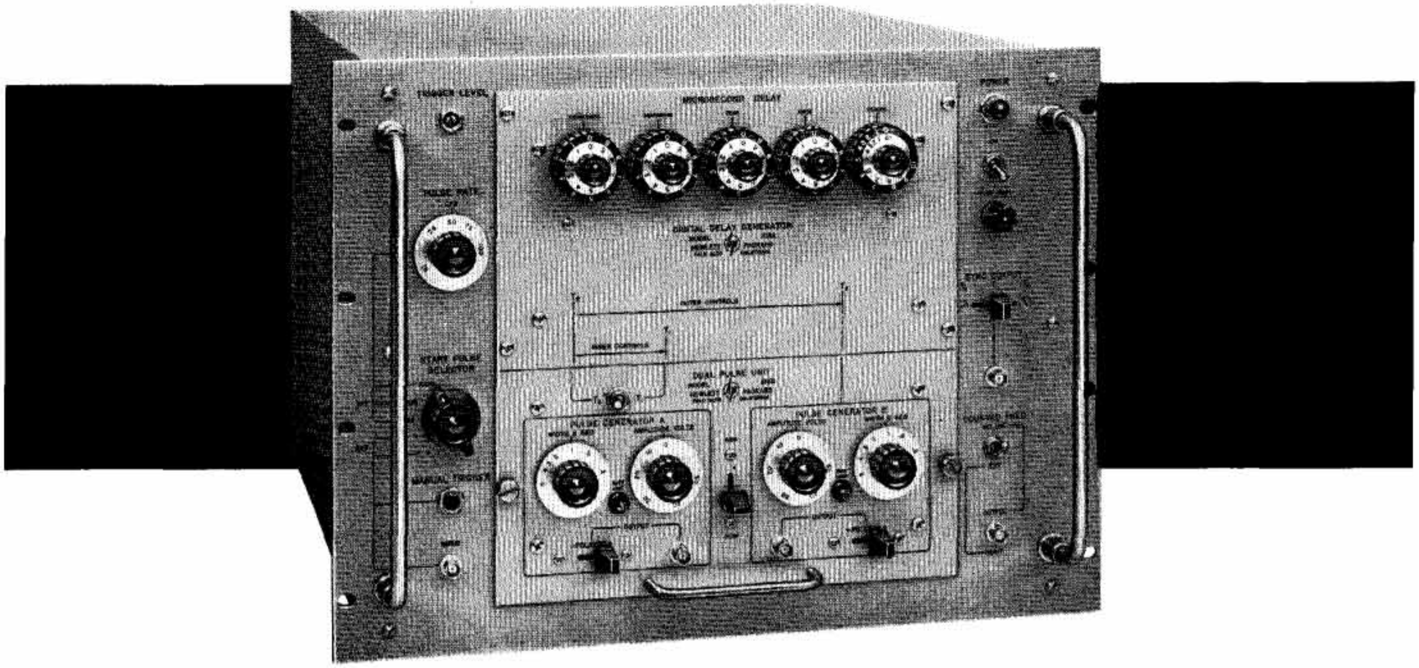
Dimensions: Cabinet Mount: 20¾" wide, 12¾" high, 14-3/16" deep. Rack Mount: 19" wide, 10½" high, 12¾" deep behind panel. Also use with hp AC-17 End Frames.

Weight: Net 56 lbs. Shipping 76 lbs. (cabinet mount); net 50 lbs. Shipping 73 lbs. (rack mount).

Accessories Available: AC-16K BNC Cable Assembly, $5.00; AC-16F Type N Cable Assembly, $12.00.

Price: $585.00 (cabinet); $570.00 (rack mount).

218AR DIGITAL DELAY GENERATOR



Advantages

Generates time intervals 1–10,000 μsec

Variety of adjustable output pulses

±0.1 μsec ±0.001% accuracy

Crystal oscillator, dual-preset counter controls delays

Perfect slave to start pulses; no ±1 count error

New ease, speed, dependability

Uses

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

1 MC dual preset counter for digital computer work

Precision variable gate generator for work with digital computers, counters

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

Totally New Accuracy Standards for Time Interval, Pulse Generation

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

Engineered to meet military performance requirements, the hp 218AR consists of three main parts: (1) a pulsed crystal oscillator which is started in known phase by the initial trigger (start) pulse, eliminating the ±1 count error, (2) a dual-preset digital counter which counts the crystal (or externally applied) frequency and operates (3) two preset gates which pass the selected pulses.

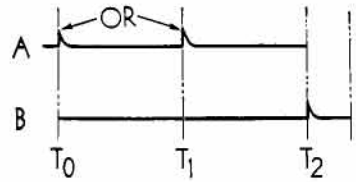
Two Independent Pulses

The hp 218AR generates independent pulses, one at the end of each preset time interval, at times T_1 and T_2. A sync pulse is available at the time of the start pulse, T_0, or at T_1 or T_2. The time intervals are independently adjustable, with directly calibrated front panel controls, in 1 μsec steps from 1 to 10,000 μsec with interpolation between steps. Either T_1 or T_2 may occur first, and accuracy is ±0.1 μsec ±0.001% of the delay selected.

Plug-ins Increase Versatility

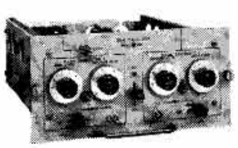
For maximum flexibility, output pulses are generated in the -hp- 219 series plug-in units. The units and the pulse options they provide are described below.

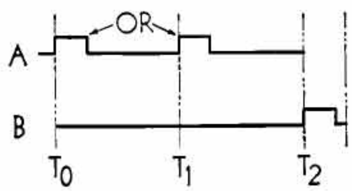
-hp- 219A Dual Trigger Unit



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

-hp- 219B Dual Pulse Unit

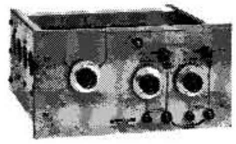


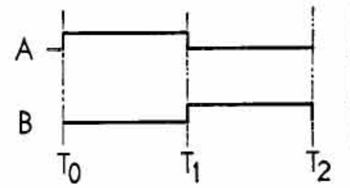


Model 219B Dual Pulse Unit contains two pulse generators providing digitally delayed, fast rise time, high power pulses. The leading edge of pulse A occurs simultaneously either with T_0 or T_1 (as selected by a panel switch) and the leading edge of pulse B occurs at time T_2. Either positive or negative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

Data subject to change without notice.

-hp- 219C Digital Pulse Duration Unit





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

Specifications

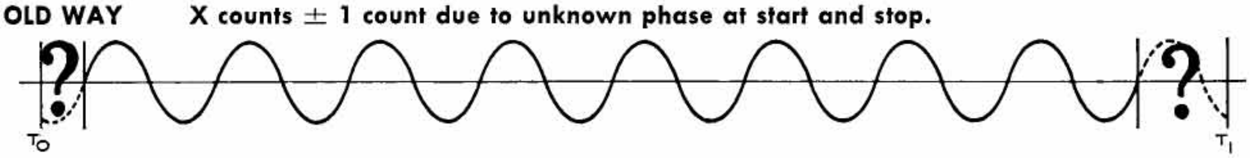
-hp- 218AR Digital Delay Generator

(Plug-in necessary to operate)

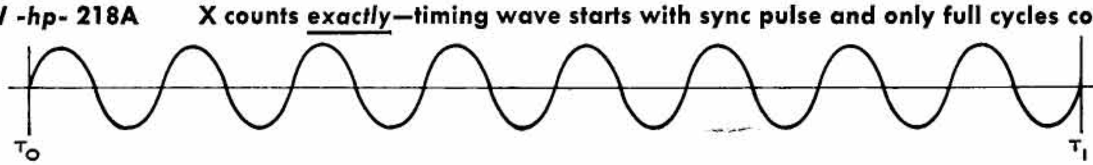
Time Interval Range: (T_0 to T_1 and T_0 to T_2) 1 to 10,000 μsec. Accuracy: ± 0.1 μsec $\pm 0.001\%$ of time interval selected.
Digital Adjustment: 1 to 10,000 μsec in 1 μsec steps.
Interpolation: Continuously adjustable. Adds 0–1 μsec to digital setting.
Input Trigger: Internal: 10 cps to 10 KC, 3 decade ranges. External: Sine wave, 5 v rms, 10 to 100 cps; 2 v rms, 100 cps to 10 KC. Pulse, 0 to 10 KC, positive or negative, 2 to 40 v peak with rise time 0.05 μsec or less. Delay between external trigger and T_0 is 0.25 μsec ± 0.05 μsec for trigger rise time 0.05 μsec or less.
Jitter: 0.02 μsec or less.
Recovery Time: 50 μsec or 10% of selected interval, whichever is larger.
Sync Output: 50 v positive pulse, 0.1 μsec rise time (from 50 ohm source). Available at T_0, T_1 or T_2.
1 MC Output: 1 v, 1 MC pulses (from 500 ohm source) provide timing comb synchronized to start pulses. Available at panel connector for duration of longer delay when counting internal 1 MC oscillator.
External Counting: External sine waves, 2 v rms, 10 cps–1 MC and pulses, periodic or random, 2 v peak, 0–1 MC can be counted instead of internal standard. Time Interval range becomes 1–10,000 periods in 1 period steps and accuracy is ± 0.1 μsec ± 1 period.
Power: 115/230 v $\pm 10\%$, 50/60 cps, 555 watts.
Size: 14″ high, 19″ wide, 24″ deep. Weight 75 lbs.
Price: -hp- 218AR (rack mount), $2,000.00.

± 1 COUNT AMBIGUITY ELIMINATED!

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



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



WAVE AND DISTORTION ANALYZERS

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.

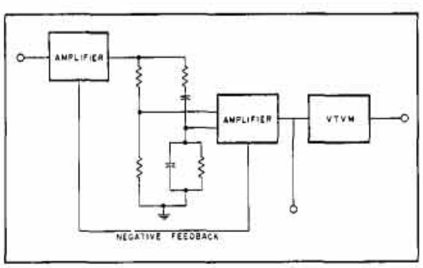


Figure 1

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

-hp- Wave Analyzer

For measuring distortion by the "fundamental" method, the new -*hp*- 302A Wave Analyzer (pages 50, 51) is ideal. This compact, completely transistorized, essentially hum-free instrument is highly selective, requires no tedious calibration or stabilization, and provides direct, accurate readings. New Model 302A covers frequencies 20 cps to 50 KC, may be battery operated if desired, has a low power consumption (approximately 3 watts) and requires no warmup time.

Model 302A is ideal for measuring and analyzing fundamentals, harmonics and intermodulation products in telemetering, carrier and vibration systems as well as audio circuits. It also speeds analysis of broadcast amplifier characteristics; modulation amplifier, film sound track and recording distortion; hum, network characteristics, etc.

-hp- Distortion Analyzers

-*hp*- 330 series Distortion Analyzers are basically selective amplifiers whose

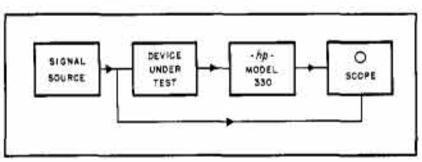
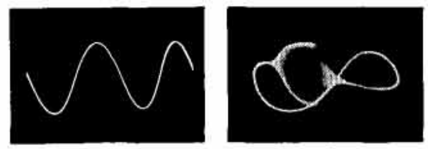


Figure 2

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

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

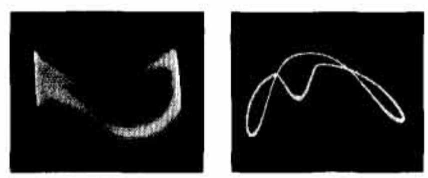
A typical setup utilizing -*hp*- 330 series analyzers for measuring by the "total" distortion method is shown in Figure 2. The combination of distortion analyzer and oscilloscope is an



A B

Figure 3

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



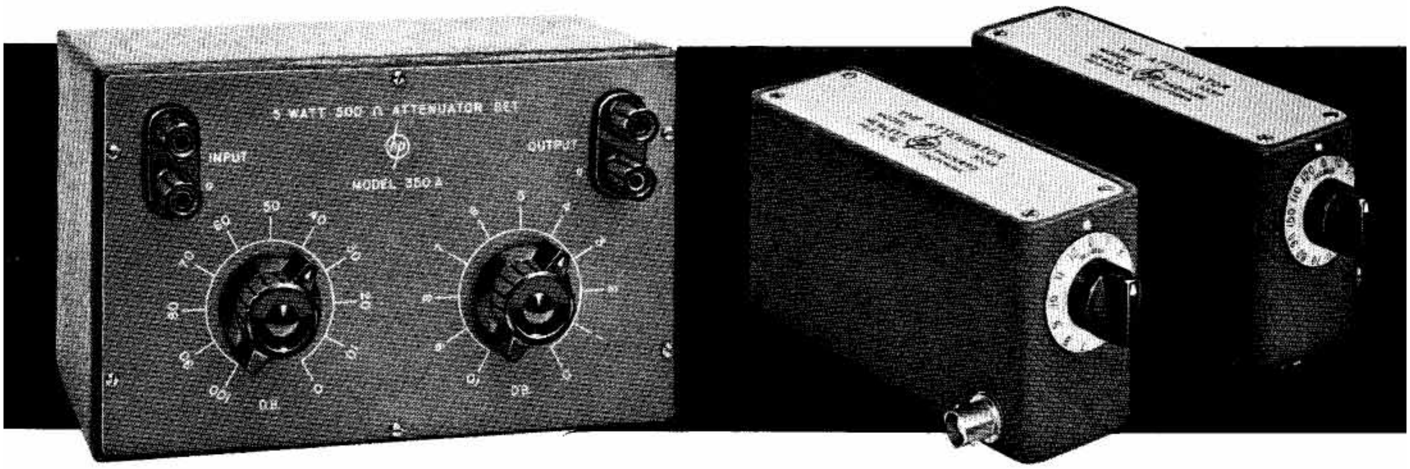
A B

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.

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.

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.)*



hp 350A/B Attenuators

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

Specifications

hp 350A, matches 500 ohm impedance.

hp 350B, matches 600 ohm impedance (one side grounded).

(Following apply to hp 350A and 350B)

Attenuation: 110 db in 1 db steps.

Accuracy, 0 to 100 KC: 10 db attenuator section: error less than ±0.125 db, any step 100 db attenuator section: error less than ±0.25 db to 80 db, less than ± 0.5 db on 90 and 100 db steps.

Power Capacity: 5 watts continuous duty.

Dimensions: Cabinet Mount: 8¼″ wide, 5⅝″ high, 5-5/16″ deep. Rack Mount: 19″ wide, 5¼″ high, 3⅞″ deep.

Weight: Net 3 lbs. Shipping 7 lbs. (cabinet mount). Net 3 lbs. Shipping 10 lbs. (rack mount).

Price: hp 350A or 350B, $85.00 (cabinet); $90.00 rack mount).

Data subject to change without notice.

hp 355A/B Precision Attenuators

MODEL 355A and 355B are precision attenuators useful as components or laboratory instruments. Covering dc to 500 MC, hp 355A/B together provide 1 db step attenuation from 0 to 132 db. Attenuation is directly set and read on single knobs. Accuracy and performance derives from a new design using balanced capacities, complete shielding of sections, and cam-driven microswitches to insert or remove attenuator sections.

Specifications hp 355A

Attenuation: 12 db in 1 db steps.

Frequency Range: Dc to 500 MC.

Overall Accuracy: ±0.25 db, full range.

Impedance: 50 ohms.

Maximum SWR: 1.2 below 250 MC, 1.5 below 500 MC.

Max. Insertion Loss: 0 at dc; 0.4 db at 60 MC; 1.0 db at 250 MC; 1.5 db at 500 MC.

Power Dissipation: 0.5 watts average, 350 v peak.

Connectors: BNC.

Dimensions: 2¾″ wide, 6″ long, 2⅝″ high.

Weight: Net 1½ lbs. Shipping 3 lbs.

Price: $125.00.

hp 355B same as 355A except:

Attenuation: 120 db in 10 db steps.

Overall Accuracy: ±1 db, dc to 250 MC; ±2 db, 250 to 500 MC.

302A WAVE ANALYZER

Advantages:

- No calibration or stabilization needed
- Direct readings; accurate
- Measures frequencies 20 cps to 50 KC
- Completely transistorized
- Battery or ac powered; hum free
- Low power consumption; no warm-up needed
- Very sharp acceptance circuits
- AFC; also frequency restorer circuit
- Compact, rugged, versatile

Uses:

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

New, Transistorized – Directly Measures Wave Components

NEW MODEL 302A Wave Analyzer represents a significant improvement in wave analyzer design.

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

Other exceptional features are low power consumption (in the order of 3 watts), provision for battery operation (18 to 28 volts) as well as ac line power, and elimination of warmup time.

Simple Operation

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

Basically, Model 302A functions by separating an input signal into individual components so that each—the fundamental, harmonics and any intermodulation products—may be evaluated separately.

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

Frequency Restorer

A frequency restorer circuit makes accurate frequency measurements possible at each component's frequency of the input wave. This circuit supplies a sinusoidal signal at the frequency of the specific component which can be measured on an electronic counter or observed on an oscilloscope. The amplitude of this signal is determined by the level of the selected component. When the mode selector switch is in the normal or AFC position, the signal appears at the output terminals if the meter is indicating.

Model 302A is also particularly useful for measuring small signals on noisy systems or transmission lines. When the mode selector is switched to "BFO" the instrument becomes an oscillator and tuned voltmeter automatically tuned by one control to the same or oscillator frequency. The selective tuned voltmeter then discriminates against the noise and measures the desired signal.

Speed and accuracy of measuring is enhanced by a linearly calibrated tuning control giving the same "tuning feel" throughout range.

Basic Laboratory Instrument

Covering the frequency range of 20 cps to 50 KC, the new ⓗⓟ 302A is equipped to perform a wide variety of daily measurements. It has broad usefulness not only in audio measurements but in vibration work, telemetry, and carrier applications. The instrument is compact, rugged and features conservative design and high quality throughout.

Specifications

Frequency Range: 20 cps to 50 KC.

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

Voltage Range: 3 μv to 300 v, full scale readings of:

300 v	300 mv	300 μv
100 v	100 mv	100 μv
30 v	30 mv	30 μv
10 v	10 mv	
3 v	3 mv	
1 v	1 mv	

Ranges provided by an input attenuator switch and a meter range switch in steps of 1:3 or 10 db. Meter range is indicated by a dial mechanically linked to input attenuator. An absolute-relative switch, in conjunction with a variable 10 db control is provided for adjustment of intermediate values.

Warm-Up-Time: None.

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

Residual Modulation Products and Hum Voltage: Greater than 75 db down.

Intermediate Frequency Rejection: Intermediate frequency present in input signal rejected by at least 75 db.

Selectivity: $\pm$ 3½ cycle b.w.—at least 3 db down
$\pm$ 25 cycle b. w.—at least 50 db down
$\pm$ 70 cycle b.w.—at least 80 db down
beyond $\pm$ 70 cycle b.w.—at least 80 db down

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

Restored Frequency Output: 1 v across 600 ohms at output terminals for full scale meter deflection. Output level control provided. Frequency response $\pm2\%$, 20 cycles to 50 KC. Output impedance approximately 600 ohms.

Oscillator Output: 1 v across 600 ohms at output terminals (mode selector in B.F.O.) Output level control provided. Frequency response $\pm2\%$, 20 cps to 50 KC. Output impedance approximately 600 ohms.

Automatic Frequency Control: Range of frequency holdin is ±100 cycles minimum.

Power: 115/230 v $\pm10\%$, 50/1600 cycles, 3 watts (approximately). Terminals provided for powering instrument from external battery source. Battery supply range 28 v to 18 v.

Weight: Net 43 lbs. Shipping 63 lbs. (cabinet mount). Net 35 lbs. Shipping 55 lbs. (rack mount).

Dimensions: Cabinet Mount: 20¾" wide; 12½" high; 14½" deep. Rack Mount: 19" wide; 10½" high; 13½" deep.

Price: \$1,750.00 (cabinet); \$1,735.00 (rack mount).

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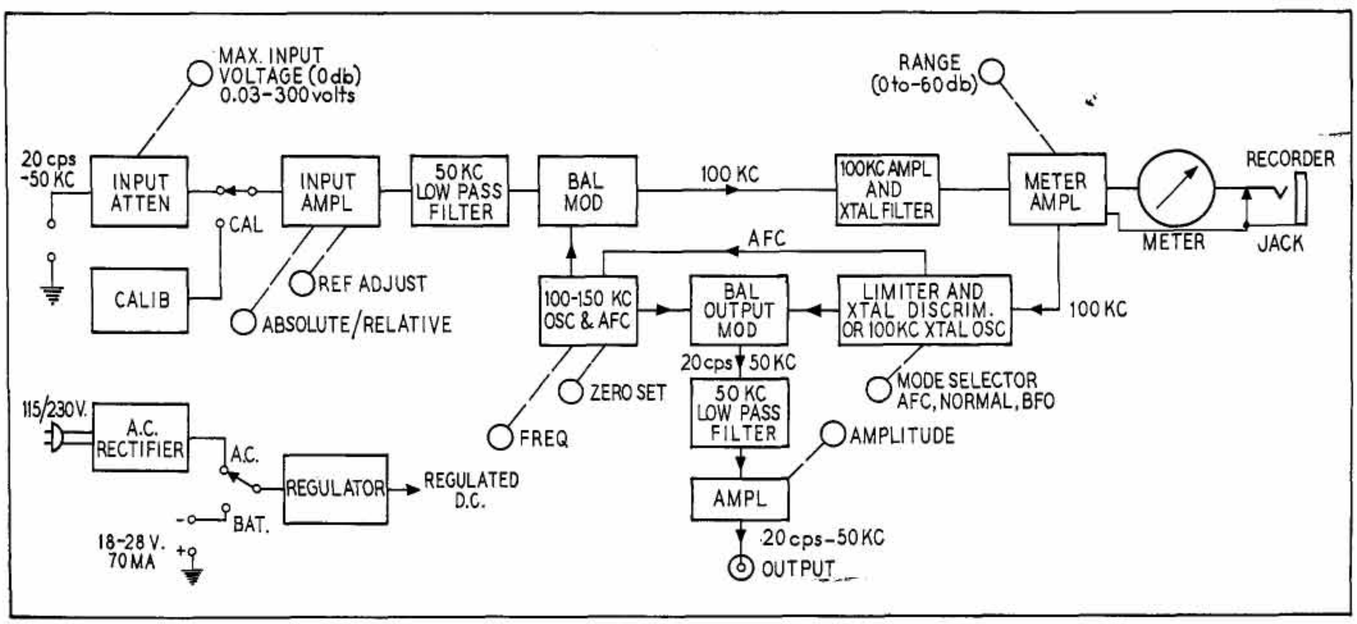


Figure 1. Block diagram, Model 302A Harmonic Wave Analyzer

ⓗⓟ 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 ⓗⓟ 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, ⓗⓟ 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 ⓗⓟ 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.

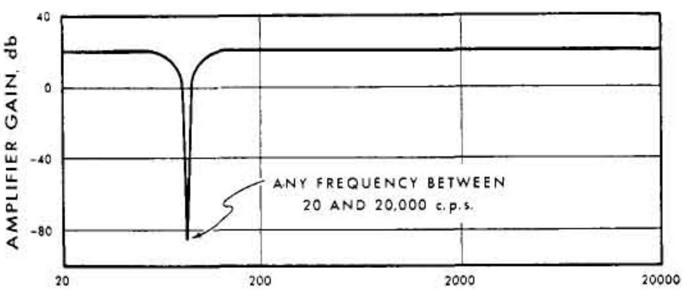


Figure 1

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: $\pm 2\%$ entire range.

Elimination Characteristics: Fundamental frequency reduced by more than 99.99% (80 db). Second harmonic attenuation less than 17%. (1.5 db) for fundamental frequencies 20 cps to 5 KC; less than 32% (3 db) for fundamental frequencies 5 KC to 20 KC.

Accuracy: Residual frequencies are measured to within $\pm 3\%$ 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 $\pm 10\%$ (104 volts to 126 volts), Model 330B within $\pm 3\%$, 10 cps to 100 KC: Models 330C and 330D within $\pm 3\%$, 10 cps to 20 KC and $\pm 6\%$, 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 $\pm 10\%$, 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). Net 30 lbs. Shipping 43 lbs. (rack mount).

Accessories Available: AC-16A Cable Assembly, $4.00; AC-16B Cable Assembly, $5.00. AC-60B Transformer (for bridging input), $60.00.

Price: -hp- 330B, $410.00△; -hp- 330C, $440.00△; -hp- 330D, $500.00△.

△ Rack mount available for $15.00 less.

Data subject to change without notice.

AC AND DC VOLTMETERS; DC MILLIAMMETER

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.

Hewlett-Packard today offers five precision ac vacuum tube voltmeters, three versatile dc instruments (including a direct-reading digital voltmeter) and a high accuracy dc milliammeter for current measurements. Each gives you the familiar ⓗⓟ characteristics of wide range, compact size, sturdy dependability and time-saving ease of operation.

High-Sensitivity ac Voltmeters

ⓗⓟ Models 400D, 400H and 400L 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

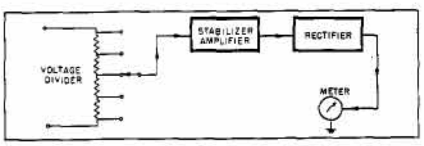


Figure 1. Block diagram, ⓗⓟ 400 series voltmeters.

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.

Model 400D Voltmeter (page 56) 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.

Model 400H (page 57), 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 ⓗⓟ 400H uses an indicating meter which has a 5-inch scale for maximum readability, a knife edge pointer and mirror to minimize parallax errors.

Model 400L (page 58) is similar to Model 400H, but has a specially designed logarithmic meter movement insuring maximum possible readability. By expanding the lower portions of the voltage scale, the logarithmic meter movement provides a voltage scale readable everywhere with the same high resolution. In addition, there is a linear db scale which spreads 12 db over more than 3 inches of scale length and is easily readable within 0.1 db. Model 400L measures voltage from 0.3 mv to 300 volts over frequencies 10 cps to 4 MC. The db range is −72 to +52 db in 12 ranges.

Transistorized ac Voltmeter

Model 403A Voltmeter (page 59) covers 1 cps to 1 MC, 100 μv to 300 v rms (max. full scale sensitivity 1 mv); also reads direct in db from −72 to +52 db. This new instrument is battery operated, portable, ideal for field as well as laboratory measurements. Very light weight, compact.

Wide-Range ac Voltmeter

Model 410B (page 61) 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.

dc Voltmeters

Three completely new direct-current voltmeters are now offered. These include the entirely automatic ⓗⓟ 405AR dc Digital Voltmeter, the revolutionary ⓗⓟ 412A Voltmeter-Ohmmeter-Ammeter and the multi-purpose ⓗⓟ 425A Microvolt-Ammeter.

Model 405AR dc Digital Voltmeter (page 60) is a completely new instrument only 7″ high (rack mount) providing true "touch-and-read" voltage measurements between 1 mv and 1,000 volts.

Automatic Range, Polarity

Range selection, even polarity, are automatically selected, and 3-digit single line readout appears automatically in bright, steady numerals. Unique circuitry provides a stability of presentation virtually eliminating jitter in the last digit—reducing uncertainty and operator fatigue. Accuracy is ± 0.2% of the reading ± 1 count and voltage sampling rate is variable from 1 reading every 5 seconds to 5 per second. Sampling rate can also be controlled by a 20 volt positive external pulse. A high degree of ac filtering insures that only the desired dc reading is indicated.

Model 412A Voltmeter-Ohmmeter-Ammeter (page 62) is designed to cover the dc measuring field. It is a dc vacuum tube voltmeter, an ohmmeter and an ammeter. The 412A has extremely high accuracy for a direct reading VTVM. Voltage measuring accuracy is 1% from 1 millivolt to 1,000 volts full scale. Current measuring accuracy is 2% from 1 microampere to 1 ampere full scale. Resistance measuring range is 0.02 ohms to 5,000 megohms. The unique instrument requires no zero adjustment, needs only a 60-second warmup and includes a 1 volt or 1 milliampere output for recorder operation.

Read 1 μμa, 1 μv Direct

Model 425A Microvolt-Ammeter (pages 64, 65) is another totally new instrument of broad usefulness not only in electronics but in the fields of physics and chemistry, medicine and biology. The instrument provides direct readings as small as 1 micromicroampere or 1 microvolt with greater convenience than possible with any commercial equipment previously available. Model 425A's high sensitivity is especially significant because it has been achieved without sacrifice in input impedance. A high input impedance of 1 megohm and high sensitivity assures reliable voltage readings with minimum circuit loading. In addition, the 425A serves as a dc amplifier with 100 db gain and can be used to measure resistance from milliohms to 10 megmegohms. Provision is made for driving commercial recorders. High ac rejection assures that only the desired dc voltage or current will be measured.

Typical uses of the Model 425A are measurement of grid and photomultiplier currents, ionization levels in vacuum, thermocouple potentials, voltaic currents in chemicals, and nerve voltages.

"Clip-On" dc Milliammeter

Employing a radically different approach to current measuring, the new Model 428A Clip-On Milliammeter (page 63) measures dc from 1 milliampere to 1 ampere *without breaking leads, without loading the circuit under test, without any direct dc connection!*

With this new instrument and its unusual pen-sized probe, you literally "clamp around" a wire and read. The instrument measures by *sensing* the magnetic field around a wire. Maximum accuracy is assured because there is effectively no circuit loading from the probe. The instrument readily measures dc currents in the presence of strong ac. Insulation is more than adequate to insure safe measurements at all normal voltage levels.

For low current measuring, sensitivity can be increased by passing one or more loops of the conductor through the jaws of the 428A probe.

Current ranges are from 1 milliampere to 1 ampere in 6 steps, and accuracy is 3% of full scale ±0.1 ma. This accuracy is constant despite line voltage changes, variations in probe jaw closure, instrument aging and effects of the Earth's magnetic field.

VTVM Calibration System

Complete calibration of Vacuum Tube Voltmeters (or Oscilloscopes) includes measurement of both frequency response and voltage accuracy. The hp Calibration System pictured in Figure 2, composed of three separate hp instruments, performs these functions quickly and accurately.

Model 738AR Voltmeter Calibrator Generator (bottom in rack mounted array, Figure 2) is a highly stable source for a wide range of precision voltages, and is specifically intended for calibration of high-impedance electronic voltmeters and oscilloscopes. It provides accurate voltage levels from 300 microvolts to 300 volts with drift of less than 0.1% on dc and less than 0.25% on ac. Total hum is less than 0.25%.

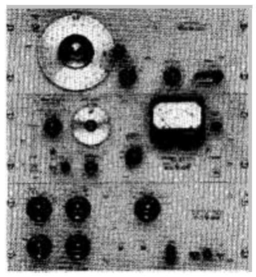


Figure 2. VTVM Calibration System.

Model 739AR Frequency Response Test Set (center in Figure 2), simplifies frequency response determination by providing a convenient constant amplitude reference voltage of variable frequency. Voltage accuracy measurements are swift and sure with this instrument. Frequency range is 300 KC to 10 MC (5 cps to 10 MC with 200SR); response is flat within ±0.5%, 10 cps to 5 MC. Output is at least 3 volts into 50 ohms.

In connection with the hp 200SR Oscillator (top in Figure 2), hp 739AR quickly checks instrument frequency response. (Model 200S, explained on pages 28 and 29, covers frequencies 5 cps to 600 KC.)

Prices: hp 738AR, $875.00. hp 739AR, $450.00. hp 200SR Oscillator, $185.00.

Voltmeter Accessories

To increase the useful range of hp voltmeters, a complete line of voltmeter accessories is offered (page 67). These include Probe Connectors, Capacitive Voltage Dividers, dc Voltage Dividers, Shunt Resistors, etc.

Voltmeter Operating Techniques

In average-reading voltmeters such as hp 400D, 400H and 400L, 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 400 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 67). 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. The 454A also makes possible measurement of higher voltages.

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 67). 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

Specifications

Voltage Range: 1.0 millivolt to 300 volts full scale, 12 ranges.

Frequency Range: 10 cps to 4 MC.

Accuracy: Within ±2% of full scale, 20 cps to 1 MC; ±3%, 20 cps to 2 MC; ±5%, 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 3 and 0 to 1; db scale—12 db to 2 db.

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

Amplifier: Output terminals provided. Output approx. 0.15 v rms, all ranges, full scale. Amplifier frequency response same as voltmeter. Internal impedance approximately 50 ohms.

Power Supply: 115/230 v ±10%, 50/1,000 cps, approx. 80 watts.

Dimensions: Cabinet Mount: 11¾″ high, 7½″ wide, 12″ deep. Rack Mount: 7″ high, 19″ wide, 10¾″ deep.

Weight: Net 18 lbs., shipping 23 lbs. (Cabinet mount.) Net 21 lbs., shipping 33 lbs. (Rack mount.)

Price: $225.00 (cabinet); $230.00 (rack mount).

10 cps to 4 MC! High Quality, High Sensitivity

HERE IS one of the most widely-used of all hp voltmeters. Advantages of this popular instrument include extremely wide voltage range, 2% accuracy to 1 MC and one of the broadest frequency coverages of any precision voltmeter offered.

An important feature is the 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 circuit arrangement minimizes switching transients during range change. High 10 megohm input impedance prevents effective loading to circuits under test. Output circuitry permits the instrument to be used as a broadband, high gain amplifier over its full frequency range.

Model 400D reads direct in voltage and dbm.

Data subject to change without notice.

High Accuracy VTVM Has 5″ Mirror True Log Voltage Scale

HERE is an unusual instrument combining a special logarithmic meter movement with the high accuracy, dependability and wide range of other hp vacuum tube voltmeters.

Model 400L is designed for broad usefulness by acoustical and communication engineers, and men working with decibel measurements.

The logarithmic voltage scale plus unusually long scale length provides an instrument of maximum readability and accuracy which is *a constant percentage (±2%) of reading*. Decibel scale is more than 5″ long, and voltage scales spread across the full scale length. The meter is mirror-backed for maximum accuracy. A range switch changes voltage sensitivity in 10 db intervals. This feature, together with the 12 db scale, provides wide overlap desirable in decibel level measurements.

Like other hp vacuum tube voltmeters, the 400L offers exceptional long-term stability, 10 megohm input impedance, high sensitivity, and generous overload protection.

The instrument may also be used as a stable amplifier to increase small signals or monitor waveforms with an oscilloscope.

Specifications

Voltage Range: 0.3 mv to 300 v. 12 ranges, 0.001 v to 300 v, 1–3–10 sequence.

Decibel Range: −70 to +52 db, 12 ranges, 0 db = 1 mw in 600 ohms.

Frequency Range: 10 cps to 4 MC.

Accuracy: At nominal line voltage ±10%. Overall accuracy within: ±2% of reading or ±1% of full scale whichever is more accurate, 50 cps to 500 KC; ±3% of reading or ±2% of full scale whichever is more accurate, 20 cps to 1 MC; ±4% of reading or ± 3% of full scale whichever is more accurate, 20 cps to 2 MC; ± 5% of reading, 10 cps to 4 MC.

Long Term Stability: Reduction in G_m of amplifier tubes to 75% of nominal value results in error of less than 0.5%, 20 cps to 1 MC.

Calibration: Calibrated in rms value of a sine wave. Logarithmic voltage scales 0.3 to 1 and 0.8 to 3. Linear db scale, −10 db to +2 db, based on 0 db = 1 mw in 600 ohms, 10 db intervals between ranges.

Input Impedance: 10 megohms shunted by 15 $\mu\mu$f, 1.0 v to 300 v, 25 $\mu\mu$f, 0.001 v to 0.3 v.

Amplifier: Output terminals provided. Output approximately 0.15 v rms, all ranges, full scale. Amplifier frequency response same as voltmeter. Internal impedance approximately 50 ohms.

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

Dimensions: Cabinet Mount: 11½″ high, 7½″ wide, 11¾″ deep. Rack Mount: 7″ high, 19″ wide, 11¾″ deep.

Weight: Net 18 lbs. Shipping 25 lbs. (cabinet mount). Net 22 lbs. Shipping 35 lbs. (rack mount).

Price: $325.00 (cabinet); $330.00 (rack mount).

Data subject to change without notice.

ⓗⓟ 400H VACUUM TUBE VOLTMETER

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 ±3%, 20 cps to 2 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. 80 watts.

Dimensions: Cabinet Mount: 7½" wide, 11½" high, 12" deep. Rack Mount: 19" wide, 7" high, 11¾" deep.

Weight: Net 18 lbs. Shipping 25 lbs. (cabinet mount). Net 21 lbs. Shipping 33 lbs. (rack mount).

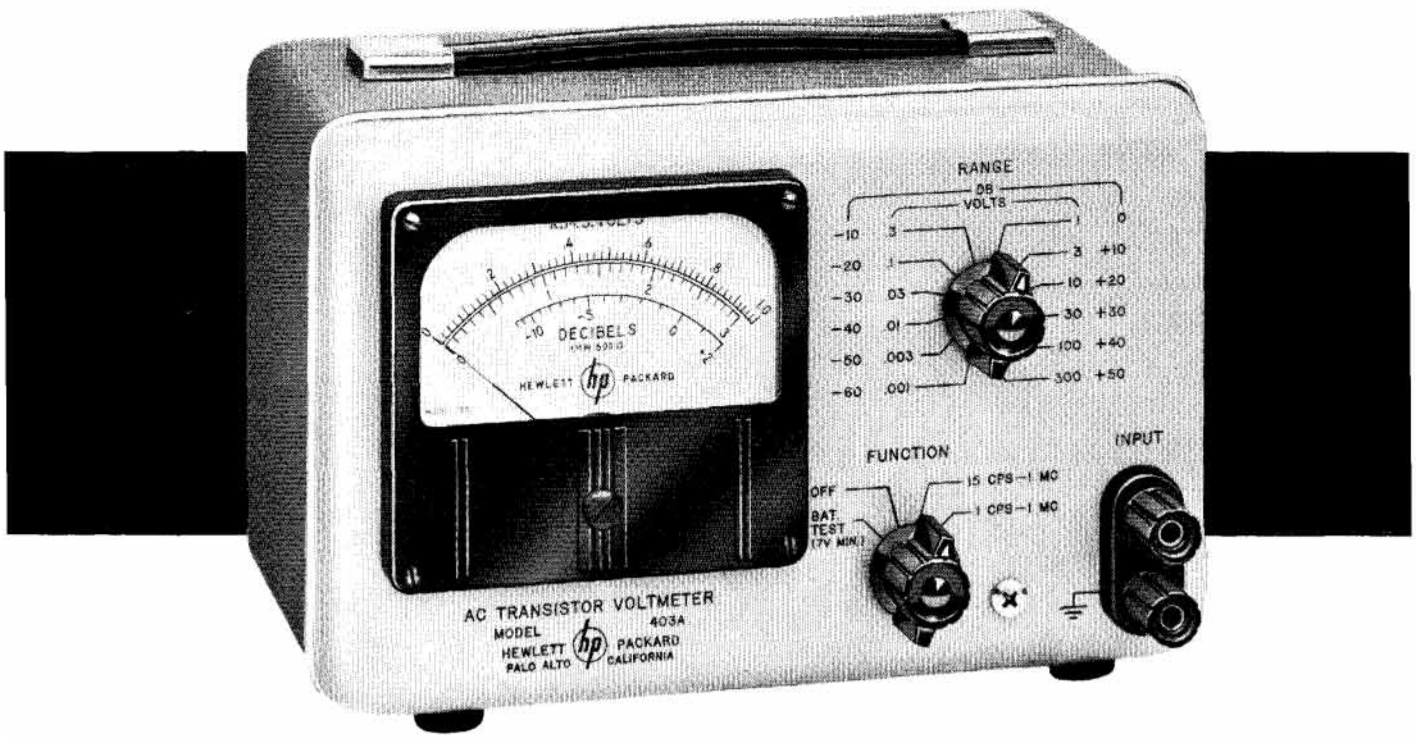
Price: $325.00 (cabinet); $330.00 (rack mount).

Extreme Accuracy of 1%; Covers 10 cps to 4 MC

THE ⓗⓟ 400H has been adapted from the popular ⓗⓟ 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 ⓗⓟ portable cabinet or for rack mounting.

Data subject to change without notice.



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

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

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

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

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

Specifications

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

Frequency Range: 1 cps to 1 MC.

Accuracy:
Within ±3% of full scale, 5 cps to 500 KC.
Within ±5% of full scale, 1 to 5 cps and 500 KC to 1 MC.

Nominal Input Impedance:
2 megohms shunted by approx. 40 $\mu\mu$f, 0.001 volt to 0.3 volt.
2 megohms shunted by approx. 20 $\mu\mu$f, 1 volt to 300 volts.

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

Power Supply: 9 radio type mercury cells (furnished with instrument). Battery life: Approximately 400 hours. Replacement cells, hp #142-4, $ .85 each.

Noise: Less than 50 μv referred to input when terminated in 100,000 ohms or less on 0.001 volt range. Less than 30 μv on all other ranges.

Turn-On Time: Low frequency position 30 seconds. High frequency position 10 seconds.

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

Weight: Net 4¾ lbs. Shipping 9 lbs.

Price: $250.00.

Data subject to change without notice

ⓗ 405AR AUTOMATIC DC DIGITAL VOLTMETER

Specifications

Range: 0.001 to 999 volts.

Presentation: 3 illuminated figures.

Accuracy: Within ±0.2% of reading ±1 count.

Floating Input: Permits measurement of systems operating within ±500 volts dc of power line ground.

Range, Polarity Selection: Automatic. Hold control disables automatic range selection and permits manual range choice.

Ranging Time: 0.2 seconds to 2 seconds depending on range change required.

Input Impedance: 11 megohms to dc on all ranges.

Sample Rate: Internal: Maximum not more than 5, not less than 4 per second. Minimum 1 every 5 seconds. External: Controlled by 20 volt positive pulse, maximum rate 5/second.

Response Time: Less than 1 second to step function.

Input Filler ac Rejection: 3 db at 1.5 cps; nominally 44 db at 60 cps.

Power: 115/230 volts ±10%, 50/60 cps, 180 watts.

Dimensions: Rack Mount: 7" high, 19" wide, 13¼" deep behind panel.

Weight: Net 26 lbs. Shipping 38 lbs.

Accessories Available: ⓗ 405A-95C Adapter for direct connection to ⓗ 560A Digital Recorder, $55.00.

Price: $825.00.

Automatic Range, Polarity Selection; Just 7" High!

HERE IS a completely new dc digital voltmeter providing, literally, *automatic "touch-and-read" convenience for voltage measurements between 100 millivolts and 1,000 volts.* Both range and polarity are automatically selected and results, including illuminated decimal point, appear in big, bright, steady numerals readable under all ambient light conditions.

New and exclusive ⓗ circuitry provides a stability of readings which virtually eliminates jitter in the last digit. This substantially reduces operator fatigue and avoids uncertainty.

Special features of the new, automatic 405AR include a floating input, electronic analog-to-digital conversion, digital recorder output and front panel control "holding" a reading indefinitely or disabling the automatic range selection in favor of manual decimal positioning. In addition, Model 405AR can be obtained to operate ⓗ Digital Recorders *(see pages 96 and 97).*

One other front panel control varies the voltage sampling rate from 1 reading every 5 seconds to 5 per second. Sampling rate can also be controlled by an external source of 20 volts or more.

410B VACUUM TUBE VOLTMETER

All-Purpose Test Instrument Measures to 700 MC

Audio, supersonic, rf and vhf voltages, antenna voltage, dc voltage in high impedance circuits—these are some of the measuring jobs the universally-known 410B can perform swiftly and dependably. This one compact instrument combines an ac voltmeter covering 20 cps to 700 MC, a dc voltmeter with more than 100 megohms input impedance, and an ohmmeter measuring from 0.2 ohms to 500 megohms.

An important reason for the 410B's perennial popularity is its special diode probe. The probe has very low capacity to minimize disturbance to circuits under test.

Other features of the 410B include low drift (maintains calibration over long periods of time) only one zero adjustment for all ranges, front panel function switching (leads are permanently attached) storage space for leads and probes at rear of the sturdy, lightweight instrument cabinet.

Specifications

Ranges: 1-300 v ac full scale in 6 ranges; 1-1000 v dc full scale 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.

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. Dc input resistance is more than 100 megohms for all ranges.

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 17 lbs. (cabinet mount). Net 14 lbs. Shipping 20 lbs. (rack mount).

Price: $245.00 (cabinet); $265.00 (rack mount).

Data subject to change without notice.

412A PRECISION DC VOLTMETER-OHMMETER-AMMETER

Specifications

Voltmeter:

Voltage Range: Pos. and neg. voltages from 1 mv to 1,000 v full scale. 13 ranges.

Accuracy: ±1% full scale on any range.

Input Resistance: 10 megohms ±1% on 1 mv, and 3 mv, and 10 mv ranges.
30 megohms ±1% on 30 mv range.
100 megohms ±1% on 100 mv range.
200 megohms ±1% on 300 mv range and above.

Ammeter

Current Range: Pos. and neg. currents from 1 μamp. to 1 amp. full scale. 13 ranges.

Accuracy: ±2% of full scale on any range.

Input Resistance: Decreasing from 1,000 ohms on 1 μamp. scale to 0.1 ohm on 1 amp scale.

Ohmmeter

Resistance Range: Resistance from 1 ohm to 100 megohms center-scale. 9 ranges.

Accuracy: ±5% of reading, 0.2 ohm to 500 megohms.
±10% of reading, 0.1 to 0.2 ohm and 500 megohms to 5,000 megohms.

Amplifier:

Voltage Gain: 1,000 maximum.

Ac Rejection: 3 db at 1 cps, approx. 80 db at 50 and 60 cps.

Output: Proportional to meter indication; 1 v at full scale. (Full scale corresponds to 1.0 on upper scale.)

Output Impedance: Less than 2 ohms at 0 cps.

Noise: Less than 0.1% of full scale on any range.

Drift: Negligible.

Power: 115/230 v ±10%, 50/60 cps, 35 watts.

Dimensions: Cabinet Mount: 11½" high, 7½" wide, 10" deep. Rack Mount: 5¼" high, 19" wide, 10" deep.

Weight: Cabinet Mount: Net 12 lbs. Shipping 17 lbs. Rack Mount: Net 14 lbs. Shipping 20 lbs.

Price: $375.00 (cabinet); $380.00 (rack mount).

Data subject to change without notice.

1% Accuracy VTVM is Also Precision Ohm, Ammeter

HERE is one compact instrument that makes all normally used dc measurements with precision and simplicity.

The new hp 412A provides 1% voltage and 2% current measurement accuracy. The unusually wide ohmmeter range covers from 1 ohm center scale to 100 megohms center scale so that resistance measurements can be made on wire sections as short as 6 inches or across insulators as high as 5,000 megohms.

The sensitivity and precision of the 412A are due in part to fresh circuitry concepts. For example, an exclusive hp developed photoconductor chopper virtually eliminates dc drift and offset. No zero set control is needed. The 412A is thus an ideal dc preamplifier for a recorder or other applications. Output terminals are provided.

The 412A insures accurate readings regardless of test conditions. Input is floating and input resistance is high, thereby avoiding errors due to loading circuits or insertion of ground connections. A very high degree of ac rejection insures that readings are accurate even in the presence of ac signals.

Measures 1 ma to 1 amp Without Direct dc Connection

No breaking of leads, no soldering on a direct connection, no circuit loading! With the completely different ⊕ 428A you simply *clamp the jaws of the pen-sized probe around a wire—and read!*

The instrument measures by sensing the magnetic field around a conductor. You are assured maximum accuracy because there is no effective circuit loading from the 428A's dc probe; it takes no power from the circuit and adds no resistance. The instrument easily measures dc currents in the presence of strong ac. Insulation is more than adequate to insure safe measurements at all normal voltage levels.

For extremely low current level measurements, sensitivity can be increased by looping the conductor through the "jaws" of the 428A probe.

Model 428A is particularly useful in transistor work, in low impedance circuits such as emitter circuits and in computer work where the large number of dc current determinations normally necessary may now be made more quickly and accurately.

Specifications

Current Range: Full scale readings from 3 ma to 1 amp. 6 ranges: 3 ma, 10 ma, 30 ma, 100 ma, 300 ma, 1 amp.

Accuracy: ±3% ±0.1 ma despite line voltage variations of ±10%, normal variations of probe closure, aging or Earth's magnetic field.

Probe Inductance: Less than 0.5 μh maximum. No noticeable loading, even up to 1 MC.

Probe Induced Voltage: Less than 15 mv peak (at 20 KC and harmonics).

Effects of ac in Circuit: Ac with peak value less than full scale affects accuracy less than 2% at frequencies different from the carrier (40 KC) and its harmonies.

Probe Insulation: 300 v, maximum.

Power: 115/230 v ±10%, 50/60 cps, 70 watts.

Dimensions: Cabinet mount, 7½″ wide, 11½″ high, 14¼″ deep. Rack mount, 19″ wide, 7″ high, 23″ behind panel.

Weight: Cabinet mount: Net 19 lbs. Shipping 24 lbs. Rack mount: Net 24 lbs. Shipping 35 lbs.

Probe Tip Size: Approximately ½″ x 9/32″. Aperture diameter 3/16″.

Price: Cabinet mount, $475.00. Rack mount, $480.00.

Data subject to change without notice.

ⓗⓟ 425A MICROVOLT-AMMETER

Advantages:

Extreme sensitivity
Virtually no noise or drift
Heavy ac filtering
No mechanical vibrator
Floating chassis
High input impedance

Uses:

Engineering:
Minute dc potentials, difference voltages, nulls
Resistances from milliohms to 10 megamegohms*
Use with potentiometer or galvanometer recorders

Physics, Chemistry:
Grid, photomultiplier currents
Ionization currents in vacuum chambers
Thermocouple potentials
Voltaic currents in chemicals

Medicine, Biology:
Voltages in living cells
Nerve voltages

*With external dc source. See text.

Read Directly 1 $\mu\mu$a and 1 μv; 10 Times Previous Sensitivity!

PRIOR to development of the ⓗⓟ 425A, many measurements of extremely small voltages and currents were either not practical, or they required expensive arrays of complex equipment and long hours of extremely delicate work.

Today, one, compact portable instrument measures both microvoltages and micromicroamperes quickly, directly, and easily, with 10 times previous sensitivity. Many hitherto impossible measurements are as simple as "touch and read."

In addition, Model 425A serves as a dc amplifier with 100 db gain and good stability.

No Mechanical Vibrator

The unique performance of the new ⓗⓟ 425A is a result of extremely careful engineering. Two important circuit aspects include very heavy ac filtering and the substitution of a photoelectric chopper developed by ⓗⓟ to replace the conventional error-inducing mechanical vibrator. Every known assurance of safety, accuracy and dependability has been incorporated; momentary overloads of 1,000 volts cause no damage; the new pickup probe minimizes thermocouple and triboelectric effects.

Literally, ⓗⓟ 425A is a necessary working tool wherever minute dc potentials are involved. In addition to its straightforward use in measuring individual voltages and currents, it has an input isolated from ground to permit difference measurements between small voltages.

Drift-Free Amplifier

In addition, the 425A's amplifier provides a 1 volt output for end scale deflection or a 1 ma output into 1,000 ohms to drive a potentiometer or galvanometer recorder. For driving sensitive potentiometer recorders, the 425A includes a built-in potentiometer for reducing output voltage. Amplifier drift is less than 2 μv/hr referred to the input, insuring reliable measurements of input signal drift even over long periods of time.

To assure that unwanted ac on the dc input does not disturb the meter indication, frequency response is down about 3 db at 0.2 cps down 50 db at 30 cps, and down approximately 60 db at 60 cps.

Versatile Ohmmeter

The new 425A measures a wide range of resistances. Milliohms may be measured by using a battery and series resistor as a constant current source. Higher resistances may be measured with higher input voltages. For example, a 100 volt supply allows the 425A to measure accurately up to 10^{13} ohms.

One of the outstanding features of the ⓗⓟ 425A is its high input impedance—a feature rarely found in combination with extreme sensitivity. This insures that a circuit under test is not disturbed by the presence of the voltmeter. The unique ⓗⓟ chopper plus careful design has yielded noise levels lower than those normally found even in low impedance instruments.

Model 425A has an inherent input impedance much higher than specified and a 1 megohm resistor directly across the input insures a constant input impedance. If an unusually high input impedance is required, the input resistor can be removed, at the factory when specified—at a slight additional cost. This results in greater than 200 megohms input impedance.

Specifications

Microvolt-Ammeter

Voltage Range: Positive and negative voltages from 10 μv end scale to 1 v end scale, 11 steps, 1–3–10 sequence.

Current Range: Positive and negative currents from 10 $\mu\mu$a end scale to 3 ma end scale, 18 steps, 1–3–10 sequence.

Input Impedance: Voltage Ranges: 1 megohm $\pm 3\%$. Current Ranges: Depends on range, 1 megohm to 0.33 ohm.

Range		*Impedance*
10	$\mu\mu$a	1.000 megohm
30	$\mu\mu$a	1.000 megohm
100	$\mu\mu$a	1.000 megohm
0.3	mμa	1.000 megohm
1	mμa	1.000 megohm
3	mμa	0.333 megohm
10	mμa	0.100 megohm
30	mμa	0.033 megohm
0.1	μa	0.010 megohm
0.3	μa	3300 ohms
1	μa	1000 ohms
0.003	ma	333 ohms
0.01	ma	100 ohms
0.03	ma	33 ohms
0.1	ma	10 ohms
0.3	ma	3.3 ohms
1	ma	1.0 ohm
3	ma	0.33 ohm

Accuracy: Within $\pm 3\%$ of end scale. Power line frequency variations $\pm$ 5 cps affect accuracy less than $\pm 2\%$.

Amplifier

Gain: 100,000 maximum.

Ac Rejection: At least 3 db at 0.2 cps, 50 db at 50 cps and approximately 60 db or more above 60 cps. A power line frequency or twice power line frequency signal 40 db greater than end scale causes less than 1% error.

Output: 0 to 1 v for end scale reading, adjustable.

Output Impedance: 10 ohms, shunted by 5,000 ohm potentiometer.

Noise: Less than 0.2 μv rms (typically less than 1.2 μv p-p) referred to the input.

Drift: After 15 minutes warm-up drift is less than ± 2 μv per hour referred to input.

General

Power: 115/230 v $\pm 10\%$, 60 cps, 40 watts. 50 cps operation on special order.

Dimensions: Cabinet Mount: 7½″ wide, 11¾″ high, 12″ deep. Rack Mount: 19″ wide, 7″ high, 13¼″ deep. 11½″ deep behind panel.

Weight: Net 17 lbs. Shipping 23 lbs. (cabinet mount). Net 21 lbs. Shipping 33 lbs. (rack mount).

Price: $500.00 (cabinet); $505.00 (rack mount).

Data subject to change without notice.

hp 456A AC CURRENT PROBE

Specifications

Sensitivity: 1 mv/ma ±2% at 1 KC.

Frequency Response: ±2%, 100 cps to 3 MC. ±5%; 60 cps to 4 MC; ±3 db, 20 cps to greater than 5 MC.

Maximum Input: 1 amp rms; 2 amp peak.

Maximum dc Current: Direct current up to 0.5 amp has no appreciable effect.

Input Impedance: (impedance added to test circuit by probe) approximately 0.03 ohm in shunt with 0.1 μh.

Output Noise: Less than 50μv rms (100 μv ac powered).

Power: 10 radio mercury cells; approx. 400 hours service normally supplied. Ac supply available. Specify hp 456A-95A, $32.00 extra. Factory installed, without batteries, $20.00 extra.

Dimensions: 5¾″ wide, 2½″ high, 4″ deep.

Weight: Net 3 lbs.

Price: $190.00.

Data subject to change without notice.

Measures ac Current Without Direct Connection to Wire

Now your conventional voltmeter or oscilloscope can measure current quickly and dependably—*without direct connection to the circuit under test or any appreciable loading to the test circuit.*

The unique hp 456A AC Current Probe clamps *around* the current-carrying wire, and provides a voltage output you read on a VTVM or scope. Model 456A's 1 mv to 1 ma unity conversion permits direct readings up to 1 ampere rms. Model 456A permits measurement of ac in logic circuits, transistors and vacuum tubes since even 0.5 ampere of dc has no appreciable effect on operation. The instrument also makes possible viewing on oscilloscopes complex current waveforms with rise times up to 0.08 μsec, or current signals ranging from 1 ma rms to 1 ampere rms.

The instrument can be relied upon for accurate measurements since it is virtually unaffected by stray fields or wire position in the aperture of the probe.

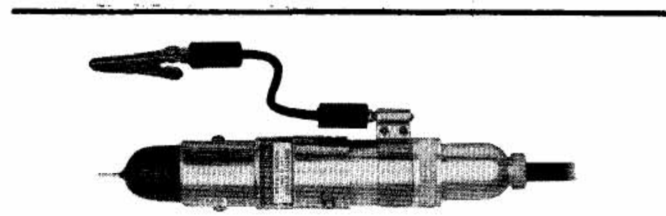
VOLTMETER ACCESSORIES

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

452A Capacitive Voltage Divider

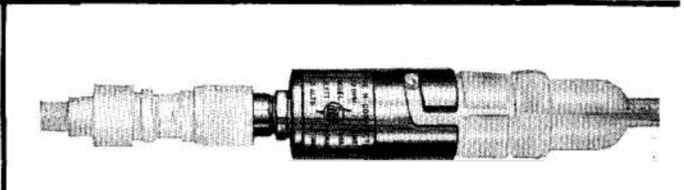
For -*hp*- 400 series and 410B. Safely measures power voltages to 25 kv. Accuracy ±3%. Division ratio 1000:1. Input capacity 15 μμf ±1. Maximum voltage ratings at 60 cps, 25 kv; 100 KC, 22 kv; 1 MC, 20 kv; 10 MC, 15 kv; 20 MC, 7 kv. Usable for dielectric heating, power and supersonic voltages. Price, $125.00.

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



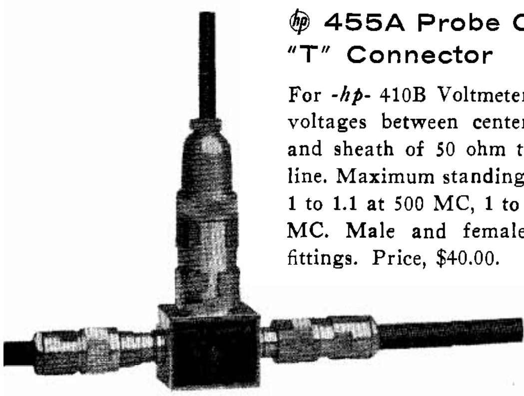
453A Capacitive Voltage Divider

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. $30.00.



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, $30.00.



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, $40.00.

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.

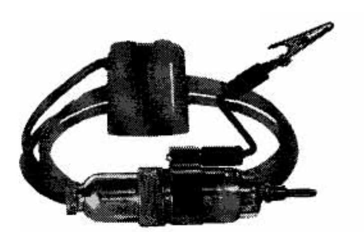
INSTRUMENT	VALUE	PRICE
-*hp*- 470A	0.1 Ω	$25.00
-*hp*- 470B	1 Ω	15.00
-*hp*- 470C	10 Ω	15.00
-*hp*- 470D	100 Ω	15.00
-*hp*- 470E	600 Ω	15.00
-*hp*- 470F	1,000 Ω	15.00

459A DC Voltage Divider

For -*hp*- 410B Voltmeter. Gives maximum safety and convenience for measuring high voltages as in television receivers, etc. Accuracy ±5%. Division ratio 100:1. Input impedance 12,000 megohms. Maximum voltage 30 kv. Maximum current drain 2.5 microamperes. Price, $30.00.

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, $30.00.



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 69) 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.

New *-hp-* 466A AC Amplifier (page 69, opposite) is an extremely compact, high stability instrument ideal wherever low distortion, wide frequency range and ready portability are required. It is particularly suited for increasing sensitivity of voltmeters and oscilloscopes, and field measurements where high impedance is required.

Distributed Amplifiers

-hp- 460A and 460B Distributed Amplifiers (pages 70, 71), 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 rated output of 8 volts into an open circuit. This is sufficient for operating scalers, etc. For higher voltages required for cathode ray tube deflection, *-hp-* 460B is recommended. This instrument is a wideband amplifier designed to supply a maximum of 125 volts peak (negative) open circuit. This is sufficient to provide full deflection on any commonly-used cathode-ray tube. One or more 460B amplifiers can be cascaded with one or more 460A amplifiers to provide a high-gain pulse amplifier with very rapid rise time and zero overshoot *(see Figure 1)*.

Cascading Amplifiers

When cascading distributed amplifiers, consideration must be given to 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 (3.0×10^{-9} seconds). In addition, the rise time of the RC combination formed by the capacity of CRT deflection plates and the internal impedance of the 460B (200 ohms) should be considered.

Traveling-Wave Tube Amplifiers

Hewlett-Packard 490B, 491A, 492A and 494A Traveling-Wave Tube Amplifiers (pages 72, 73) 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 factor is proportional to $1/\sqrt{n}$, where n is the number of tubes in the first stage. *-hp-* 460B has less internal generated noise than *-hp-* 460A (460B has 13 tubes in the first stage whereas 460A has only 5). *-hp-* 460B should thus be used to start a cascade chain when extremely small signals are to be examined.

-hp- Traveling-Wave Tube Amplifiers have low noise figures but 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.

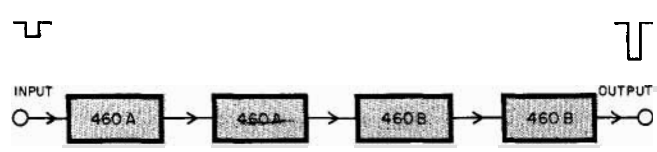
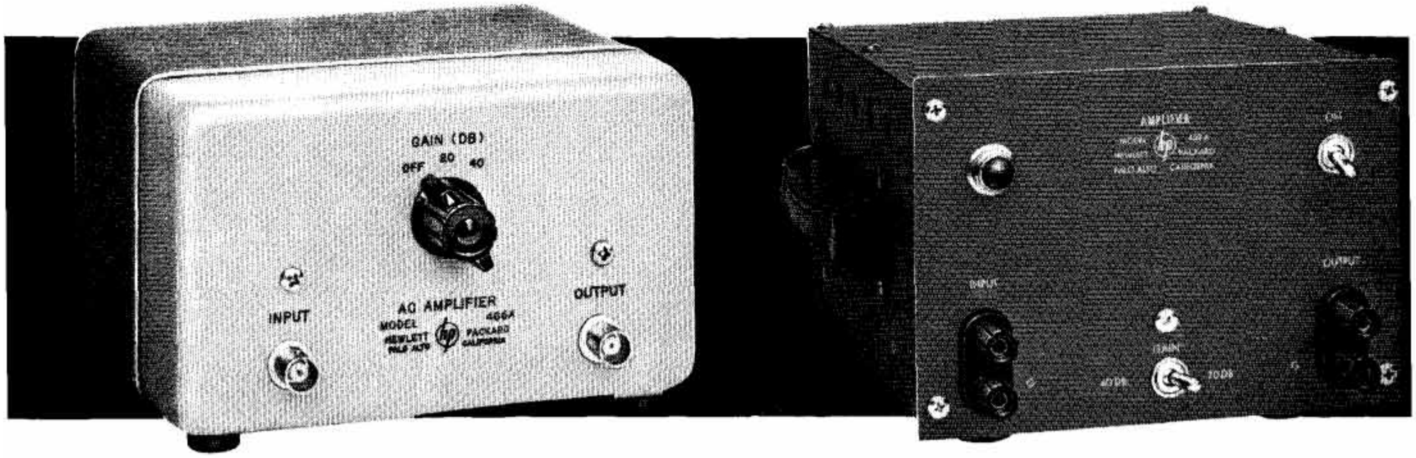


Figure 1. Typical cascading of 460A/B Amplifiers to give approximately 70 db gain and 125 volt pulse output.



466A AC Amplifier

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

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

Specifications

Gain: 20 or 40 db ±0.2 db at 1,000 cps.

Frequency Response: ±0.5 db, 10 cps to 1 MC; ±3 db, 5 cps to 2 MC.

Output Voltage: 1.5 v rms across 1,500 ohms.

Noise: 75 μv referred to input, 100,000 ohms.

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

Distortion: Less than 1%, 10 cps to 100 KC.

Power: 12 radio-type mercury cells; ac line (requires hp 466A-95A Power Supply).

Size: 6¼″ wide, 4″ high, 6¼″ deep. Weight 3 lbs.

Price: $150.00.

Data subject to change without notice.

450A Stabilized Amplifier

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

Specifications

Gain: 20 or 40 db ±⅛ db at 1,000 cps.

Frequency Response: ±0.5 db, 10 cps to 1 MC.

Stability: ±2%, normal line voltage.

Impedance: Input, 1 megohm, 15 μμf shunt, Output, less than 150 ohms.

Distortion: Less than 1%, 2 cps to 100 KC; less than 5% above 100 KC.

Output: 10 v max into 3,000 ohm or greater load.

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

Size: 8¼″ wide, 5½″ high, 10½″ deep. Weight 10 lbs. (Rack mount, 5¼″ high, also available.)

Price: $140.00 (cabinet); $145.00 (rack).

-hp- 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 to over 100 MC
- General laboratory amplifier

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

-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 0.003 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's, pulse amplification of 125 volts open circuit, limited duty cycle.

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 incorporates an 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 page 61)* 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.)

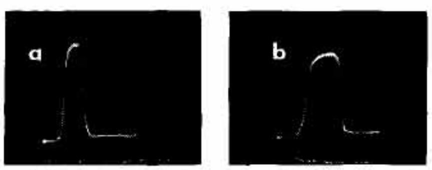


Figure 1. (a) 0.01 μsec pulse through *-hp-* 460B Amplifier. (b) 0.02 μsec pulse through 3 amplifiers in cascade.

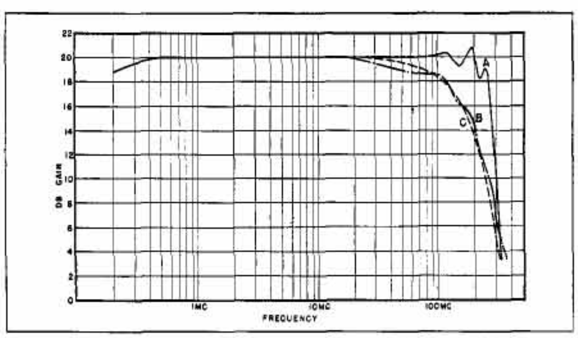


Figure 2. Typical response of 460A Amplifier working into (B) resistive load and (A) using *-hp-* 410B Vacuum Tube Voltmeter. (C) Gaussian curve.

Specifications

460AR*

Frequency Response: *High Frequency*—closely matches Gaussian curve when operating into a 200-ohm resistive load. 3 db point is 120 MC. *Low frequency*—off approximately 3 db at 100 KC when operating into a matched load. Off approximately 3 db at 3 KC when operating into an open circuit (i.e. CRT plates) on succeeding amplifier. 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.

Rated 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. 0.003 μsec (10% to 90% amplitude). No appreciable overshoot.

Power: 115/230 v ±10%, 50/1,000 cps, 60 watts.

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

Weight: Net 11 lbs. Shipping 18 lbs.

Price: $185.00.

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.

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

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. $15.00.

-hp- 46A-95D Adapter—Bayonet sleeve for connecting *-hp-* 410B VTVM to output of 460A amplifiers. $20.00.

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

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

-hp- 460B-95A Adapter—Connects to *-hp-* 150A/AR oscilloscope plates. $20.00.

Data subject to change without notice.

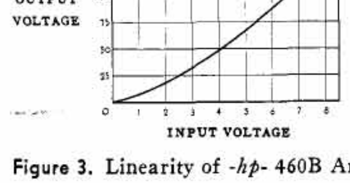


Figure 3. Linearity of *-hp-* 460B Amplifier.

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

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, 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.

-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.

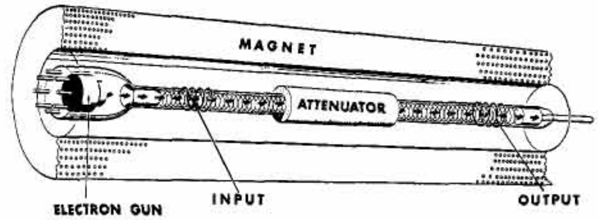


Figure 1. Construction of the *-hp-* Traveling-Wave Tube showing input and output coupling helices and attenuator helix.

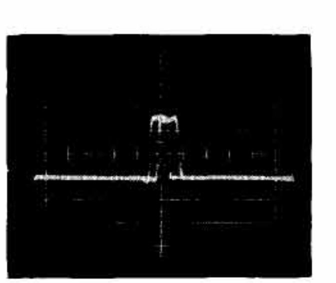


Figure 2. Unique modulating fidelity of *-hp-* 490B is shown in double-exposure oscillogram of 0.1 μsec pulses. First pulse (applied by *-hp-* 212 Pulse Generator) is modulating pulse with rise time of 0.02 μsec; delay through tube approximately 50 millimicroseconds. Second pulse is rf output. Note absence 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 100 K.	Approx. 50 volts peak to peak. Provides 360° phase shift. Input impedance 100 K.
Hum, Spurious Modulation:	At least 30 db below signal level.	At least 30 db below signal level.	At least 35 db below signal level.	At least 35 db below signal level.
Input Impedance:	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.	50 ohms, SWR less than 2.
Output Internal Impedance:	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.	50 ohms, SWR less than 3.
Dimensions and Weight:	7½" wide, 11½" high, 19½" deep. 55 lbs.	7½" wide, 11½" high, 20" deep. 73 lbs.	7½" wide, 11½" high, 20" deep. 66 lbs.	7½" wide, 11½" high, 20" deep. 64 lbs.
Power Supply:	115 volts ±10%, 50-1000 cps, approx. 125 w.	115 volts ±10%, 50-60 cps, approx. 370 w.	115 volts ±10%, 50-60 cps, approx. 200 watts.	115 volts ±10%, 50-60 cps, approx 225 watts.
Traveling-Wave Tube:	Huggins Laboratories HA-1HP.	Huggins Laboratories HA-2HPA.	Huggins Laboratories HA-26HP.	Huggins Laboratories HA-4HP.
Price (including tube):	$1400.00.	$1400.00.	$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.*

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 of frequency and time can be made with precision approaching 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 frequency and time measuring instruments depends largely upon their application.

Complete Coverage

Hewlett-Packard frequency measuring equipment covers the range from 0 cps to 40 KMC. ⓗ instruments for measuring time cover 1 microsecond to 100 days. ⓗ frequency standards offer stability as high as 3 parts in 10^8.

Hewlett-Packard instruments for frequency and time measurements are listed under Figure 4, at right.

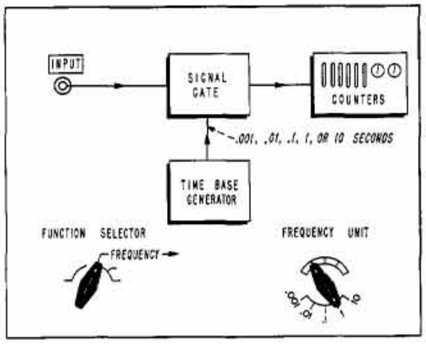


Figure 1. Frequency measurement circuitry in ⓗ electronic counters (ⓗ 524 illustrated).

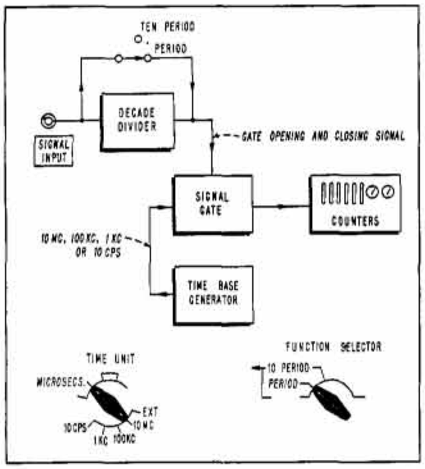


Figure 2. Period measurement circuitry in ⓗ electronic counters (ⓗ 524 illustrated).

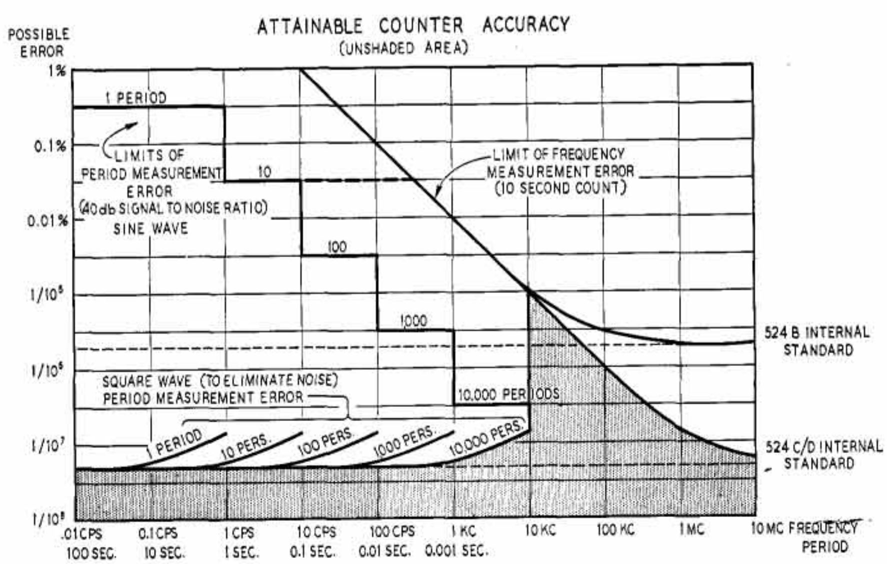


Figure 3. Possible error factor in frequency measurement (ⓗ 524B, 525A).

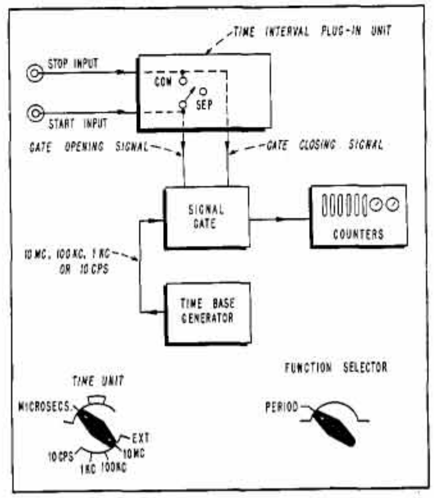


Figure 4. Time interval measurement circuitry in ⓗ electronic counters (ⓗ 524, 526B illustrated).

- Frequency Standards
- Electronic Counters
- Digital Recorders
- Digital Delay Generators
- Transfer Oscillators
- Waveguide Frequency Meters
- Electronic Frequency Meters
- Electronic Tachometers and Tachometer Transducers

Frequency Standards

The new ⓗ 100ER Precision Frequency Standard offers stability of 5/100,000,000 per week, plus a wide variety of outputs including six standard sine frequencies and four pulse signals. The instrument also includes a timing comb for calibrating or measuring sweeps and time intervals. Detailed information on the new 100ER appears on page 81.

The internal standards in the 522, 523 and 524 series counters also serve as frequency standards in many applications. The standards in Models 524C and 524D are especially useful, offering short-term stability of 3 parts in 10^8 and long-term stability of 5 parts in 10^8 per week.

Frequency Divider and Clock

For very accurate local time comparison or generation, new ⓗ 113AR

Frequency Divider and Clock is offered. This instrument makes possible precision time comparisons between stable oscillators and standard transmitted time signals — permitting adjustment of systems for maximum accuracy, simplifying recording of drift rates and measuring time or frequency differences between oscillators in widely separated systems. Propagation path errors are averaged out and Doppler errors are virtually eliminated. More details on ⓗ 113AR appear on page 82.

Electronic Counters

The development of pulse counter circuits has led to the manufacture of electronic counters capable of many measurements which were not possible previously—particularly those involving frequency and time. Hewlett-Packard electronic counters offer the convenience of instantaneous, automatic readings, in direct numerical form, of frequency, period, time interval and phase angle. They are designed for simple operation and may readily be used by non-technical personnel. They are engineered for utmost dependability and accuracy.

Frequency Measurements

Frequency and time measurements with ⓗ electronic counters are described below. Operation with transducers for measuring speed and other quantities is described in separate sections.

The unknown frequency (fx) to be measured is applied to the signal gate *(Figure 1)*. The gate is held open for a precise length of time determined by the time base generator, a crystal oscillator with high stability. The fx pulses, passed to the counter circuits while the gate is open, are totalized and displayed on the instrument. Accuracy is determined by the stability of the time base generator and the ± 1 count error inherent in the gate-and-count type of instrument *(See Figure 2)*.

Period Measurements

ⓗ Counters are arranged to measure period (1/fx) directly *(Figure 2)*. This is particularly important for measurements at lower frequencies when the ± 1 count error in frequency becomes a significant factor. In period measurement, the unknown frequency (fx) opens and closes the signal gate for one period or ten periods, and a standard frequency from the time base generator is applied to the counter circuits. With a 1 v rms signal, a one-period measurement can be made to an accuracy of 0.3%; a measurement averaged over ten periods increases the accuracy to 0.03%. Even better accuracy may be obtained with larger signals or, with the Model 524 series counters, by using the 526C Period Multiplier Unit for 100-, 1,000-, or 10,000-period measurements. Readings are displayed directly in microseconds, milliseconds or seconds.

Time Interval Measurements

Time interval measurements are similar to period measurements except that the trigger point on the signal waveform or waveforms are adjustable. This adjustment permits separate signals to be used as start and stop signals or permits measurements to be made from one part of a waveform to another part of the same waveform.

As in the case of period measurements, the input signals control the opening and closing of the gate, while the standard frequencies are passed to the counters as time units *(Figure 4)*. Thus the unknown interval is measured in terms of microseconds, milliseconds or seconds. Accuracy of this method is ± 1 count of the standard frequency counted $\pm$ the stability of the standard frequency.

Phase Angle Measurements

ⓗ Counters in the 522, 523 and 524 series are excellent instruments for phase angle measurements. Their speed and simplicity of operation make the counters suitable for phase measurements on the production line as well as in the laboratory. Phase difference is measured in microseconds by using the internal standard. Phase angle at a frequency fx may be read directly in degrees by counting an external frequency of 360 fx or 3600 fx while the gate is open.

ⓗ 523 and 524 series counters are probably the most accurate, convenient, wide-range phase-measuring instruments available.

Random Event Counting

Random events may be totalized over any selected gate time or may simply be totalized by use of the manual gate feature on all ⓗ counters. Provisions are made on some models for the use of external time bases such as electro-mechanical timers for the longer totalizing periods encountered in nuclear work.

Ratio Measurements

The ratio of f_1/f_2 may be made with ⓗ counters by using f_2 to open and close the gate and counting f_1 when the gate is open. With proper transducers, ratio measurements may be extended to any phenomena which may be represented by frequencies or pulse rates within the range of the counter.

Totalizing

All Hewlett-Packard counters are equipped with manual gate features which permit totalizing of electrical events.

Digital Recorders and Other Output Devices

Once any variable has been measured with an ⓗ electronic counter, output information is available in a form which is, or can be made, compatible with digital data handling devices such as digital recorders, tape punches, card punches, magnetic tape recorders, automatic typewriters, computers and similar equipment. Typical digital control systems available in the electronics industry include automated test systems, go-no go systems, multiple comparator systems, and digital servo systems.

ⓗⓟ Digital Recorders

Hewlett-Packard builds two types of digital recorders, Model 560A and Model 561B.

The ⓗⓟ 560A is an 11-digit, parallel entry recorder which operates on the one-line staircase code from ⓗⓟ decade counter units. It will print up to 11 digits at a maximum rate of 5 lines per second.

Model 560A has a unique output feature which provides analog records of unusual flexibility and resolution. Data plots may correspond to any three successive columns being printed and are especially useful for close observation of trends.

Since the analog output is synthesized from digital information, error-free zero-suppression is possible. This provides records of extreme resolution from potentiometer or galvanometer strip chart or x–y recorders.

Another important characteristic of the analog output is an inherent range-shifting featuring which applies known zero-suppression or elevation as required to keep the record on-scale.

Hewlett-Packard 560A was designed specifically to record from any ⓗⓟ counter. It may be used with other instruments, such as digital voltmeters or clocks, with the proper one-line staircase output.

Hewlett-Packard Model 561B Digital Recorder has the same printing capabilities as the 560A, but utilizes a 10-line code. Since input information may be in the form of contact closures or voltage changes, the ⓗⓟ 561 is appropriate for a great many uses.

ⓗⓟ 560A and 561B Digital Recorders are described in greater detail on pages 96 and 97.

For special applications the printer unit only, ⓗⓟ 565A Digital Printer is available. Units are priced at \$640.00 each (1 to 9), \$620.00 each (10 to 24), and \$600.00 each (25 or more).

Other Recording Systems

The ⓗⓟ 500B Electronic Frequency Meter and the 500C Electronic Tachometer are equipped with recorder output jacks for operating potentiometer strip chart and x–y recorders, as well as galvanometer recorders requiring up to 1 ma. This approach is suitable when the extreme accuracy of digital or digital/analog recording is not required.

Digital Delay Generators

The ⓗⓟ 218A Digital Delay Generator is a unique new instrument providing two independent delays adjustable from 1 microsecond to 10,000 microseconds in steps of 1 microsecond. Vernier controls permit interpolation to 0.1 microsecond. With circuitry which eliminates the usual ± 1 count error, the accuracy of the 1 microsecond steps is determined only by the internal standard frequency. The ⓗⓟ 218A and associated plug-in units provide an extremely versatile system for generating or measuring time intervals to very high accuracy. Detailed description will be found on pages 46 and 47.

Transfer Oscillators

Direct frequency measurements with ⓗⓟ electronic counters may be made up to 220 MC (524 series counter with ⓗⓟ 525B frequency converter unit). Development of the Hewlett-Packard Model 540B transfer oscillator makes it possible to extend frequency measurements to 12.4 KMC and beyond with electronic counter accuracy.

Model 540B employs a highly stable 100 to 220 MC oscillator generating harmonics to at least 12.4 KMC. The instrument contains a broad band mixer system, an amplifier and an oscilloscope for comparison of these frequencies with the unknown. Recently developed untuned mixers and an excellent vernier tuning system make it a simple matter to obtain zero beat, at which time the fundamental frequency is measured with the 524/525B combination. The ⓗⓟ 540B is equipped with an AFC system which may be used for locking its harmonic to an unknown signal for drift measurements. A harmonic generator is also included which may be used to drive external traveling wave amplifiers and waveguide mixers for extending measurements considerably above X-band.

For detailed information on the ⓗⓟ 540B, please refer to pages 94 and 95.

Microwave Frequency Meters

Hewlett-Packard builds waveguide frequency meters covering the complete range from 5.2 KMC to 40 KMC. These instruments are described in detail on page 153.

Electronic Frequency Meters

For frequency applications not requiring the extreme accuracy of electronic counters, the ⓗⓟ 500B frequency meter responds in proportion to the rate of input pulses instead of directly counting each input pulse. Frequency is indicated on a meter, and scale expansions of x3 and x10 are provided. The instrument is equipped with an output for driving potentiometer strip chart and x–y recorders and galvanometer recorders requiring up to 1 milliampere.

The 500B also provides a pulse output consisting of constant amplitude pulses whose lengths and repetition frequency are determined by the rate of input pulses. The pulse output may be used for stroboscopic purposes and is especially useful for measuring or recording FM deviation. Model 500B is described on pages 78 and 79.

Tachometry Instruments

The use of digital techniques offers great advantages in the measurement of speed and speed ratios. By developing digital tachometer transducers, Hewlett-Packard has extended to speed measurement the accuracy, simplicity, speed and versatility of operation which have proven so valuable with electronic counters and associated equipment in other applications.

⊕ 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.

Types of ⊕ tachometry equipment are:

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

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

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

Transducers

The two types of ⊕ transducers are (1) Tachometer Generators and (2) Optical Tachometer Pickups.

The Tachometer Generator is a low torque, compact unit for measuring shaft speed. It can also be used to determine the instantaneous rate of rotation for torsional vibration measurements. When connected to a rotating shaft, the Tachometer Generator produces output pulses which can be counted with any ⊕ counter. Useful shaft speed range is approximately 15 rpm to 40,000 rpm. The four models available in the ⊕ 508 Tachometer Generator series are described in detail on page 80.

Another ⊕ transducer, Model 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 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 180 rpm to 3,000,000 rpm. Detail data on the ⊕ 506A may be found on page 80.

Tachometer Indicators

Tachometer indicators measure the rate at which the transducers produce electrical pulses, and display this information in terms of revolutions per second or revolutions per minute. Tachometer system accuracy depends largely upon these indicators.

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

The Hewlett-Packard Model 500C Electronic Tachometer is of the frequency meter type and is described on pages 78 and 79. A similar instrument, calibrated in frequency, is the ⊕500B, also described on pages 78 and 79.

These instruments will measure speeds from 180 to 6,000,000 rpm with accuracy better than $\pm 2\%$. For small differentials in readings or small changes in repetitive readings these instruments have even better accuracy.

Any ⊕ electronic counter will operate with either type of ⊕ tachometer transducer for speed measurement. Following are some of the advantages which electronic counter measurement of speed offers:

- Extreme accuracy
- Direct, numerical readout
- Simple operation
- Digital recording
- Analog recording with extreme resolution
- Speed ratio measurement and control
- Operation into digital control and data handling systems measuring other quantities with ⊕ counters and frequency meters.

Various manufacturers offer a variety of transducers for measurement of physical quantities in terms of frequency or pulses. With these transducers, the advantages of electronic counter measurement may be applied to many measurements other than frequency and time. Transducers are presently available for measuring the following quantities with electronic counters:

Voltage	Pressure
Current	Temperature
Resistance	Flow
Force	Liquid level
Weight	

In addition to the normal measurement of the quantities listed above, it is important to note that the counters provide a simple, accurate method of measuring ratios of any of these quantities.

-hp- 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 recorder for a continuous frequency record or X–Y plot.

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 when checking for the presence of vibration or torsion.

Specifications 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 22 lbs. (cabinet mount). Net 20 lbs. Shipping 32 lbs. (rack mount).

Accessories Available: *-hp-* 506A Optical Tachometer Pickup, $125.00. *-hp-* 508A/B/C/D Tachometer Generator, $100.00. *-hp-* AC-2A/B Dual Rack Panel, $25.00.

Price: $285.00 (cabinet); $290.00 (rack mount).

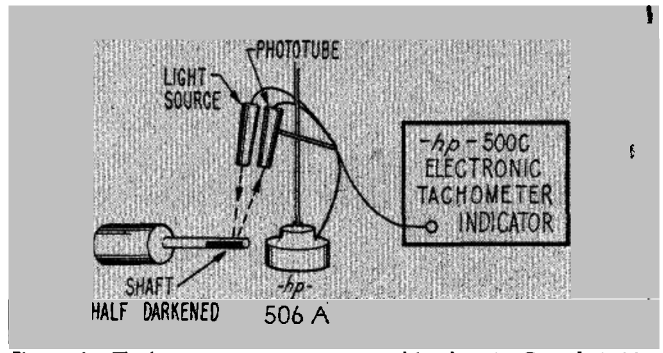


Figure 1. Tachometry measurements with *-hp-* 500C and 506A.

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 500C

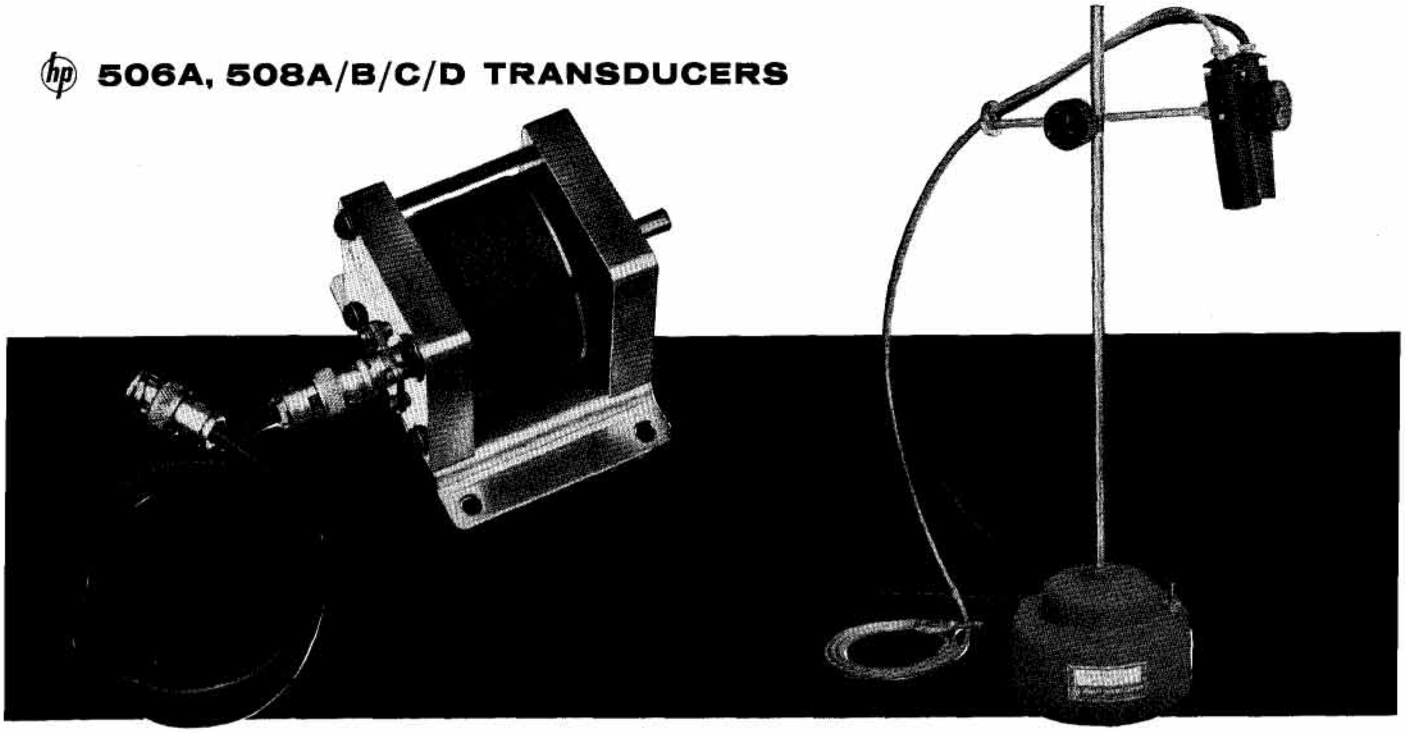
Circuit and Construction same as *-hp-* 500B except for meter calibration.

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

Price: $285.00 (cabinet); $290.00 (rack mount).

Data subject to change without notice.

-hp- 506A, 508A/B/C/D TRANSDUCERS



-hp- 508 Tachometer Generators

Models 508A/B/C/D Tachometer Generators are rotational speed transducers for use with electronic counters or frequency meters in making fast, accurate rpm measurements from 15 to 40,000 rpm. They are specifically designed to operate with *-hp-* electronic counters and frequency meters.

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: 508A, 40 to 40,000 rpm; 508B, 30 to 30,000 rpm; 508C, 40 to 25,000 rpm; 508D, 50 to 5,000 rpm.

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

Output Voltage: Greater than 0.2 v rms over shaft speed range.

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

Running Torque: Approximately 0.15 in.-oz.; 1/2 in.-oz. at 1,500 rpm.

Peak Starting Torque: Approximately 4 in.-oz.

Dimensions: 2-7/16" high x 3½" wide x 3¾" deep.

Price: (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: 180 to 300,000 rpm. (Measurements of higher speeds are possible by using an amplifier such as *-hp-* 450A; lower speeds by using a multisegment reflector.)

Output Voltage: At least 1 v rms, 300 to 100,000 rpm (into 1 megohm or more impedance) with reflecting and absorbing surfaces ¾" square.

Light Source: 21 candlepower, 6 volt automotive bulb.

Phototube: Type 1P41.

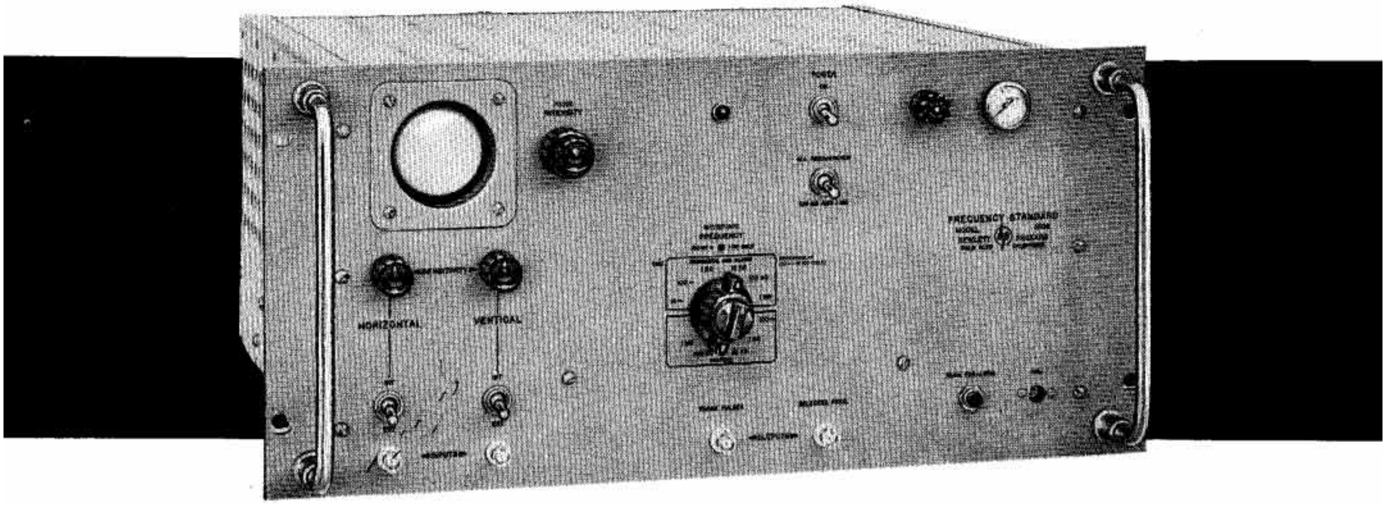
Phototube Bias: +70 to +90 volts dc (supplied by *-hp-* 500B/C, 521A/C).

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

Price: $125.00.

Data subject to change without notice.

100ER PRECISION FREQUENCY STANDARD



New! $5/10^8$ Stability, Yet Compact, Just 8-3/4" High

STABILITY equivalent to complex, expensive primary standards and the versatility of a wide variety of outputs are offered by the new hp 100ER Precision Frequency Standard.

This compact, highly convenient new instrument provides six standard sine frequency signals and four pulse signals for use at many different stations on a production line or in the laboratory.

Stability of 5 parts in 100,000,000 per week is obtained by careful aging and testing of the crystal controlled oscillator and oven.

A particularly useful feature of Model 100ER is a timing comb providing output pips at 100, 1,000 and 10,000 microsecond intervals. The comb simplifies "fast" sweep and time interval measurements and calibration.

Model 100ER includes a built-in oscilloscope which may be used as a comparison device to calibrate external equipment such as oscillators through use of Lissajous figures. The oscilloscope also may be used to check the Standard's internal frequency division.

Data subject to change without notice.

Specifications

Stability: Short term, 3 parts in 10^8. Long term, 5 parts in 10^8 per week.

Output Frequencies: Sinusoidal, 10 cps, 100 cps, 1 KC, 10 KC, 100 KC and 1 MC. Pulse 10 cps, 100 cps, 1 KC and 10 KC.

Output Voltages: Sinusoidal 5 v rms minimum into rated load. Pulse approx. 15 v peak-to-peak. Harmonics to 5 MC from 10 KC pulses.

Rated Load: 50 ohms nominal, 100 KC and 1 MC. 5,000 ohms nominal, 10 cps, 100 cps, 1 KC and 10 KC.

Source Impedance: Approx. 50 ohms, 100 KC and 1 MC. Approx. 300 ohms, 10 cps, 100 cps, 1 KC and 10 KC.

Distortion: (Sinusoidal) Less than 4% into rated load.

Timing Comb: Marker pips at 100 μsec intervals. Double amplitude pips at 1,000 μsec, triple amplitude pips at 10,000 μsec intervals.

Oscilloscope: Vertical sensitivity adjustable approx. 3 v rms/inch. Vertical bandwidth approx. 100 cps to 1 MC. Horizontal sensitivity adjustable approx. 1.5 v rms/inch. Horizontal bandwidth approx. 20 cps to 150 KC.

Frequency Shifter: Panel pushbutton lowers oscillator frequency approx. 0.1 cps at 1 MC to aid in frequency comparisons.

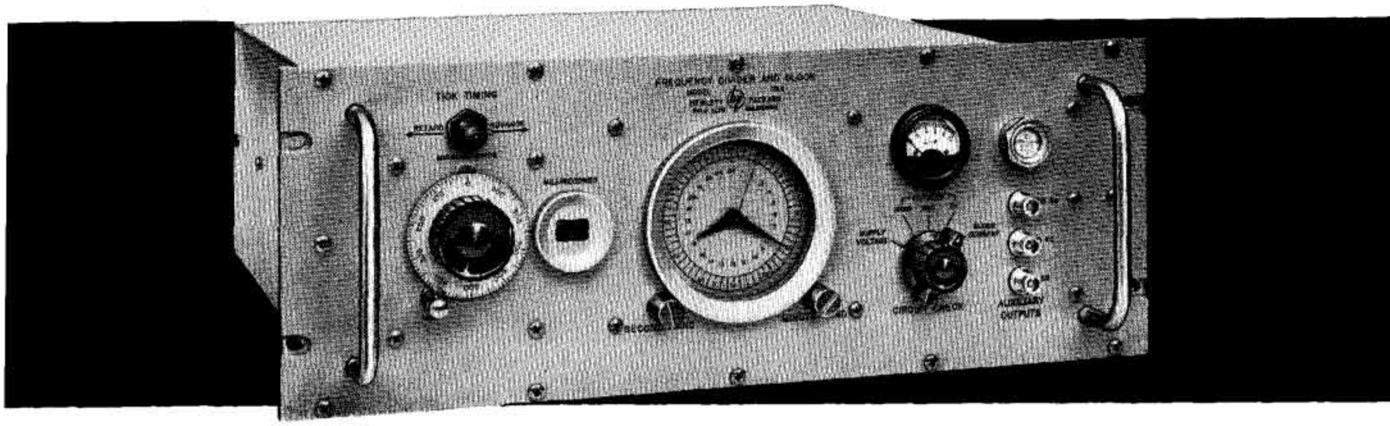
Power: 115/230 v $\pm$10%, 50/1,000 cps, 140 watts.

Dimensions: Rack mount. 8¾" high, 19" wide, 18" deep behind panel, 20½" deep overall.

Weight: Net 35 lbs. Shipping 50 lbs.

Price: $900.00.

113AR FREQUENCY DIVIDER AND CLOCK



Specifications

Frequency Input: 100 KC for solar time, input bandwidth ± 300 cps. 100.3 KC for sidereal time, on special order.
Accuracy: 1) Accuracy of output pulse and sine-wave signals determined by accuracy of input frequency.
2) Time reference dial accuracy ± 10 μsec.
Effect of Transients: Will not gain or lose time because of :1) ±300 volt step function on 100 KC input. 2) 0 to ±50 volt pulses, 0 to 500 pps, 1 to 10 μsec duration on 100 KC input. 3) ±4 volt step in 26 v dc input.
Voltage Input: 0.5 to 5 volts rms.
Input Impedance: 300 ohms nominal.
Tick Output: Pulse rate, 1 pps; jitter, less than 1 μsec; amplitude, 10 volts minimum; rise time, less than 10 μsec; duration, 5 to 30 μsec; source impedance, 5,000 ohms nominal.
100 ms Pulse: Pulse rate, 1 pps; amplitude, 4 volts minimum; rise time, less than 10 μsec; duration, 100 ms nominal; source impedance, 50 ohms nominal.
1 KC Pulses: Pulse rate 1000 pps; amplitude, + and − pulses, at least 4 volts peak; duration, 8 μsec nominal; source impedance, 5,000 ohms nominal.
Time Reference: Continuously adjustable. Directly calibrated in ms and 10 microsecond increments.
Auxiliary Output: 100, 10, and 1 KC sinusoidal, 0.25 volts rms, source impedance 1,200 ohms.
Frequency Divider: Regenerative type, fail-safe (non-selfstarting).
Clock: 24-hour dial; minute hand adjustable in 1 minute steps; second hand continuously adjustable, manual start. Front panel adjustment of clock hands does not affect tick output. 12-hour dial on special order.
Monitor Meter: Ruggedized meter and selector switch on front panel for checking supply voltage, divider current (100 KC, 10 KC, 1 KC) and clock current.
Power Required: 26 ±2 volts dc, 10 to 25 watts.
Dimensions: 19″ wide, 7″ high, 19½″ deep behind panel.
Weight: Net 35 lbs. shipping approximately 51 lbs.
Accessories Furnished: 113A-16E Cable, 6 ft. long, connects 113AR to 724AR Standby Power Supply.
Price: $2,500.00.

Data subject to change without notice.

New! Very Accurate Local Time Comparison or Generation

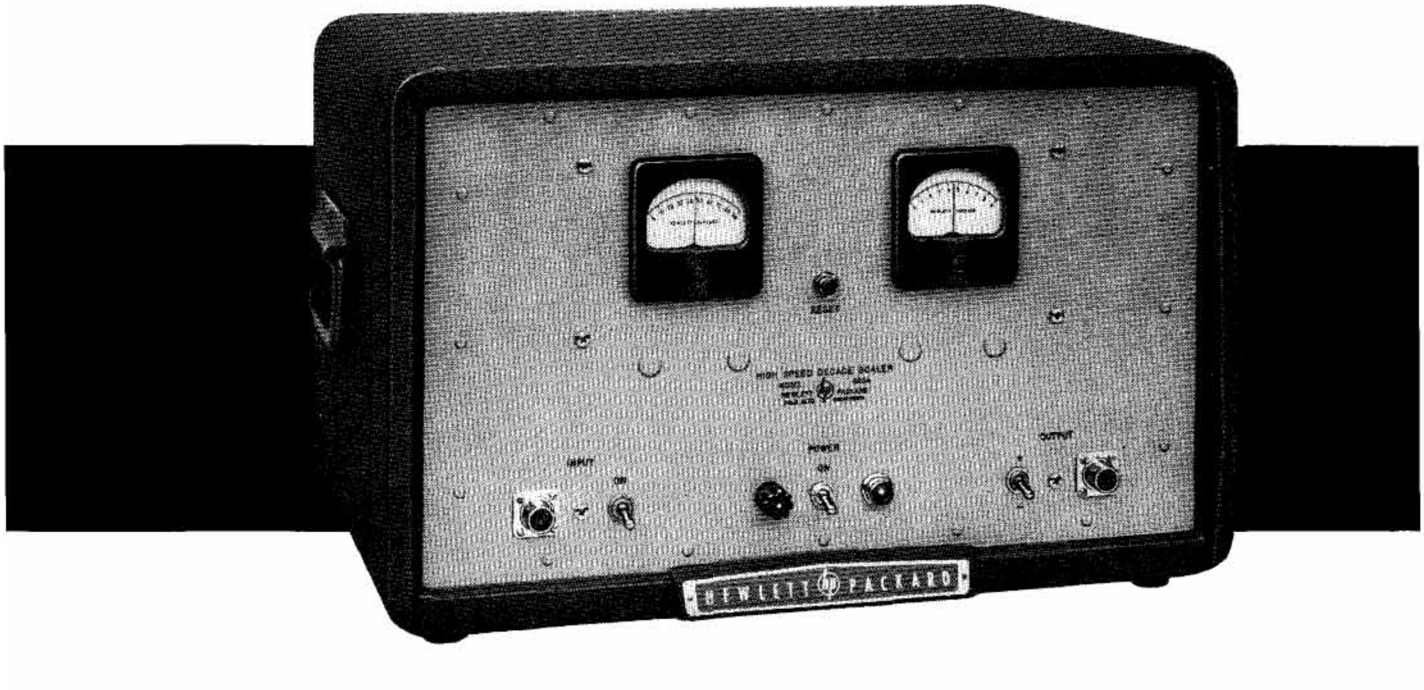
THIS NEW hp 113AR Frequency Divider and Clock makes possible precision time comparisons between stable oscillators and standard transmitted time signals. This permits adjustment of systems for maximum accuracy, and simplifies recording of drift rates, or time or frequency differences between oscillators in widely separated systems.

Propagation path errors are averaged out and Doppler errors are virtually eliminated.

hp 113AR's unique optical gate (no contacts, no wear, cannot add jitter) and a directly calibrated precision phase shifter make possible the unique accuracy of the clock and provide a time comparison capability of ±10 microseconds.

Regenerative dividers and a motor which are not self-starting reduce the possibility of taking erroneous data since interruptions in the driving signal or power stop the clock.

Model 113AR is conservatively designed from premium components, fully transistorized, and meets performance requirements of MIL-E-16400. The unit is rugged, mobile, dependable and measures only 7″ high.



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 ⓗⓟ 521 Series and 522B) to record large numbers of occurrences. This feature make the ⓗⓟ520A useful for measurement of frequencies up to 10 MC, in applications where the accuracy of the last two places is unimportant.

Data subject to change without notice.

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, approximately 35 volts amplitude and approximately 5 μsec wide at base. Rise time approximately 1 μsec.

Output Impedance: Operates into 5,000 ohm load, or higher.

Power: 115 v ±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 59 lbs. (cabinet mount). Net 34 lbs. Shipping 78 lbs. (rack 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 (cabinet); $600.00 (rack mount).

ⓗⓟ 521 SERIES INDUSTRIAL COUNTERS

Model 521D

Model 521C

Low Cost, Flexible, Easy-To-Use; 1 cps to 1.2 MC!

Advantages:

Quick, convenient, accurate
Easily used by non-technical personnel
Unique versatility, low cost
Five models for every need
Simple conversion to operate printer
Rugged, compact, functional

Uses:

Measure frequency, speed, rpm, rps
Count random events, totalize
Count to 120 cps or 1.2 MC (521G)
With proper transducers, measure weight, pressure, temperature, acceleration, etc.

The Hewlett-Packard 521 Series Electronic Counters are rugged, versatile instruments designed for a broad array of production, processing and laboratory applications. These instruments ably fill the need for laboratory-quality equipment capable of highly accurate measurements heretofore possible only with much more elaborate and expensive equipment.

ⓗⓟ 521 Series Counters measure frequency and speed, and count events occurring at random within a selected period of time. With proper transducers converting mechanical into electrical phenomena, the instruments will measure weight, pressure, temperature and other quantities which can be related to frequency. ⓗⓟ 521 Series Counters are intended for use with such transducers as ⓗⓟ 506A Optical Tachometer Pickup and ⓗⓟ 508A/B/C/D Tachometer Generators *(see page 80)*.

521 Series Counters read in cycles per second and (when used with ⓗⓟ 506A and 508 Series transducers) will indicate rps and rpm directly. Display time of results is variable or can be "held" indefinitely by a front panel control. The

instruments have self-check circuits confirming accuracy of operation, and three accessory power supplies of —150 volts dc, 300 volts dc and 6.3 volts ac.

Digital Recorder Operation

Versatile 521 Series Counters may be adapted easily to operation of hp 560A or 561B Digital Recorders with the installation of a kit. This kit can be installed by the hp factory before shipment (slight extra charge), or can be purchased for field installation at a later date.

The hp Digital Recorder and 521 Counter combination offers a printed record of counter readings at rates up to 5 lines per second. The 560A has an analog output signal proportional to the number printed in any three-column group. This feature provides digital zero suppression which makes possible extremely accurate analog recording. An inherent range switching system insures that the analog recorder is kept on scale. The analog output will drive either strip chart or X-Y Recorders such as the Moseley Autograf Model 2-D.

521 Series Highlights

Five different 521 Series Counters are offered. Each has similar basic characteristics and functions, but significant details such as registration, method of readout and frequency range differ.

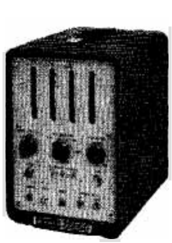
hp **521A.** Four-place columnar registration, maximum count 9,999. Range 1 cps to 120 KC, or 220 KC at slight extra cost.

hp **521C.** Five-place columnar registration, maximum count 99,999. Range 1 cps to 120 KC, or 220 KC at slight extra cost. Three gate times instead of two.

hp **521D.** Four-place in-line digital display tube readout, maximum count 9,999. Range 1 cps to 120 KC.

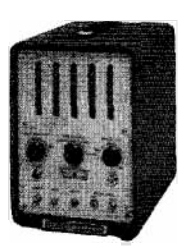
hp **521E.** Five-place in-line digital display tube readout, maximum count 99,999. Range 1 cps to 120 KC. Three gate times instead of two.

hp **521G.** Five-place columnar registration, maximum count 99,999. Range 1 cps to 1.2 MC, designed for applications where high counting rate is required but accuracy requirement is moderate.



Model 521A

Model 521E



Model 521G

Specifications

hp 521A Industrial Counter

Range: 1 cps to 120 KC.*

Accuracy: ± 1 count $\pm$ accuracy of 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 $\mu\mu$f shunt.

Gate Time: 0.1 and 1 second.

Display Time: Variable 0.1 to approx. 15 seconds; or held indefinitely.

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

Dimensions: Cabinet Mount: 9¾″ wide, 15¼″ high, 14″ deep. Rack Mount: 19″ wide, 8¾″ high, 13″ deep.

Weight: Net 25 lbs. Shipping 39 lbs. (cabinet mount). Net 25 lbs. Shipping 37 lbs. (rack mount).

Price: $475.00 (cabinet); $480.00 (rack mount). (Add $45.00 for operation with 560A; add $35.00 for 220 KC operation.)

hp 521C Industrial Counter

Same as the hp 521A except:

Accuracy: ± 1 count, $\pm 0.01\%$.

Registration: 5 places. Total count capacity 99,999.

Gate Time: 0.1, 1.0, and 10.0 seconds.

Time Base: Crystal controlled.

Price: $650.00 (cabinet); $655.00 (rack mount). (Add $45.00 for operation with 560A; add $35.00 for 220 KC operation.)

hp 521D Industrial Counter

Same as the hp 521A except:

Registration: 4 in-line digital display tubes; total count 9,999.

Price: $675.00 (cabinet); $680.00 (rack mount). Add $45.00 for operation with 560A or 561B.)

hp 521E Industrial Counter

Same as the hp 521C except:

Registration: 5 in-line digital display tubes; total count 99,999.

Price: $875.00 (cabinet); $880.00 (rack mount). (Add $45.00 for operation with 560A or 561B.)

hp 521G Electronic Counter

Same as the hp 521A except:

Range: 1 cps to 1.2 MC

Registration: 5 places. Total count capacity 99,999.

Price: $650.00 (cabinet); $655.00 (rack mount). (Add $45.00 for operation with 560A.)

*220 KC on special order.

Data subject to change without notice.

hp 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 low cost.

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-4 Decade Counters with etched circuitry *(see page 93)*.

Operation

For frequency counting, hp 522B's range is 0.00001 cps to 120 KC (220 KC with AC-4B installed). 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, 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 or 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 over various portions of the input waveform. *(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).

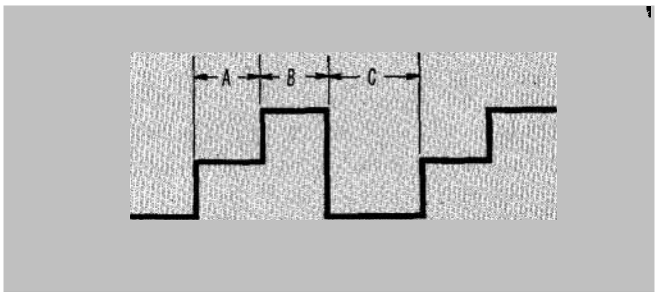


Figure 1. Threshold feature for time interval measurements permits measurement of duration of each step of voltage.

Specifications

Frequency Measurement:

Range: 10 cps to 120 KC. (220 KC with AC-4B.)

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 $\mu\mu$f 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 $\mu\mu$f 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 $\mu\mu$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 —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- 508 Series Tachometer Generators; -hp- 506A Optical Tachometer Pickup.
(b) Operates with -hp- 520A Decade Scaler for high speed nuclear scaling.
(c) Measures frequency ratios.
(d) Makes time interval measurements with externally applied standard frequency.
(e) Operates as electronic stop watch with manual start, stop and reset.
(f) Totalizes events to 99,999.
(g) Operates as a secondary frequency standard providing precise rectangular output voltages at 1, 10, 100 cps: 1 and 10 KC and a 100 KC sine wave. Amplitude, approximately 1 volt peak.

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

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

Weight: Net 52 lbs. Shipping 72 lbs. (cabinet mount). Net 46 lbs. Shipping 65 lbs. (rack mount).

Accessories Furnished: 2 AC-16D Cable Assemblies.

Price: $915.00 (cabinet); $900.00 (rack mount).

For 220 KC operation, $950.00 (cabinet); $935.00 (rack mount). For use with -hp- 560A Digital Recorder (-hp- 522B-95A installed), $960.00 (cabinet); $945.00 (rack mount).

Data subject to change without notice.

523B/CR/DR ELECTRONIC COUNTERS

Advantages:

- Direct frequency, period or time interval readings
- Highest quality, broad applicability, yet moderate cost
- Basic accuracy ± 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
- Rps and rpm
- Oscillator stability
- Repetition rates
- Weight, pressure, temperature and acceleration—remote if desired

Time Interval, Period:
- Phase delay, phase angle
- Time between impulses
- Pulse length, shutter speeds
- Projectile velocity
- Relay operating times
- Precise event timing
- Interval stability
- Frequency ratios, phase delay
- Very low frequencies
- Power line frequencies

New! Measures Period, Time or Frequency 10 cps to 1.2 MC!

NEW Model 523CR Electronic Counter is similar in many respects to the widely known cabinet mounted Electronic Counter, hp 523B. Significant improvements in sensitivity and trigger level circuitry, however, set this new instrument apart from all others. Model 523CR measures frequency, period, time interval, phase delay, random events and ratios. It also totalizes electrical events, periodic or random.

Operation of the hp 523CR is simple, fast and accurate. Measurements are made automatically and readings are displayed in direct numerical form with automatic decimal point. Controls are logically arranged and are color coded for simple operation even by non-technical personnel.

Frequency Measurements

Typical frequency measurements with the 523CR include oscillator and signal generator calibration and stability checks, measurement of telemeter and carrier frequencies, pulse repetition frequencies, test frequencies for narrow bandwidth circuits and rates of random pulses.

The hp 523CR measures sine wave frequencies from 10 cycles to 1.2 MC and the repetition rates of periodic or random pulses from 0 to 1,200,000 pps. Gate times of 0.001, 0.01, 0.1, 1 or 10 seconds are selected with a front panel band switch. Display time is adjustable from 0.1 seconds to 5 seconds, or readings may be retained until reset manually.

Period, Time Interval, Phase Measurements

Accuracy and resolution of the 523CR make possible precise period measurements of power line voltages, test signals used in low frequency work and subsonic signals in general. Time for one cycle may be measured, or average time per cycle for 10 periods may be obtained. Time may be measured in terms of internal or external standard frequencies.

Model 523CR is ideally suited to such time interval measurements as pulse length, pulse spacing, ballistic measurements, shutter speeds and relay operating times. Time interval between any two events (represented by electrical pulses), from 1 μsec to 10^6 seconds are measured and indicated directly in μsec, milliseconds, or seconds. For normalized or measurements in other than time units, external frequencies may be counted. Separate start and stop channels are provided and each channel has trigger level and slope controls.

Pulses, generated whenever trigger level and slope conditions are met, may be used for intensity modulating an oscilloscope to identify the time interval measurement or for triggering auxiliary equipment.

Sensitivity and stability of the new discriminator circuits make possible phase delay measurement with greatly improved accuracy. Accuracy of zero level determination makes the 523CR ideal for phase measurements.

Phase delay is measured directly in μsec, milliseconds or seconds. Phase angle may be measured in degrees or 1/10 degrees by counting an external frequency (360 f_1 or 3,600 f_1) instead of the internal standard.

Measuring Other Quantities

ⓗⓟ optical and magnetic type speed transducers used with the 523CR make possible highly accurate automatic speed measurements of jet engines, superchargers, centrifuges, etc.

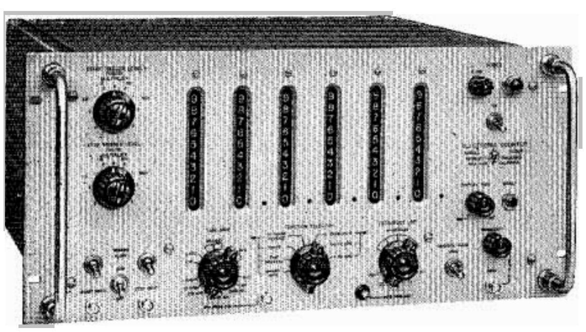
The 0.7 μsec resolving time of the 523CR is well suited to nuclear measurements; i. e., totalizing or random rates.

Ratio measurements may involve any phenomena which can be represented by electrical impulses in the proper frequency range. The measurement of ratio provides increased accuracy in many measurements and is especially useful in certain control applications.

Transducers, available from various manufacturers, permit measurement of speed, acceleration, displacement, force, pressure, temperature, flow, and other physical variables.

The 523CR can be furnished with internal circuitry and output jack for operating the ⓗⓟ Digital Recorders. Eleven columns of data can be printed by the Digital Recorders at rates up to five lines per second. Since only six columns are required for recording from the 523CR, information from other counters, digital voltmeters or digital clocks may be recorded in the remaining columns.

ⓗⓟ 523DR Electronic Counter



ⓗⓟ 523DR Electronic Counter is identical to ⓗⓟ 523CR except that registration is by 6 neon indicators.

ⓗⓟ 523B Electronic Counter

ⓗⓟ Model 523B is a cabinet mounted instrument similar to Model 523D except for specifications below:

Range: Freq., 10 cps to 1.2 MC; period, 0.00001 cps to 10 KC; time int. 3 μsec to 10^5 sec.

Input Sensitivity: Freq., 0.2 v rms min.; period, time int., 1 v rms min., coupled.

Input Impedance: Freq., 1 megohm, 45 μμf; period, 1 megohm, 100 μμf; time int. 1 megohm, 120 μμ.

Standard Frequency: 10 cps, 1 KC, 100 KC, 1 MC, external.

Output Frequency: 10 cps, 1 KC rect.; 100 KC, 1 MC sine.

Power: 115/230 v ±10%, 50/60 cps, approx. 285 watts.

Dimensions: 13¼" wide, 16¾" high, 20¼" deep. Net weight 50 lbs.

Price: $1,245.00. ($1,290.00 for operation with ⓗⓟ560A.)

Specifications ⓗⓟ 523CR/DR

General:

Registration: 523CR, six in-line digital display tubes; 523DR, six decimal places each indicated by lighted numbers.
Stability: 2/1,000,000 per week.
Answer Display Time: Variable from approximately 0.1 to 10 seconds; display can be held indefinitely if desired.
Self Check: Automatic count of internal 100 KC and 1 MC.

Frequency Measurement:

Range: 10 cps to 1.2 MC.
Accuracy: ± 1 count ± stability.
Input Sensitivity: 0.1 volt rms; adjustable; 150 volts rms maximum input.
Input Trigger Level: −300 volts to +300 volts, either slope or −0 to ± 300 volts, either slope.
Input Impedance: Approx. 1 megohm, 50 μμf shunt.
Gate Time: 0.001, 0.01, 0.1, 1, 10 seconds.
Reads In: Kilocycles; automatic decimal point.

Period Measurement:

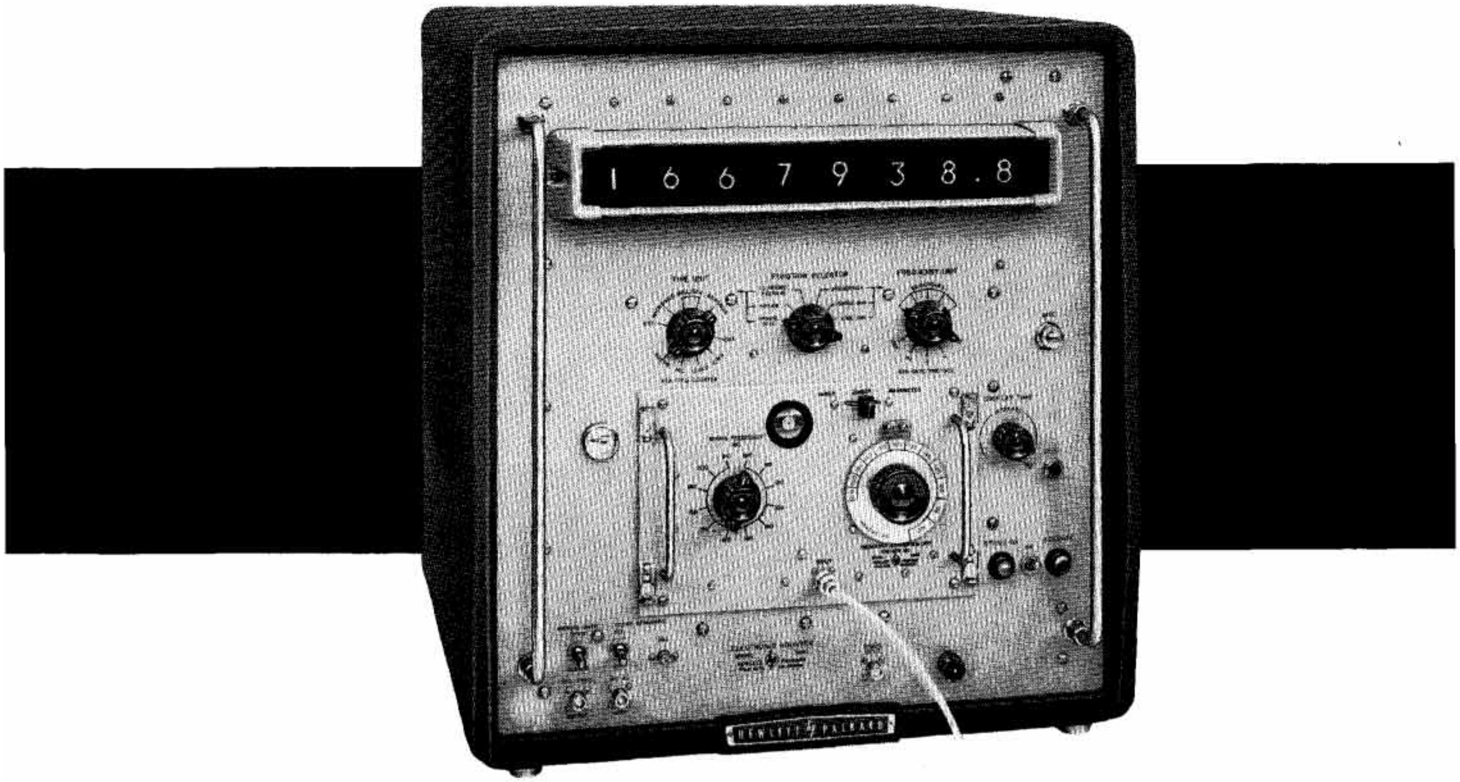
Range: 0.00001 cps to 100 KC.
Accuracy: ±0.3% ±1 count (one period). ±0.03% ±1 count (10 period average) at 0.1 volt rms. Increases with input voltage.
Input Requirements: 0.1 v rms minimum; direct coupled.
Input Impedance: Approx. 1 megohm 50 μμf shunt.
Measurement Period: 1 or 10 cycles of unknown.
Standard Frequency Counted: 1 cps, 10 cps, 100 cps, 1 KC, 10 KC, 100 KC, 1 MC, external frequency.
Reads In: Seconds, msec, μsec, automatic decimal.

Time Interval Measurement:

Range: 1 microsecond to 10^6 seconds.
Accuracy: ±1 count ± stability.
Input Impedance: Approx. 1 megohm, 50 μμf shunt.
Input Requirements: 0.1 v rms minimum. Dc or ac coupling.
Start and Stop Inputs: Separate or common input.
Start and Stop Marker Outputs: Approx. 5 μsec duration and +20 v peak, for oscilloscope intensity modulation.
Trigger Level: Both channels, 0 to ±300 volts, either slope.
Standard Frequency Counted: 1, 10, 100 cps, 1, 10, 100 KC, 1 MC; external.
Reads In: Seconds, msec, μsec, automatic decimal point.
Other Data Measurement: Displays f_1/f_2, or $10f_1/f_2$, as an integer, with accuracy of ± 1.
f_1; 10 cps to 1.2 MC. f_2: 0.00001 cps to 100 KC
Totalize: Electrical events, periodic or random, to 999,999 at rates to 1.2 million/sec.
Output Frequencies: 1 cps, 10 cps, 100 cps, 1 KC, 10 KC rectangular, 100 KC and 1 MC sine wave. Stability $2/10^6$ per week.
External Standard: 100 KC can be applied.
Power: 115/230 v ±10%, 50/60 cps, approx. 350 watts.
Size: Rack Mount: 19" wide, 8¾" high, 16" deep.
Weight: Rack Mount: 48 lbs. Shipping weight approx. 85 lbs.
Accessories Furnished: 2 ⓗⓟ AC-16K Cable Assemblies.
Price: ⓗⓟ 523CR, $1,485.00 ($1,530.00 for operation with 560A and 560B). ⓗⓟ 523DR, $1,285.00 ($1,330.00 for operation with 560A).

Data subject to change without notice.

(hp) 524C/D ELECTRONIC COUNTERS



Advantages:

- Direct, instantaneous automatic readings
- Easily used by non-technical personnel
- Bright, big-numbered readout
- Resolution 0.1 microseconds
- New stability 5/100,000,000
- Standardize with WWV
- Available for printer operation
- 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 12.4 KMC*
- Time interval measurements 1 μsec to 100 days
- Period measurements 0 cps to 10 KC
- Standard frequency output of 10 cps, 1 KC 100 KC, 10 MC
- Time and frequency ratios
- High resolution tachometry ballistics measurements

Measures Frequency 10 cps to 12.4 KMC*—Time Interval 1 Microsecond to 100 Days

HERE is the Electronic Counter that gives you exactly the frequency, time interval or period measuring coverage you want. You buy the basic -*hp*- 524C 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. Still wider usefulness may be obtained by using the 524C in conjunction with -*hp*- 540B Transfer Oscillator for frequency measurements to 12.4 KMC, and -*hp*- Digital Recorders for a permanent, printed record of measurements.

Great Versatility

The compact, moderately priced 524C 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

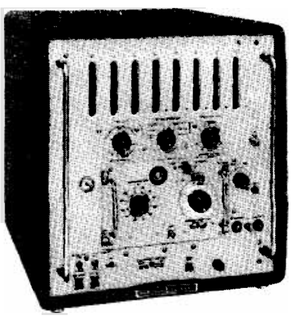
*With -*hp*- 540B Transfer Oscillator.

the usual primary standards. It is simple to operate and readily used by non-technical personnel.

Basic Counter Details

In the basic 524C Counter (without Plug-In Units) frequency from 10 cps to 10 MC is read over 5 selected gate times—0.001, 0.01, 0.1, 1 and 10 seconds. Display time is variable, counts are automatically reset, and action is repetitive. Low frequencies (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.

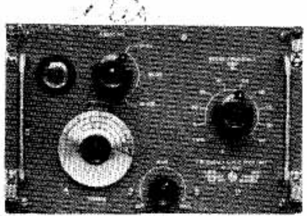
-hp- 524D Electronic Counter



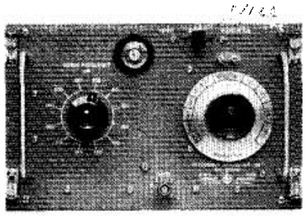
Model 524D is identical electrically with the new *-hp-* 524C, but has 8-decade numerical readout using the widely accepted *-hp-* neon indicators instead of inline "number tube" readout. Model 524D offers the same time-saving convenience of direct, instantaneous, automatic readings without calculation or interpolation, but is priced slightly lower than the premier Model 524C.

Counter Plug-in Units

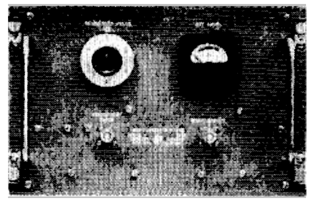
Addition of *-hp-* 525 and 526 series Plug-In Units will extend any *-hp-* 524 Counter's frequency range to 220 MC, provide increased sensitivity, and make available uniquely flexible time interval circuits that may be started and stopped by *almost any electrical impulse.*



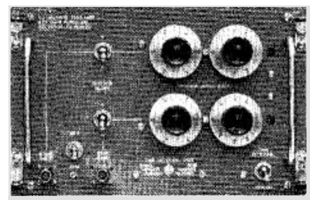
-hp- 525A Frequency Converter. This instrument extends the Counter's 10 MC direct-reading range in decade steps through 100 MC. It maintains Counter accuracy throughout the extended range. It provides additional amplification to increase sensitivity. It contains a tuned input circuit to simplify determining 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 ±0.0001%. 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.

Digital Recorder Operation

At nominal additional charge, Model 524C or 524D Electronic Counters can be modified to provide the following output signals:

a. A 4-line (1–2–2–4) binary coded decimal output for connection to data processing equipment.

b. A 10-line code decimal output for operation of the *-hp-* 561B Digital Recorder. (524C only.)

c. A single-line staircase output for operation of the *-hp-* 560A Digital Recorder.

Models 561 and 560A (pages 96, 97) are 11-column recorders which are slaves to the counter and print the counter reading at rates up to 5 recording per second.

Specifications

-hp- 524C/D Electronic Counter

Basic Unit, for Frequency Measurements, 0 cps to 10.1 MC

Frequency Measurement: (without plug-in units)
- **Range:** 10 cps to 10.1 MC.
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 seconds or manual control.
- **Accuracy:** ± 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:** 524C, 8 digital display tubes; 524D, 8 numbered columns; 99,999,999 maximum count.
- **Stability:** 3/100,000,000 short term; $5/10^8$ per week. May be standardized against WWV or used with external 100 KC or 1 MC primary standard.

Display Time: Variable 0.1 to 10 seconds in steps of gate time selected. Display can be held indefinitely.

Output Frequencies: Secondary standard frequencies available at front panel: 10 cps, 1 KC rectangular; 100 KC positive pulse; 10 MC sine wave. (Stability as above.)

Self Check: Panel control provides automatic count of internal standard 100 KC and 10 MC frequencies to assure accuracy of gate and proper operation of counter.

Input Voltage: 1 v rms minimum 1.5 v peak. Rise time 0.2 sec max.

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

External Standard: 100 KC or 1 MC signal from external primary standard can be applied to unit for highest accuracy. 2 volts required. Input impedance, nominal: 470K, 40 $\mu\mu$f shunt capacitance.

Power: 115/230 v $\pm 10\%$, 50/60 cps, 600 watts.

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

Weight: Net 118 lbs. Shipping 161 lbs. (cabinet mount). Net 110 lbs. Shipping 161 lbs. (rack mount).

Accessories Furnished: 1 AC-16D Cable Assembly.

Accessories Available: AC-16K Video Cable Assembly, $5.00; 524B-16P ($20.00) and 524B-16Q ($15.00). Test Cable Sets for *-hp-* 525/526 units.

Price: 524C, $2,300.00. Modified to operate *-hp-* 560A, $2,375.00. Modified to operate *-hp-* 561B, $2,450.00. 524D, $2,150.00. Modified to operate *-hp-* 560A, $2,225.00. Rack mount models available.

-hp- 525A Frequency Converter Unit

for Frequency Measurement, 10 cps to 100 MC. Plugged into -hp- 524:

Range: As amplifier for counter, 10 cps to 10.1 MC. As converter for counter, 10.1 MC to 100 MC.

Accuracy: Retains accuracy of 524 Counter.

Registration: 8 places; first place indicated on converter selector switch labeled 0, 10, 20 . . . 90; next 7 as indicated by counter.

Input Voltage: 0.1 v rms minimum, 10 cps to 10.1 MC; 10 mv rms minimum, 10.1 MC to 100 MC.

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

Weight: Net 5 lbs. Shipping 8 lbs.

Price: $250.00.

-hp- 525B Frequency Converter Unit

for Frequency Measurement, 100 MC to 220 MC. Plugged into -hp- 524:

Range: 100 MC to 220 MC.

Accuracy: Retains accuracy of 524 Counter.

Registration: 9 places; first two places indicated on converter selector switch labeled 100, 110, 120 . . . 210, next 7 indicated by counter.

Input Voltage: 0.2 v rms minimum.

Input Impedance: Approximately 50 ohms.

Level Control: Same as 525A above.

Weight: Net 5 lbs. Shipping 8 lbs.

Price: $250.00.

-hp- 526A Video Amplifier Unit

for Frequency Measurement, 10 cps to 10.1 MC high sensitivity. Plugged into -hp- 524:

Range: 10 cps to 10.1 MC.

Accuracy: Retains accuracy of 524 Counter.

Input Voltage: 10 mv rms minimum.

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

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

Reads In: Same as basic 524 Counter.

Weight: Net 5 lbs. Shipping 8 lbs.

Accessories Furnished: 1 526A-16A Probe.

Price: $175.00.

-hp- 526B Time Interval Unit

for Time Interval Measurement. Plugged into -hp- 524:

Range: 1 μsec to 10^7 seconds.

Accuracy: ± 1/standard frequency counted. $\pm$ stability (see 524 General).

Input Voltage: 1 v 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.

Weight: Net 5 lbs. Shipping 8 lbs.

Accessories Furnished: 1 AC-16D Cable Assembly.

Price: $175.00.

-hp- 526C Period Multiplier Unit

for Period Measurement. Plugged into -hp- 524:

Range: 0 to 10 KC.

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

Accuracy: ± 1 count $\pm 3\%$/number of periods measured. $\pm$ stability (see 524 General).

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

Reads In: Seconds, milliseconds, or microseconds.

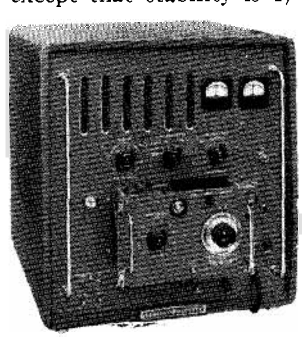
Input Voltage: 1 v rms minimum.

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

Price: $225.00.

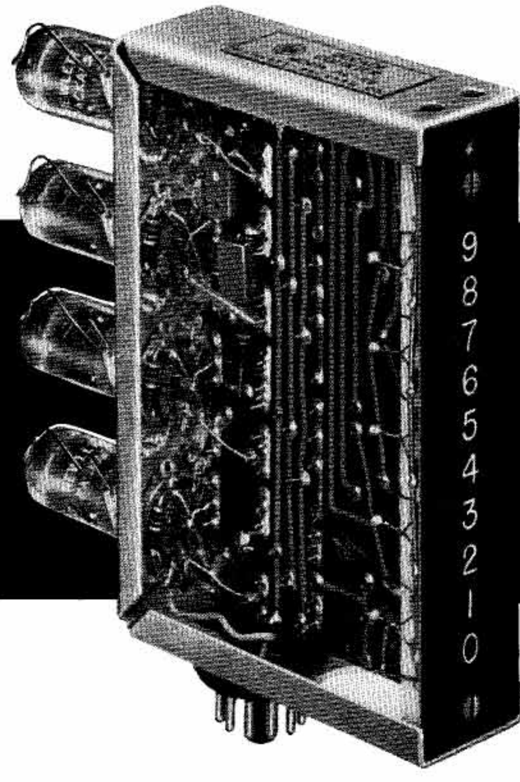
-hp- 524B Electronic Counter

Model 524B is generally similar to Models 524C/D except that stability is $1/10^6$ instead of $5/10^8$ and registration is on neon lamp decades for the first six places and meters on the last two.



Frequency range, time and period measuring capabilities, and utility with plug-ins, recorders and the *-hp-* 540B (for measurement to 12.4 KMC) are identical with the 524C and 524D. Price $2,150.00.

Data subject to change without notice.



Counting Rates to 1.2 MC; Staircase Printer Output

THREE dependable, convenient AC-4 Decade Counters are now available, with maximum counting rates of 120 KC, 220 KC, and 1.2 MC. Specific characteristics of each decade are given in the table below. Each is of improved design providing high reliability, brilliant illumination and staircase output voltage for remote register or driving 560A Digital Recorder. Units may be cascaded for any count capacity; they may be used to totalize, or as scale-of-10 dividers with remainder indicated. Readout is provided on brightly-lighted columnar numerals.

On special order, any Model AC-4 Decade Counter can be supplied with a 4-line binary coded (1–2–2–4) decimal output for direct connection to computers, printers and data reduction equipment.

For replacement in counters using octal-based Decade Counters, Model AC-4A, 120 KC and Model AC-4B, 220 KC, are available at $35.00 and $70.00, respectively.

Specifications

	AC-4C	AC-4G	AC-4E[1]
Maximum Counting Rate:	220 KC	120 KC	1.2 MC
Double Pulse Resolution:	4 μsec	7 μsec	0.7 μsec
Driving Voltage:	−50 v pulse	−80 v pulse	−20 v pulse, 0.2 μsec rise time
Output Voltage:	−80 v pulse	−80 v pulse	−80 v pulse
Reset:	To zero: open base pin connection or apply + 90 volt pulse 5 μsec duration. To nine, apply negative pulse.		
Display:	Illuminated numerals in a column.		
Output Code:	Staircase voltage + 135 volts at count of zero, + 55 volts at count of nine.		
Mounting:	12 pin male plug.		
Power:	+ 300 v at 18 ma	+ 300 v at 15 ma	+ 300 v at 30 ma
Price:	$70.00	$35.00	$80.00

[1] Models AC-4D-95 and modification kit is available as a replacement for the AC-4D in -hp- 523B Electronic Counters. Price $80.00.

ⓗ 540B TRANSFER OSCILLATOR

Now! Measure Frequency to 12.4 KMC With Electronic Counter Accuracy

Advantages:

- Extends frequency counter accuracy to microwave region
- No external mixer or tuning required
- Permits measurement of pulsed, FM, CW, AM or noisy signals
- Provides multiple check for positive accuracy
- Measures FM deviation
- Includes self-contained oscilloscope
- Circuit elements usable separately
- Simple to use, compact, eliminates complex set-ups

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

THE ⓗ 540B Transfer Oscillator provides significant improvements in sensitivity, range, and convenience over its predecessor, Model 540A. Measurements far into the microwave region can now be made with accuracy and simplicity heretofore available only at much lower frequencies.

Model 540B contains a highly stable, 100 to 220 MC oscillator generating harmonics to at least 12.4 KMC for comparison. Comparison is made by means of a broadband, untuned, diode mixer system, amplifier and oscilloscope, all within the instrument. In addition, a new, built-in harmonic generator provides signals for driving external amplifiers and mixers for measurements considerably above X-band.†

Combined with an ⓗ 524 series Counter with ⓗ 525B Frequency Converter plug-in, the 540B extends the 524's range to 12.4 KMC and beyond.

In operation, with approximate signal frequency known, the ⓗ 540B 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 use of external traveling wave amplifiers and wave guide mixers for measurements in P, K and R bands is described in Application Note No. 27, available on request.

the 524 counter. The 524 frequency reading, times the multiplying factor, gives the frequency of the unknown signal. When the signal frequency is totally unknown, a convenient calculation employing two or more harmonics is used to determine the multiplying factor.

In measuring carrier frequency of pulsed signals, an external oscillosynchroscope is used to display the detected pulse. Zero beat appears as horizontal lines across the pulses when the oscillator is tuned to an exact sub-multiple. Video amplifier frequency response controls can be used to simplify this procedure.*

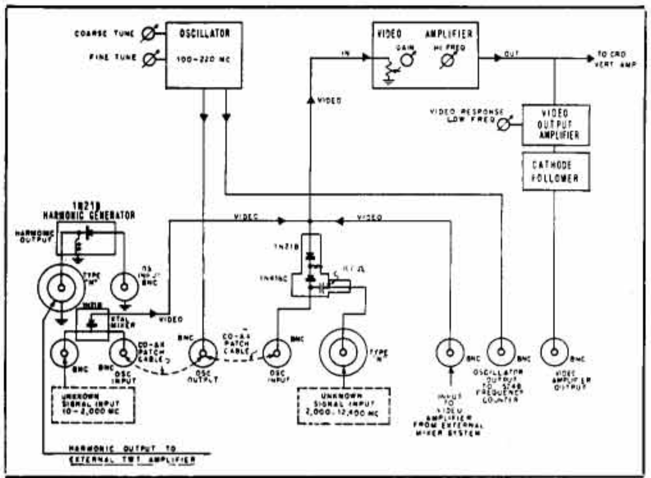


Figure 1. ⓗⓟ 540B, simplified block diagram.

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

In signals with appreciable FM, the 540B's oscilloscope presents a characteristic pattern pin-pointing upper and lower frequency deviation limits. If FM deviation is present, center frequency may also be determined.*

Accuracy

A direct-coupled reactance control circuit allows the oscillator to be locked at a sub-multiple of the measured frequency when it is desirable to measure automatically or record drift characteristics of microwave signal sources.

The system's accuracy approaches that of the electronic counter on clean CW signals. On pulsed signals, accuracy is governed by carrier frequency and pulse length. On noisy or intense AM signals, the transfer oscillator system with ⓗⓟ 540B 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 ⓗⓟ 540B *(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, or external signals from 20 cps to 5 KC.

**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 12,400 MC.

Input Signal: CW, FM, AM or pulse.

Input Signal Level: Varies with frequency and individual crystals. *(See Figure 2.)*

Accuracy: CW: Approximately 1/10,000,000 or better.

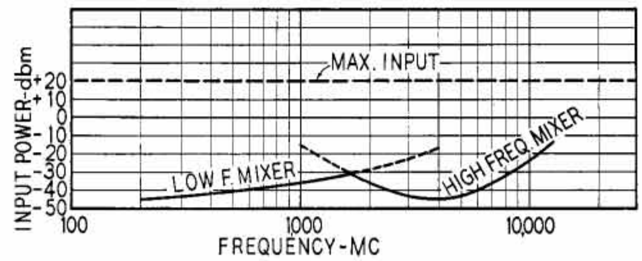


Figure 2. Typical sensitivity, model ⓗⓟ 540B.

Oscillator

Fundamental Frequency Range: 100 MC to 220 MC.

Harmonic Frequency Range: Above 12,400 MC.

Stability: Less than 0.002% change per minute after 30-minute warmup.

Dial: Six inch diameter, calibrated in 1 MC increments. Accuracy: ±0.5%.

Output: Approximately 2 v into 50 ohms.

Amplifier

Gain: 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, 20 cps to 5 KC.

Miscellaneous

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

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

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

Auxiliary Equipment:

-hp- 524 Electronic Counter *(see pages 90, 91, 92).*

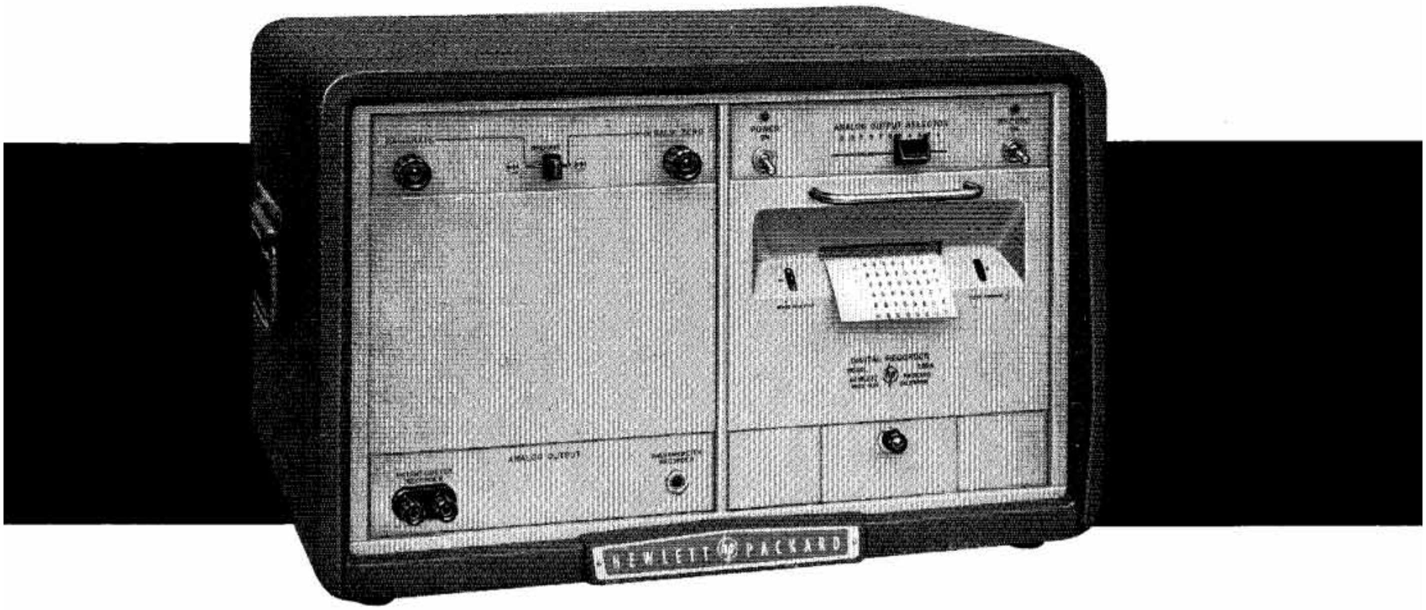
-hp- 525B Frequency Converter, $250.00.

Price: *-hp-* 540B, $750.00 (cabinet); $735.00 (rack mount).

-hp- 540A Transfer Oscillator. Similar to *-hp-* 540B except requires external mixers above 5,000 MC. Includes broadband input attenuator. *-hp-* 540A, $615.00 (cabinet); $600.00 (rack mount).

-hp- 540B mixer available for use with *-hp-* 540A. Specify Model 934A, $150.00.

Data subject to change without notice.



Advantages:

- 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 or X-Y recorder (560A)

Uses:

- Recorder for frequency counters, digital voltmeters
- Recording of time functions
- Digital to analog converter for strip-chart recording
- Test, calibration, check-out of telemetering systems
- Monitoring, final tabulation and plotting of tests
- Investigating drifts in systems and equipment

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

THE REVOLUTIONARY hp 560 series Digital Recorders are completely new instruments based on a fresh design concept rather than an adaptation of conventional adding machines. Although specifically designed for use with hp electronic counters and voltmeters, they are extremely versatile and useful in a wide variety of applications.

Basically, the Recorders consist of a motor-driven print mechanism with inked ribbon, printing paper, eleven identical number wheels and eleven circuits which position the number wheels according to the count appearing on an associated electronic counter.

Both Models 560A and 561B have a printing speed of five, 11-digit lines per second. The 11-digit line allows secondary or coding data to be entered simultaneously with primary data. Since each recorder is literally a slave to its associated input, the recorder accuracy is the same as the accuracy of the data gathering input.

Hewlett-Packard digital recorders are normally controlled by hp frequency counters and digital voltmeters. *(See Counter and Voltmeter specifications.)* However, the recorders may be controlled by other electronic or electromechanical devices.

Operation—Model 560A

In normal electronic operation, the 11 number wheels are locked in position while the counter is counting. At the end of each counting period, the staircase voltage generated during the count by each decade in the counter comes to rest on the step or voltage level corresponding to the digit displayed by that decade. Each staircase voltage step is sent to the recorder along with a print command pulse which occurs at the end of the count period.

The command pulse then initiates a scanning cycle during which the number wheels are simultaneously positioned according to the staircase voltage levels received from the counter decades and locked in position. At the end of the scan cycle a print of the data is made, and the paper automatically advanced to display the printed count.

Analog Output—Model 560A

Unique features of the 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.

Specifications—Model 560A/AR

Accuracy: Identical to that of basic counter used.

Printing Rate: 5 lines/sec. max.

Column Capacity: 11 columns (11 digits per line).

Number Wheels: 12 position, having numerals 0 through 9, a minus, and a blank. Other symbols available.

Driving Source: Parallel entry staircase voltages derived from modified decade type frequency counters (such as hp or Dymec, Inc. types). (See Counter specifications.)

Print Command Signal: Positive or negative pulse, 10 μsec or greater in width, 15 v peak or greater in amplitude.

Paper Required: Standard 3″ roll or folded paper.

Line Spacing: Single or double, adjustable.

3 Digit Analog Output: 1000 step staircase directly proportional to count indicated by any three (or the right-hand two) adjacent columns selected by analog output selector switch. (Example: if consecutive digits were 3, 8, and 6; output voltage would be 38.6 millivolts; and 99.9 millivolts if consecutive digits were 999.)

Output Available: 1 ma for galvanometer strip-chart recorders. 100 mv for potentiometer strip-chart recorders.

Power Requirement: 115/230 v $\pm 10\%$, 60 cycles (50 cycles on special order), 250 watts.

Dimensions: Cabinet: 20¾″ wide, 12½″ high, 18½″ deep. Rack: 19″ wide, 10½″ high, 16⅞″ behind panel.

Weight: Cabinet Mount: Net 60 lbs. Shipping 85 lbs. Rack Mount: Net 55 lbs. Shipping 80 lbs.

Accessories Available: Additional comparators to increase print-out of basic 560A from 6 columns to a maximum of 11 columns. These comparators plug into sockets in the 560A. Price: 560A-58 Plug-in Comparator Unit. $25.00 each. No. 1052-24 Folded Paper Tape, Prices: single packet, $1.00; 24 packet carton, $20.00.

Price: $1,265.00 (cabinet); $1,250.00 (rack mount). (Includes 6 plug-in comparators.)

Operation—Model 561B

Model 561B Digital Recorder differs from Model 560A in that input is a 10-line coded decimal entry. The 561B is normally operated from an hp Digital Voltmeter or by a modified Frequency Counter (in-line readout types). Model 561B can also be operated from relays, stepping switches and beam switching tubes because separate connections are made for each wheel position.

The principle of operation is as follows: When a print command is received, the clutch engages, turning the number wheels. Each number wheel turns until its armature contacts a voltage which is negative with respect to the cathode of a tube. A negative voltage on the grid of the tube de-energizes the solenoid and drops the pawl, thus stopping the number wheel in the appropriate position.

Specifications—Model 561B/BR

Same as 560A except:

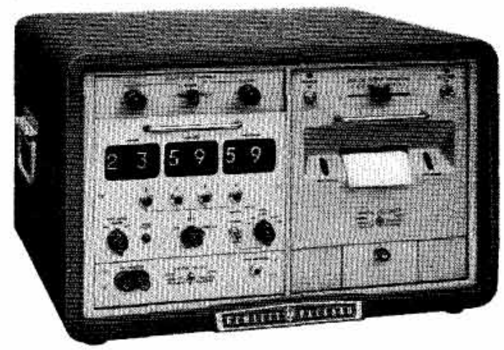
Driving Source: hp modified in-line readout counters. *(See Counter specifications.)* hp Digital Voltmeter. *(See Voltmeter specifications.)* Stepping Switches, Relays, Beam Switching Tubes, contact closure, or —10 to —100 volts connected to appropriate number wire. Operates from 10-line coded systems.

Print Command: An external contact closure, or a negative pulse 15 volts peak or more, 10 μsec minimum width. Manually controlled by a momentary contact toggle switch. Print commands during scan and print action have no effect.

Power: 60 cps, 115 ± 10 v or 230 ± 20 v as specified. Approx. 75 watts at 115/230 v ac. 50 cps operation available on special order.

Price: hp 561B, $1,065.00 (cabinet); $1,050.00 (rack mount).

hp 570A/571B Digital Clocks



Models 570A and 571B Digital Clocks mount in the left-hand side of hp 560A and 561B Digital Recorders, respectively. These clocks provide time-of-day information for addition to other recorded data, and can control rates at which measurements are made.

Time is indicated in a 23-hour, 59-minute, 59-second arrangement; display is by bright, in-line indicator tubes with all time digits available for printing.

For maximum flexibility, two operating modes are provided. In the first, hp or Dymec Digital Counters, Digital Voltmeters or other external equipment initiate print commands; time is printed along with primary data. In the second mode, (for long-term tests which require less-than-frequent readings) the Digital Clocks determine the rate at which readings are made. Sampling intervals are selected on a front panel switch offering sampling rates of 1/second, 6/minute, 1/minute, 6/hour, 1/hour. Models 570A/571B operate from an internal or external time base.

hp 570A (fits 560A/AR) $1,050.00.

hp 571B (fits 561B/BR) $ 950.00.

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 hf, vhf, uhf, and shf signal generators, 12 precision instruments operating at frequencies between 50 KC 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.

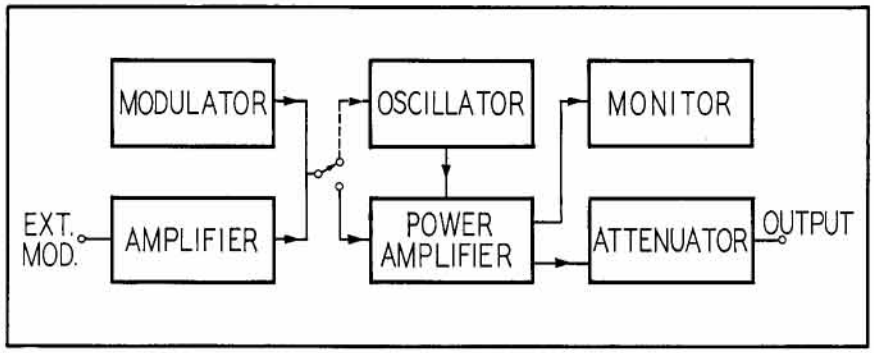


Figure 1. Block diagram of Signal Generators in Group I.

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 for optimum performance over the range of each generator.

Group I signal generators (except *-hp-* 612A) are capacitively tuned, and Group II signal generators (including *-hp-* 612A) are tuned by adjusting a shorting element that tunes the cavity resonator associated with the oscillator tube. 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 616B) 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.

Group	Generator	Frequency Range (MC)	Frequency Accuracy	Calib. Output Range	Output Accuracy	Max. SWR of Output	Modulation	
							Internal	External
I	606A	0.05-65	± 1%	0.1 µv to 3 v	± 1 db	1.1	Sine 400 cps ± 5% 1,000 cps ±5%	Sine Wave, Pulse Sq. Wave
I	608C	10-480	± 1%	+ 13 to —127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine Wave, Pulse, Sq. Wave
I	608D	10-420	± 0.5%	+ 7 to —127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine Wave, Pulse, Sq. Wave
I	612A	450-1,230	± 1%	+ 7 to —127 dbm	± 1 db	1.2	Sine wave 400 and 1,000 cps	Sine Wave, Pulse, Sq. Wave
II	614A	800-2,100	± 1%	0 to —127 dbm	± 1 db —10 to —127 dbm	1.6	Pulse, FM	Pulse, Sq. Wave
II	616B	1,800-4,200	± 1%	0 to —127 dbm	±1.5 db —7 to —127 dbm	1.8	Pulse, FM	Pulse, Sq. Wave
II	618B	3,800-7,600	± 1%	0 to —127 dbm	± 2 db —7 to —127 dbm	2	Pulse, FM, Sq. Wave	Pulse, Sq. Wave FM
II	620A	7,000-11,000	± 1%	0 to —127 dbm	± 2 db —7 to —127 dbm	2	Pulse, FM, Sq. Wave	Pulse, Sq. Wave FM
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	± 1 db ± 2% of attenuation in db	2.5 at + 10 dbm 1.2 at 0 dbm	Pulse, Sq. Wave FM	Pulse, Sq. Wave, FM
II	628A	15,000-21,000	± 1%	+ 10 to —90 dbm	± 1 db ± 2% of attenuation in db	2.5 at + 10 dbm 1.2 at 0 dbm	Pulse, Sq. Wave FM	Pulse, Sq. Wave FM

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

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

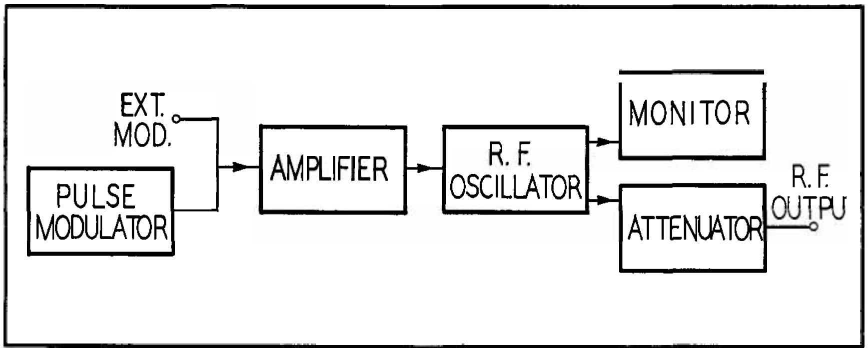


Figure 2. Block diagram of Signal Generators in Group II.

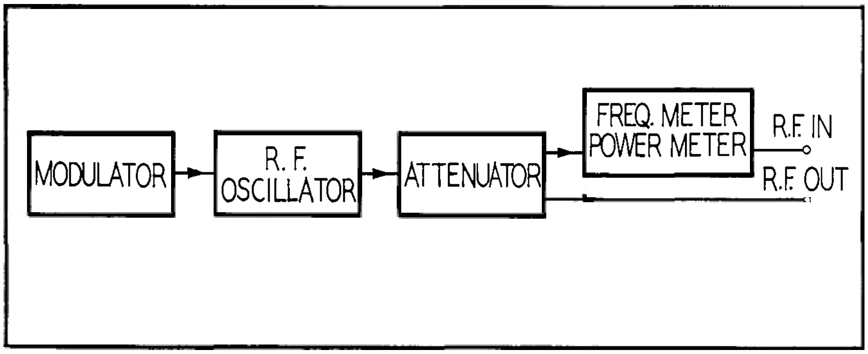


Figure 3. Block diagram of Signal Generators in Group III.

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-* 606A, 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 606A and 608C/D is accomplished in the amplifier section, and either sine wave, pulse or square wave modulating voltages can be employed. Because the amplifier section of the 608C/D employs a grounded grid circuit, the power is not completely cut off between pulses. The reduction in power output between the time the pulse is on and off is better than 20 db 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 606A, 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.

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-* 606A, 626A and 628A), and operate on magnetic coupling for the lowest order mode. This type of attenuator is characterized by linear relation between the attenuation (in db) and displacement (in length units) of the coupling elements. The linear relationship holds except for approximately the first 7 db of attenuation. As long as the attenuator waveguides are well below cut-off, 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 130).

Signal generator output impedance is held close to 50 ohms by utilizing pads in the attenuator and output connectors. This

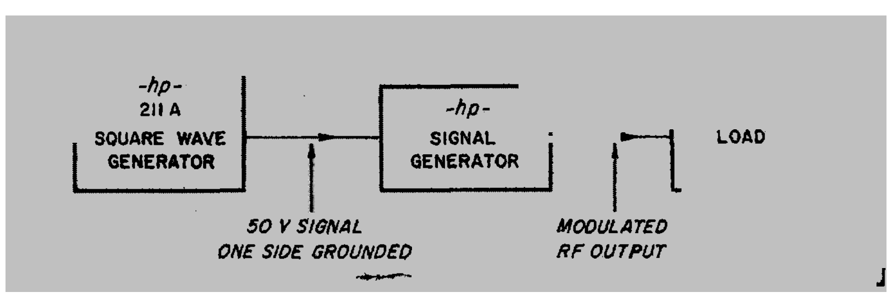


Figure 4. Typical setup for applying modulation to *-hp-* signal generators.

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.

New 606A HF Signal Generator

The new Model 606A High Frequency Signal Generator (pages 102, 103) is a compact, convenient, moderately priced instrument providing constant output and constant modulation level from 50 KC to 65 MC. Output is high—continuously adjustable from 0.1 uv to 3 volts into 50 ohms. Feedback circuitry reduces envelope distortion and eliminates the tedious, error-producing resetting of output level and per cent modulation.

Covering the high frequency spectrum, (which includes the 30 and 60 MC radar IF bands) the new 606A is exceptionally useful in driving bridges, antennas and filters, and measuring gain, selectivity and image rejection of receivers and IF circuits.

Output is constant within ±1 db over the full frequency range, and is adjustable from +20 dbm (3 volts rms) to −110 dbm (0.1 μv rms). No level adjustments are required during operation; the instrument has a minimum of controls and high accuracy results are assured due to the constant internal impedance. The generator can be provided with a 10:1 voltage divider and dummy antenna lowering minimum output to 0.01 μv (from 5 ohms) and simulating IRE standards for precision receiver measurements. *(See Specifications, page 103.)*

The new 606A may be modulated by sine waves and complex waveforms from dc to a maximum of 20 KC. A meter indicates per cent modulation.

To insure maximum accuracy of frequency setting, the 606A includes an internal crystal calibrator providing check points at 100 KC and 1 MC intervals with error less than 0.01%.

626A/628A SHF Signal Generators

Models 626A and 628A (pages 114, 115) 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 μμw). 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 5).

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

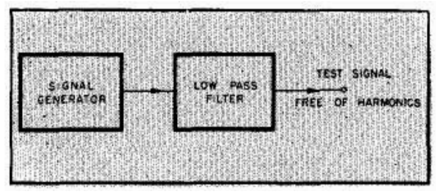


Figure 5. Typical setup for eliminating harmonics.

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 6. In order to determine the amount of error

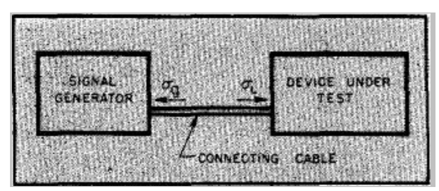


Figure 6. Typical setup for making measurement on signal generators.

due to mismatch, the values of SWR of the signal generator and the load should be measured. Maximum and minimum power

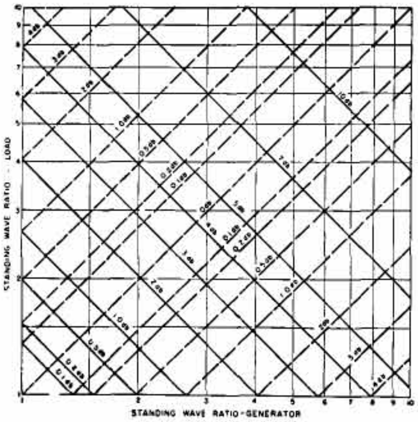


Figure 7. Power loss curves. Solid lines indicate ^{P}max; broken lines ^{P}min. (Courtesy Sperry Gyroscope Co.)

loss is obtained by substituting the values of SWR in the equation below:

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

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

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

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

Where σ_g = SWR of signal generator
Where σ_L = SWR of device under test

Note: These losses are with respect to the maximum available power output. (Calibration of the signal generator.)

These formulas can be drawn up in chart form as shown in Figure 7. 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 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 8.

Sweep Oscillators

In addition to precision signal generators, *-hp-* offers five sweep oscillators covering frequencies in the ranges 2.0 to 18.0 KMC. *(See pages 116, 117.)* Models 683A, 684B, 686A, 687A, and H01 686A collectively cover frequencies from 2.0 to 18.0 KMC. They generate CW and swept frequencies at output levels up to 10 mw (+ 10 dbm) into a matched load. The rf output frequency is swept linearly with time. Voltage-tuned backward-wave oscillator tubes are employed as the rf signal source and are swept electronically through the desired frequency range, Δ FREQUENCY. This total frequency change, Δ FREQUENCY, is selectable in steps. 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. 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, these instruments may be amplitude and frequency modulated. A 400 to 1,200 cps squarewave modulator is provided to amplitude modulate the oscillators internally when used in conjunction with standing wave indicators, ratio meters or other tuned vacuum tube voltmeter devices. The instruments 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 FREQUENCY are set up by front panel selectors. Any of these adjustments may be changed during operation. The RF SWEEP RATE selector and the Δ FREQUENCY selector are differentially ganged so that combinations resulting in undesirably short sweep times 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.

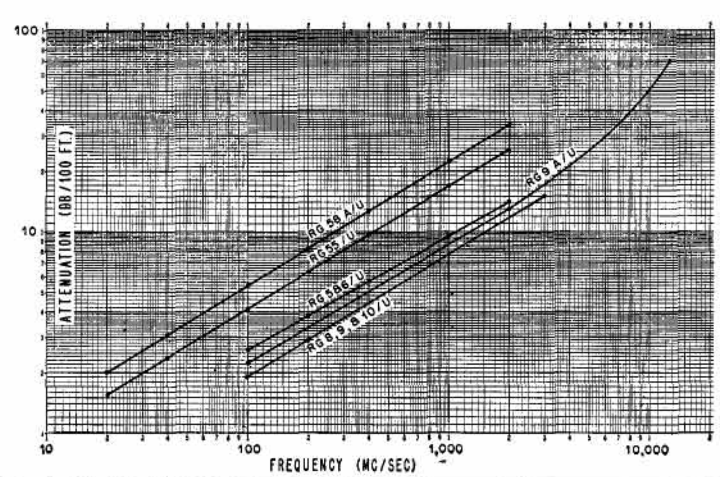
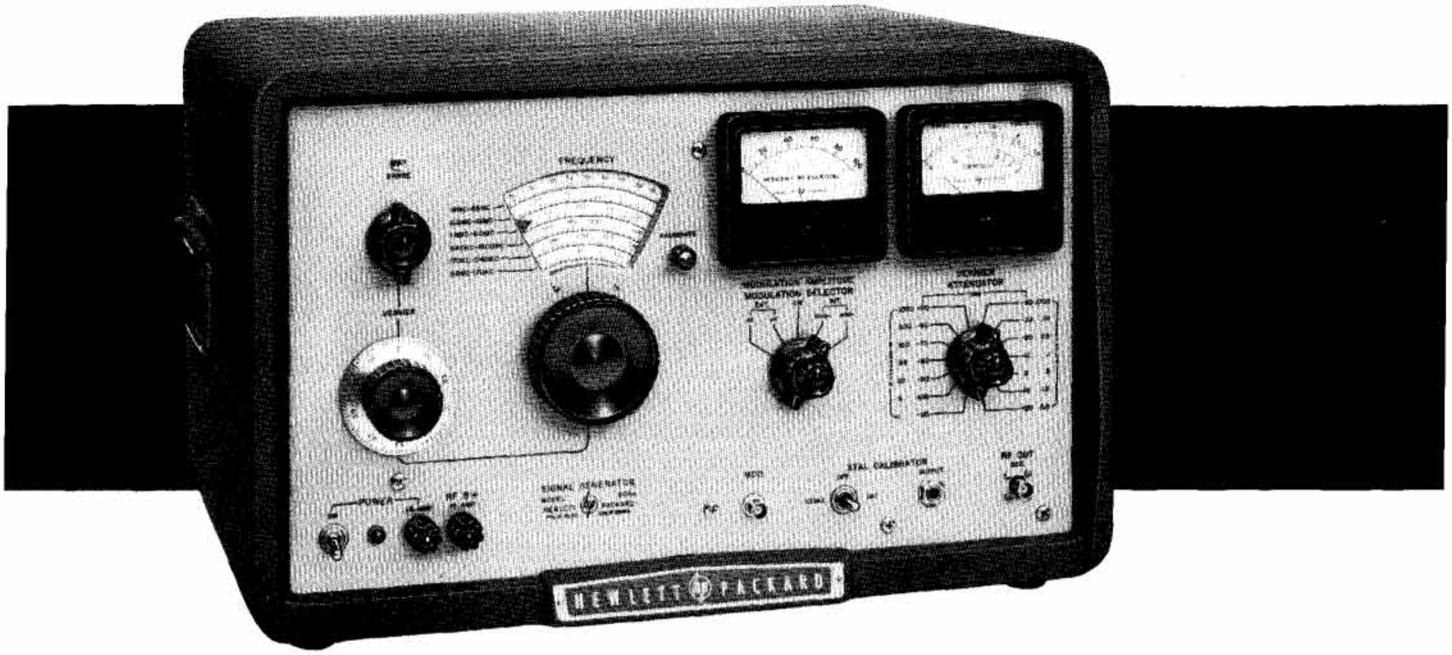


Figure 8. Attenuation vs. frequency curves for several cables.

606A HF SIGNAL GENERATOR



At Last! A Stable, Dependable 50 KC to 65 MC Generator

Advantages:

- Wide range. Includes 30 and 60 MC IF bands
- Constant output level
- Constant modulation level
- Wide modulation capabilities
- 3 volt output into 50 ohms
- Crystal calibrator insures exact frequencies
- Low envelope distortion

Uses:

- Measuring receiver and IF circuit gain, selectivity and image rejection
- Driving bridges, antennas, filters

COMPACT, convenient, moderate price—constant output and modulation level —0.1 μv to 3 volts output —3% envelope distortion—these are basic characteristics of the new 606A HF Signal Generator.

Throughout range, output power level is constant within ±1 db and modulation level is constant within ±0.5 db, regardless of carrier frequency and output level setting. This high order of stability eliminates tedious error-producing resetting of output level and per cent modulation, and materially speeds measurements in the HF range.

Simulate IRE Standards

As an additional convenience for receiver measurements, the output of 606A is adjustable from +20 dbm to −120 dbm (3 volts rms to 0.1 μv rms). Further, the generator can be provided with a 10:1 voltage divider and dummy antenna 606A-34A Output Termination, see Specifications). This accessory lowers minimum output of the generator to 0.01 μv (from 5 ohms) and simulates IRE standards for precision receiver measurements.

Versatile Modulation

A front panel meter on hp 606A indicates per cent amplitude modulation for frequencies within the modulation bandwidth of the signal generator. Complex waveforms, square waves and dc voltages may be used to modulate the instrument in testing and evaluating filters, networks, amplifiers and receivers. Due to its wide modulation bandwidth (dc to 20 KC) and low envelope distortion (3%, 0 to 70% modulation) the hp 606A is particularly suited for distortion measurements on receivers, IF amplifiers and detectors.

Crystal Calibrator

To insure maximum accuracy of frequency setting, the 606A includes an internal crystal calibrator providing check points at 100 KC (useful to 6 MC) and 1 MC (useful to 65 MC) intervals. Check points are accurate within 0.01% from 0° to 50° C. Overall frequency accuracy of hp 606A is within ±1%.

hp 606A - 34A Output Termination (10:1) and IRE dummy antenna. See "Accessories Available" under "Specifications."

Specifications

Frequency Range: 50 KC to 65 MC in six bands:

50 - 170 KC	1.76 - 6.0 MC
165 - 560 KC	5.8 - 19.2 MC
530 - 1800 KC	19.0 - 65.0 MC

Frequency Accuracy: Within ±1%.

Frequency Calibrator: Crystal oscillator provides check points at 100 KC and 1 MC intervals accurate within 0.01% from 0° to 50° C.

RF Output Level: Continuously adjustable from 0.1 μv to 3 volts into a 50 ohm resistive load. Calibration is in volts and dbm (0 dbm is 1 milliwatt or 0.223 volts rms into 50 ohms).

Output Accuracy: Within ±1 db into 50 ohm resistive load.

Frequency Response: Within ±1 db into 50 ohm resistive load over entire frequency range at any output level setting.

Output Impedance: 50 ohms, SWR less than 1.15:1. BNC output connector mates with UG-88A/B/C/D.

Spurious Harmonic Output: Less than 3%.

Leakage: Negligible; permits receiver sensitivity measurements down to at least 0.1 microvolt.

Amplitude Modulation: Continuously adjustable from 0 to 100%. Indicated by a panel meter. Modulation level is constant within ±0.5 db regardless of carrier frequency.

Internal Modulation: 0 to 100% sinusoidal modulation at 400 cps ±5% or 1000 cps ±5%. Internal modulation voltage appears at modulation jack.

Modulation Bandwidth: Dc to 20 KC maximum, depends on carrier frequency, f_c, and per cent modulation as shown in the following table:

Max. Mod. Frequency

30% Mod.	*70% Mod.*	*Squarewave Mod.*
0.06 f_c	0.02 f_c	0.003 f_c (3 KC max)

External Modulation: 0 to 100% sinusoidal modulation dc to 20 KC. 4.5 volts peak produces 100% modulation at modulating frequencies from dc to 20 KC (see Modulation Bandwidth). Input impedance is 600 ohms. May also be modulated by squarewaves and other complex signals.

Envelope Distortion: Less than 3% from 0 to 70% modulation at output levels of 1 volt or less.

Modulation Meter Accuracy: Within ±5%, 0 to 90%.

Power: 115/230 v ±10%, 50 to 1000 cps, 135 watts.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13½" deep behind panel.

Weight: Net 46 lbs. Shipping 66 lbs. (cabinet mount). Net 43 lbs. Shipping 65 lbs. (rack mount).

Accessories Available: hp 606A - 34A Output Termination with 50 ohms termination, 5 ohms termination (10:1 voltage division), and IRE standard dummy antenna (10:1 voltage division). $50.00.

Price: $1,200.00 (cabinet); $1,185.00 rack mount).

Data subject to change without notice.

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 are designed as the ultimate in vhf signal generators. They offer the highest stability attained in production equipment of their type. There is almost a complete absence of incidental FM (less than 1 KC for the 608D). 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.

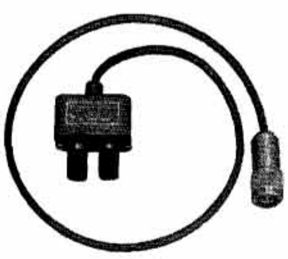
Finest Construction

An important feature of -*hp*- 608D is the mechanical design and construction employed throughout. 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.

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

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 0.1 μv.

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

Power: 115/230 v ±10%, 50/1,000 cps, 220 watts.

Dimensions: Cabinet Mount: 13¾" wide, 16¼" high, 21" deep. Rack Mount: 19' wide, 14" high, 21" deep.

Weight: (Cabinet or Rack Mount) Net 63 lbs. Shipping 88 lbs.

Accessories Available: 608A-16D Cable Assembly, $10.00; AC-16K Video Cable Assembly, $5.00; AC-16F rf Cable Assembly, $12.00; 360A Low Pass Filter, $40.00; 608A-95A Fuseholder, $20.00.

Price: $1,100.00 (cabinet); $1,120.00 (rack mount).

608C

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

Frequency Range: 10 to 480 MC, 5 bands.

Frequency Calibration Accuracy: ±1% full range.

Crystal Calibrator: In Model 608D only.

Output Level: 0.1 μv to 1.0 v into 50 ohm resistive load.

Incidental FM: Less than 0.0025% at 30% amplitude modulation for rf output frequencies 21 to 480 MC.

Price: $1,000.00 (cabinet); $1,020.00 (rack mount).

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.

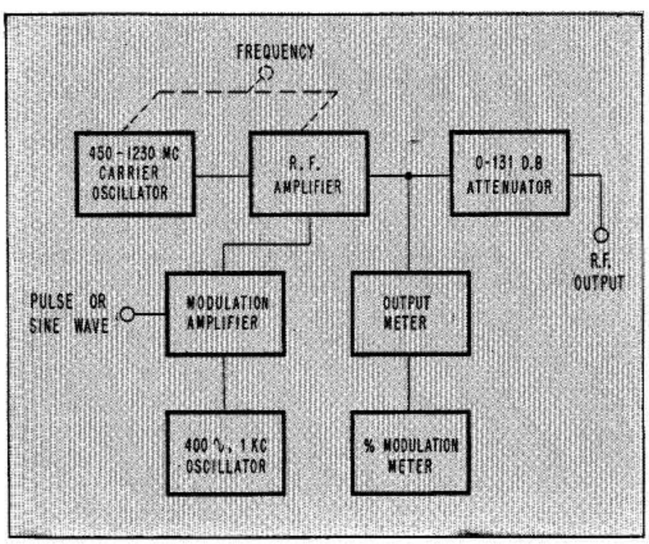


Figure 1. Block diagram, -*hp*- 612A Signal Generator.

The -*hp*- 612A covers the 450 to 1,230 MC band in one continuous range. The tuning dial has an expanded scale that covers 15 inches and is calibrated every 5 megacycles. The dial can be read to approximately 1 megacycle and is accurate within 1%.

Specifications

Frequency Range: 450 to 1,230 MC in one band. Scale length approximately 15 inches.

Calibration Accuracy: Within ±1%. Resettability better than 5 MC at high frequencies.

Output Voltage: 0.1 μv to 0.5 v into 50 ohm load. Calibrated in volts and dbm (0 dbm = 1 mw).

Output Accuracy: ±1 db, 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.

Power: 115/230 v ±10%, 50/1,000 cps, 215 watts.

Dimensions: Cabinet Mount: 13¾″ wide, 16¾″ high, 22″ deep. Rack Mount: 19″ wide, 14″ high, 19½″ deep behind panel.

Weight: Net 57 lbs. Shipping 85 lbs. (cabinet mount). Net 57 lbs. Shipping 83 lbs. (rack mount).

Accessories Available: AC-16F rf Cable Assembly, $12.00; 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 (cabinet); $1,220.00 (rack mount).

Data subject to change without notice.

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, 1.8 to 4.2 KMC

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- 616B gives complete coverage of frequencies from 1.8 to 4.2 KMC, has constant internal impedance with less than 1.8 SWR, and output accuracy of ± 1.5 db from -7 dbm to -127 dbm.

On both instruments, operation is extremely simple. Carrier frequency is set and read directly on the large tuning dial. No voltage adjustments are necessary during operation because of the 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 616B consists of a reflex klystron in an external coaxial resonator. Frequency of oscillation is determined by a movable plunger which varies the resonant frequency of the resonator. Oscillator output is monitored by a temperature-compensated thermistor bridge circuit which is virtually unaffected by ambient temperature conditions. Voltage 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 616B Signal Generators are ideal for almost all precision uhf measurements. They are compact in size and ruggedly built of highest quality components for long, trouble-free service.

Specifications

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; delay variable from 3 to 300 μsec between sychronizing signal and rf pulse. Pulse rise and decay less than 0.2 μsec each.

External Pulse Modulation: By external pulses, pos. or neg. peak amplitude 40 to 70 v, width 1.0 μsec to 2,500 μsec. May be square wave modulated.

Trigger Pulses Out: (1) Simultaneous with rf pulse. (2) In advance of rf pulse, variable 3 to 300 μsec. (Both approx. 1 μsec rise time, 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%, 50/1,000 cps, 150 watts.

Dimensions: Cabinet Mount: 17″ wide, 13½″ high, 13⅝″ deep. Rack Mount: 19″ wide, 14″ high, 11½″ deep behind panel.

Weight: Net 60 lbs. Shipping 82 lbs. (cabinet mount). Net 57 lbs. Shipping 80 lbs. (rack mount).

Accessories Furnished: 1 AC-16F rf Cable Assembly.

Accessories Available: 360C Low Pass Filter, $40.00. AC-16K Video Cable Assembly, $5.00.

Price: $1,950.00 (cabinet); $1,970.00 (rack mount).

616B

Frequency Range: 1.8 to 4.2 KMC. 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 μv (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.

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 2 μsec to 2,500 μsec. May be square wave modulated.

Trigger Pulses Out: (1) Simultaneous with rf pulse. (2) In advance of rf pulse, variable 3 to 300 μsec. (Both approximately 1.0 μsec rise time, 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%, 50/1,000 cps, 160 watts.

Dimensions: Cabinet Mount: 17″ wide, 13½″ high, 13⅝″ deep. Rack Mount: 19″ wide, 14″ high, 11½″ deep behind panel.

Weight: Net 62 lbs. Shipping 83 lbs. (cabinet mount). Net 61 lbs. Shipping 80 lbs. (rack mount).

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 (cabinet); $1,970.00 (rack mount).

Data subject to change without notice.

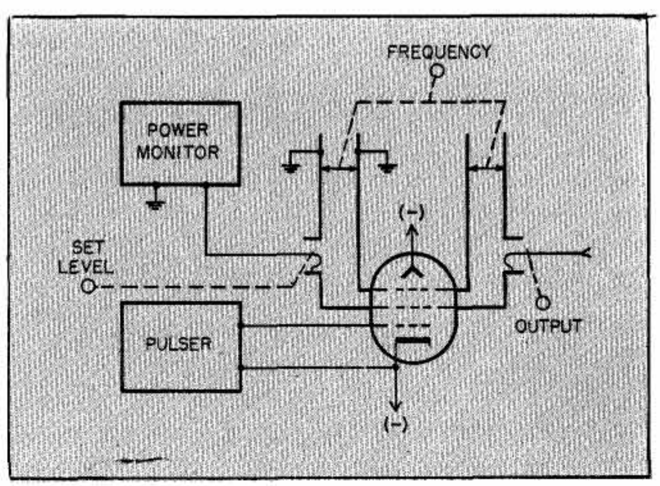


Figure 1. Block diagram, *-hp-* 614A Signal Generator.

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 *-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, 275 watts.

Dimensions: Cabinet Mount: 17½″ wide, 13⅞″ high, 19½″ deep. Rack Mount: 19″ wide, 14″ high, 17″ deep behind panel.

Weight: Net 95 lbs. Shipping 118 lbs. (cabinet mount). Net 96 lbs. Shipping 119 lbs. (rack mount).

Accessories Furnished: 1 AC-16Q rf Cable Assembly.

Accessories Available: AC-16K Video Cable Assembly, $5.00.

Price: $2,250.00 (cabinet); $2,270.00 (rack).

hp 620A

(Same as *-hp-* 618B except:)

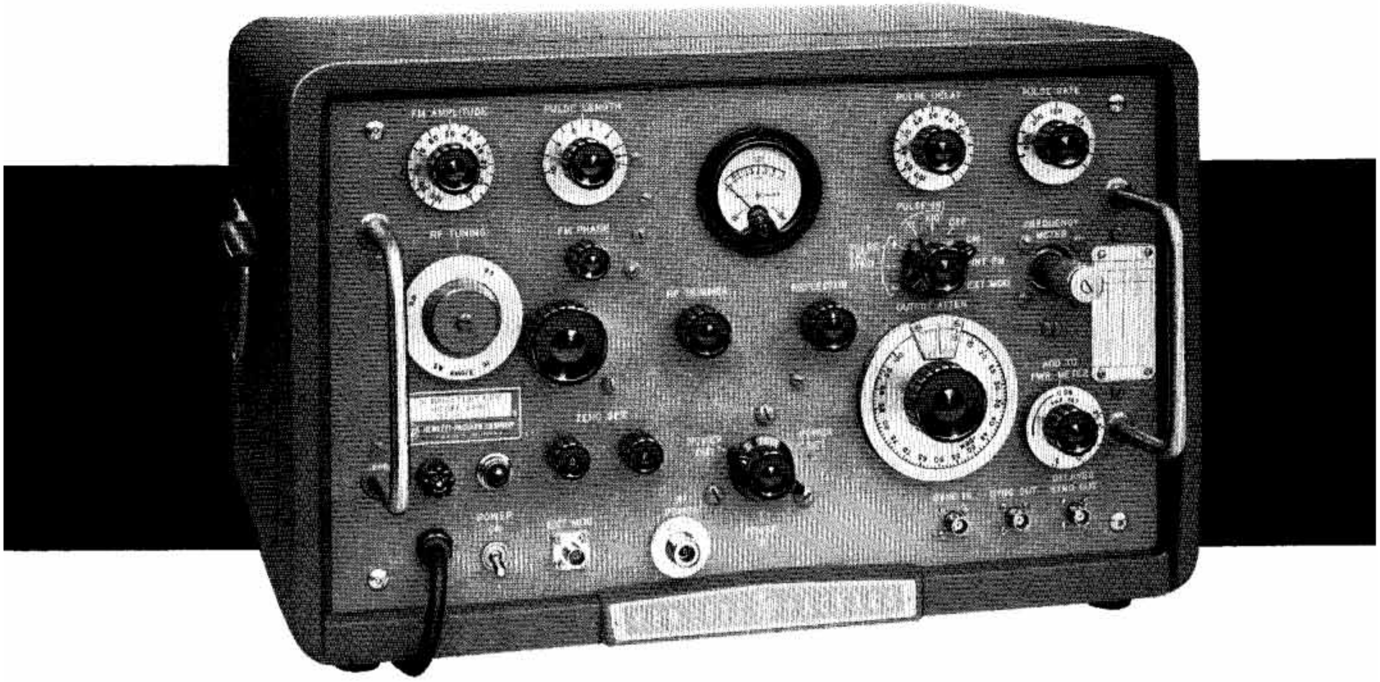
Frequency Range: 7,000 to 11,000 MC covered in a single band. Repeller voltage automatically tracked and proper mode automatically selected.

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 (cabinet); $2,270.00 (rack).

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.

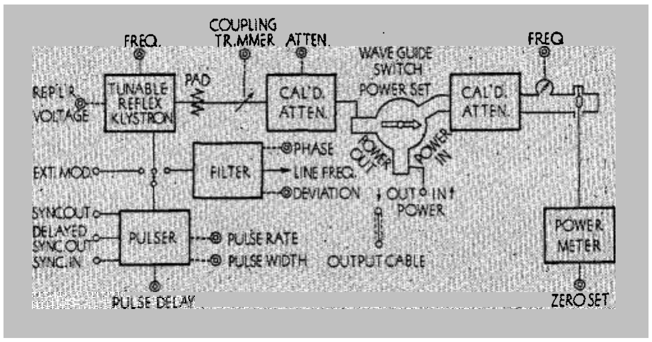


Figure 1. Simplified circuit diagram *-hp-* 624C Test Set.

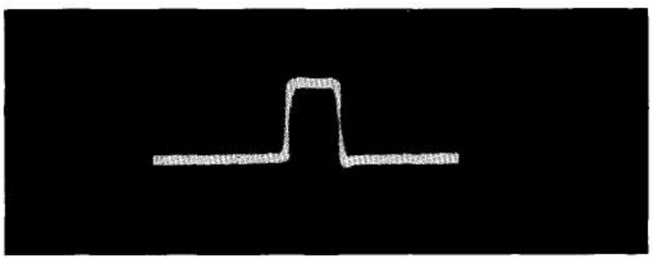


Figure 2. Typical rf pulse envelope, 0.25 μsec, 624C.

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: Pulse 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.

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: 17″ wide, 13¾″ high, 15″ deep. Rack Mount: 19″ wide, 10½″ high, 10¼″ deep behind panel.

Weight: Net 56 lbs. Shipping 83 lbs. (cabinet mount). Net 50 lbs. Shipping 73 lbs. (rack mount).

Accessories Furnished: 1 AC-16Q rf Cable Assembly; 1 X281A Adapter.

Accessories Available: AC-16K Video Cable Assembly, $5.00.

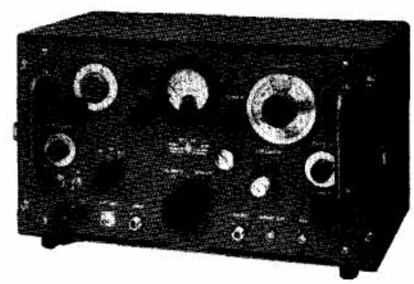
Price: $2,265.00 (cabinet); $2,250.00 (rack mount).

-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 ±7.5 MC.

External Modulation: FM, 30 cps to 100 KC. May be pulse or square-wave modulation, 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, 180 watts.

Dimensions: Cabinet Mount: 21″ wide, 12″ high, 14″ deep. Rack Mount: 19″ wide, 10½″ high, 14″ deep.

Weight: Net 56 lbs. Shipping 76 lbs. (cabinet mount).

Accessories Furnished: 2 AC-16Q rf Cable Assemblies; 1 J281A Adapter; 1 212-44 Spare Crystal.

Accessories Available: AC-16K Cable Assembly, $5.00.

Price: $1,900.00.

Data subject to change without notice.

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.

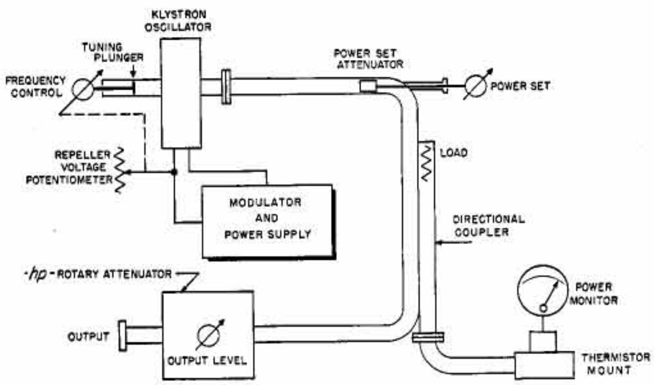


Figure 1. Basic circuit, -*hp*- 626A/628A.

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 ±1%.

Output Range: 10 mw to 1 μμw. (+ 10 dbm to − 90 dbm, 0 dbm = 1 mw.) Attenuator dial directly calibrated in output dbm. SWR less than 2.5 at + 10 dbm; 1.2 at 0 dbm and lower.

Output Monitor Accuracy: Better than ± 1 db.

Output Attenuator Accuracy: Better than ±2% of attenuation in db introduced by output attenuator.

Leakage: Less than minimum calibrated signal generator output.

Modulation: Internal or external pulsed, FM, or square wave.

Internal Pulse Modulation: Repetition rate variable from 40 to 4,000 pps. Pulse width variable 0.5 to 10 μsec.

Internal Square Wave Modulation: Variable 40 to 4,000 cps controlled by "pulse rate" control.

Internal Frequency Modulation: Power line frequency, deviation up to ± 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 v ±10%, 50/60 cps, approx. 210 watts.

Dimensions: Cabinet Mount: 17″ wide, 14″ high, 14¾″ deep.

Weight: Net 65 lbs. Shipping 83 lbs.

Accessories Furnished: -*hp*- 626A (a) MX 292A Waveguide Adapter, WR-75 to WR-90 guide. (b) MP 292A Waveguide Adapter, WR-75 to WR-62 guide.

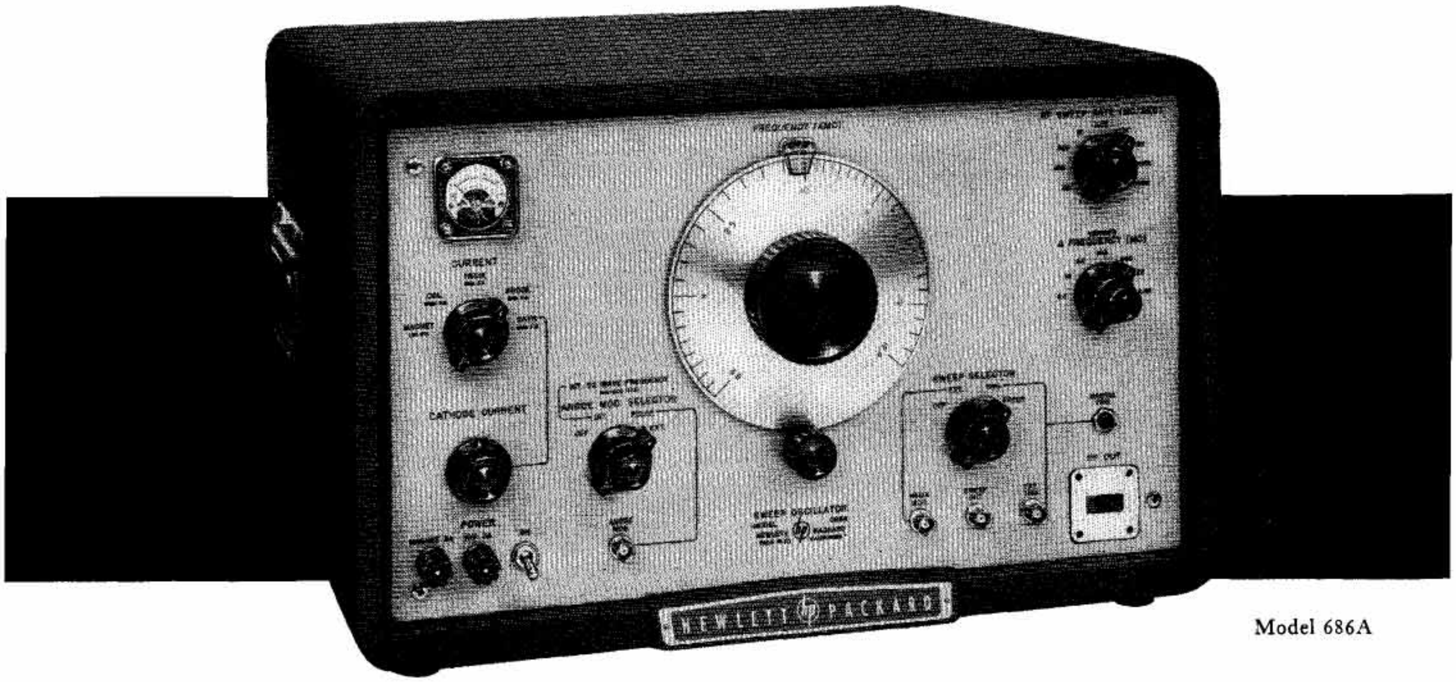
-*hp*- 628A (a) NP 292A Waveguide Adapter, WR-51 to WR-62 guide. (b) NK 292A Waveguide Adapter, WR-51 to WR-42 guide.

Accessories Available: -*hp*- AC-16K Video Cable Assembly, $5.00. -*hp*- 626A, M362A Low Pass Filter. -*hp*- 628A, N362A Low Pass Filter, $125.00 each.

Price: -*hp*- 626A or -*hp*- 628A, $3,250.00.
-*hp*- 626A or -*hp*- 628A (rack mount), $3,270.00.

Data subject to change without notice.

683A/687A ELECTRONIC SWEEP OSCILLATORS



Model 686A

Advantages:

- Electronic sweep
- 2 to 18 KMC
- Simple to operate, direct reading
- Continuously adjustable sweep width and rate
- 10 mw output minimum
- Frequency sweep linear with time
- Slow sweep for mechanical recorders; fast sweep for non-flickering oscilloscope presentation
- Single sweep manually started or externally triggered
- External FM or AM modulation

Uses:

New, convenient source of CW and swept rf frequencies for:

- Reflectometer measurements
- Slotted line measurements
- Antenna checks

Transfer characteristics of:

- Networks
- Filters
- Attenuators
- Amplifiers
- Ferrite devices

New Electronic Sweep for Simple, Error-free Full-Band Coverage

Now Hewlett-Packard offers five new backward-wave sweep oscillators that eliminate sweep motors, tuning plungers, previous range limitations and mechanical problems . . . *and cover all or part of a given band with a simple, flexible, broadly adjustable, quiet electronic sweep!*

Four of the new Sweep Oscillators cover the S, G, J, X and P bands (2 to 18 KMC). A fifth oscillator, Model H01 686A, covers the frequencies 7 to 11 KMC.

With these new instruments, you have complete freedom of sweep combination—both sweep width and rate of change of frequency (sweep rate) are independently controlled and direct reading. CW or swept rf frequencies may be obtained over any part of the range; sweep width may be adjusted instantly without interrupting operation. The full range can be covered in periods slow enough for high resolution mechanical recording or fast enough for flickerless oscilloscope presentations (see Specifications). Sweep rate is adjustable in nine steps over various ranges as indicated under Specifications.

Linear Frequency Sweep

A unique means is used to achieve a swept frequency that is a linear function of time. Output frequency of a backward wave oscillator tube is an exponential function of the voltage applied to its helix, so by making the sweep voltage applied to the helix the proper exponential function of time, a frequency sweep results which is linear.

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 instrument 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 the instruments is at least 10 milliwatts full range into a reflectionless load, and output variation over a given 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 connectors on four models are Type N; (2.4 through 11 KMC) while X and P band instruments have waveguide connectors.

Broad Modulation Capabilities

In addition to their swept frequency output, the oscillators may be internally or externally AM modulated, externally pulse modulated and externally FM modulated.

Internal amplitude modulation is produced by a square wave variable 400 to 1,200 cps. During modulation, peak power is the same as the unmodulated CW output.

External amplitude modulation is produced by a signal applied to the backward wave oscillator through a built-in amplifier. Pass band of this amplifier is dc to 300 KC, and 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. 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

Model	Freq. (KMC)	Sweep Range	RF Sweep Rate of Change	Sweep Time	Output Power Variation	Output Connector	PRICE Rack	Cabinet
683A	2 - 4	2.1 MC to 2.1 KMC, seven steps, continuous control between steps.	16 MC/sec to 300 KMC/sec in nine steps.	0.0135 sec to 135 sec for full band sweep, determined by sweep range and rate.	Less than 6 db over entire frequency range.	Type N (Female)	$2,985.00	$3,000.00
684B	4 - 8.1	4.1 MC to 4.1 KMC in seven steps Continuous control between steps.	32 MC/sec to 320 KMC/sec in nine steps.	0.0135 sec to 135 sec for full band sweep, determined by sweep range and rate.	Less than 10 db over entire frequency range.	Type N (Female)	$2,885.00	$2,900.00
H01686A	7 - 11	4.4 MC to 4.4 KMC in seven steps. Continuous control between steps.	32 MC/sec to 320 KMC/sec in nine steps.	.0139 sec to 139 sec for full band sweep, determined by sweep range and rate.	Less than 6 db over entire frequency range.	Type N (Female)	$2,985.00	$3,000.00
686A	8.2 - 12.4	4.4 MC to 4.4 KMC in seven steps. Continuous control between steps.	32 MC/sec to 320 KMC/sec in nine steps.	.0139 sec to 139 sec for full band sweep, determined by sweep range and rate.	Less than 3 db over entire frequency range.	X-band cover flange (UG-135/U)	$2,885.00	$2,900.00
687A	12.4 - 18	6 MC to 6 KMC in seven steps. Continuous control between steps.	44 MC/sec to 440 KMC/sec in nine steps.	.0136 sec to 136 sec for full band sweep, determined by sweep range and rate.	Less than 9 db over entire frequency range.	P-band cover flange (UG-419/U)	$3,385.00	$3,400.00

For All Models:

Sweep Mode: Recurrent; externally triggered; manually triggered. Rf frequency sweep is linear with respect to time and is downward from frequency dial setting.

Sweep Output: +20 to +30 volt peak sawtooth provided concurrently with swept rf output for recorder and oscilloscope sweeping. Source impedance approximately 10,000 ohms and 20 $\mu\mu$f in parallel.

Power Output: 10 milliwatts or greater into load (50 ohms for Type N output) having an SWR of 1.25 or less. Output continuously adjustable to zero.

Maximum SWR: 2.5:1 or less.

Dial Accuracy: $\pm 1\%$.

Modulation:

Internal AM: Square wave modulation continuously adjustable from 400 - 1200 cps; output peak rf output power is within 1 db of the CW setting.

External AM: Direct coupled dc to 300 KC/sec: —20 volts or more reduces rf output level from rated CW output to zero. Input impedance: 100K ohms, and 45 $\mu\mu$f (approximately) in parallel.

External FM: Approximately 350 volts peak required to modulate full frequency range of instrument. 10 cps to 60 cps. Modulating voltage must be decreased with modulating frequencies higher than 60 cps. Input impedance: 1 megohm and 140 $\mu\mu$f (approximately) in parallel; ac coupled.

External Pulse: +10 volts or greater pulse required; 5 millisecond maximum pulse length. Peak rf pulse level within 1 db of CW setting. Pulse rise and decay times less than 1 μsec. Input impedance: 100K ohms and 45 $\mu\mu$f (approximately) in parallel; ac coupled.

Power: 115/230 volts $\pm 10\%$, approximately 540 watts.

Dimensions: Width 20-9/16", height 12¾", depth 18" (cabinet mount). Width 19", height 10½", 16¾" deep behind panel (rack mount).

Weight: Net 105 lbs. Shipping 134 lbs (cabinet mount). Net 104 lbs. Shipping 134 lbs. (rack mount).

721A TRANSISTOR POWER SUPPLY

Specifications

Regulated Output Voltage: 0 to 30 v dc, continuously variable.

Full Load Output Current: 150 ma.

Load Regulation: With meter monitoring voltage, change in output voltage no load to full load is less than 0.3% or 30 mv, whichever is greater.

Line Regulation: Change in nominal line voltage of ±10% causes change of less than ±0.3% or ±15 mv whichever is greater.

Ripple and Noise: Less than 150 μv rms.

Output Impedance: Less than 0.2 ohm in series with less than 30 μh.

Meter Ranges: Full scale indications of: 10 ma, 30 ma, 100 ma, 300 ma, 10 v, 30 v.

Overload Protection: Maximum current selected by switch in four steps, 25 ma, 50 ma, 100 ma, 225 ma.

Output Terminals: Positive and negative terminals are isolated from chassis. A maximum of 400 volts may be connected between ground and either output terminal.

Power: 115/230 v ±10%, 50 to 60 cps, 16 watts.

Weight: Net 4 lbs. Shipping 7 lbs.

Dimensions: 7″ wide, 4⅜″ high, 5¼″ deep.

Price: $145.00.

Data subject to change without notice.

150 ma Output. High Regulation. Protects Transistors from Damage

NEW ⓗⓟ 721A is designed to provide stable dc test voltages for transistor investigations. It offers a continuously variable 150 ma output, 0 to 30 v dc with high regulation and very low ripple. Output is more than adequate for most transistors.

A special feature is the circuitry limiting output current to a pre-selected value safely under levels which can damage transistors under test. Output current may be limited by a front panel control to 25, 50, 100 or 225 milliamperes. Either output voltage or current may be monitored continuously on the front panel meter, eliminating the need for extra equipment.

Output of Model 721A is brought to a convenient 3-terminal front panel jack so either positive or negative terminals may be grounded. Or, the supply may be "stacked" on another voltage for still greater usefulness.

The 721A is extremely compact in size (7″ on largest dimension) and is of sturdy, transistorized construction.

-hp- 711A LABORATORY POWER SUPPLY

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, 6 amps maximum load; 12.6 volts CT, 3 amps maximum load.

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

Ripple: Less than 1.0 mv.

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

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

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

Power: 115 volts ±10%, 50/1,000 cps. Approximately 150 watts depending on load and line voltage.

Dimensions: Cabinet Mount: 7⅜" wide, 11½" high, 14¼" deep. Rack Mount: 19" wide, 7" high, 12⅞" deep behind panel.

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

Price: $250.00 (cabinet); $255.00 (rack mount).

Data subject to change without notice.

712B REGULATED POWER SUPPLY

0.01% Regulation at 500 Volts, 200 Milliamperes

THE 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 v (without switching), 200 ma max. load.

Dc Regulated Fixed Bias: −300 v, 50 ma max. load.

Dc Variable Bias: 0 to −150 v, 5 ma max. load.

Ac Unregulated: 6.3 v, CT, 10 amps max. load.

Regulation: (For line voltage 115 v ± 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 AC-17 End Frames.

Weight: Net 69 lbs. Shipping 90 lbs. (cabinet mount). Net 64 lbs. Shipping 85 lbs. (rack mount).

Price: \$365.00 (cabinet); \$350.00 (rack mount).

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-wave modulated internally at the nominal frequency of 1,000 cps, or sine wave modulated at the power line frequency.

To minimize the chance of accidental damage to a klystron, the instrument's reflector supply is arranged with a protective circuit preventing the reflector from becoming appreciably more positive than the 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, with respect to Supply No. 1; max. current, 10 microamperes; regulation, within 1% for line voltages of 115 v ±10% for fixed currents; ripple, less than 10 mv; calibrated voltage controls provided.

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

Modulation: Square wave modulation provided on supply No. 2; amplitude adjustable from 0 to 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, 200 watts.

Dimensions: Cabinet Mount: 7½" wide, 11¾" high, 13¾" deep.

Weight: Net 18 lbs. Shipping 24 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, $5.00.

Price: $300.00.

Data subject to change without notice.

372 PRECISION ATTENUATORS

Specifications

Accuracy: Mean attenuation (average of maximum and minimum attenuation across band) is within ±0.4 db from nominal. Variation across band is less than ±0.5 db from mean.

Calibration within ± 0.1 may be obtained at ten points across the band for a small additional charge.

SWR: 1.05: 1.

Model	Freq. (KMC)	Nominal Attenuation	Fits Waveguide Size (in.)	Power (watts ave)	Price
S372C	2.6 - 3.95	10	3 x 1½	2	$375.00
S372D	2.6 - 3.95	20	3 x 1½	2	375.00
G372C	3.95 - 5.85	10	2 x 1	2	250.00
G372D	3.95 - 5.85	20	2 x 1	2	250.00
J372C	5.85 - 8.2	10	1½ x ¾	1	140.00
J372D	5.85 - 8.2	20	1½ x ¾	1	140.00
H372C	7.05 - 10.0	10	1¼ x ⅝	1	120.00
H372D	7.05 - 10.0	20	1¼ x ⅝	1	120.00
X372C	8.2 - 12.4	10	1 x ½	1	100.00
X372D	8.2 - 12.4	20	1 x ½	1	100.00
P372C	12.4 - 18.0	10	0.702 x 0.391	1	115.00
P372D	12.4 - 18.0	20	0.702 x 0.391	1	115.00

Data subject to change without notice.

New! Attenuation Not Affected by Aging or Ambient Conditions

New Model 372 Precision Attenuators are rugged, ultra-dependable, broad band instruments, which remain precisely calibrated regardless of humidity, temperature or other ambient conditions—or aging of the instrument. Models with either 10 or 20 db of attenuation are offered. (See table.)

The 372 series attenuators provide invarient attenuation because attenuation does not depend on the position of, or power absorbed, by a resistive card or vane. Instead, the attenuators are similar in design to precision multi-hole couplers with attenuation a function of the coupling hole array between two sections of permanently joined waveguide.

Another important advantage of this design approach is the permanently low standing wave ratio achieved since there are never any protrusions into the waveguide.

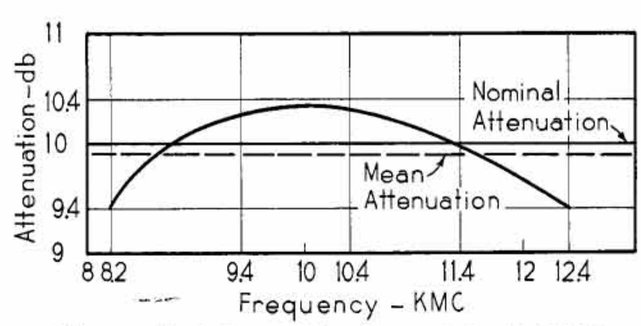


Figure 1. Typical attenuation characteristics, X372C 10 db attenuator.

HEWLETT-PACKARD microwave test equipment is designed to provide a complete set of high-quality, low-cost instruments for measurement of microwave parameters including power, impedance, noise figure, attenuation, 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 123, 124, 127, 131 to 133, 141 to 143. Details of *-hp-* microwave instruments, themselves, begin on page 125. *-hp-* Signal Generators for microwave use are shown separately in a section beginning on page 98 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:

Band	*Fits Waveguide Size (In.)*	*Freq. Range*
"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 an "A" suffix is used to identify the original instrument while "B," "C" and other suffixes indicate a revised, modified or special version of the basic model.

However, in the case of certain *-hp-* microwave elements, the *suffix* letter indicates specific attenuation or coupling factors. Six designator letters are used:

"A"	3 db	"D"	20 db
"B"	6 db	"E"	30 db
"C"	10 db	"F"	40 db

Thus, the 20 db coupling version of *-hp-* 750 Cross-Guide Coupler will be designated as *-hp-* 750D.

The model of the 750 built for 1″ x ½″ waveguide systems will, of course, have the size *prefix* designator "X." Therefore, the complete model number of a 750 series Coupler with 20 db coupling for use with 1″ x ½″ equipment is *-hp-* X750D Cross-Guide Coupler. Use of this prefix and suffix code will simplify and speed inquiries and ordering.

Flanges

All *-hp-* waveguide equipment is equipped with plain AN cover flanges. When it is desired to connect between Hewlett-Packard instruments and a choke flange system under actual operating conditions *-hp-* 290A Cover to Choke Flange Adapters may be used. K band (18 to 26.5 KMC) and R band (26.5 to 40.0 KMC) waveguide equipment is normally supplied with rectangular flanges. However, when specified, circular flanges may be obtained on most K- and R-band instruments at no extra charge.

Waveguide Equipment

Hewlett-Packard Broad Band Waveguide Instruments are based on a unique design approach. The fundamentals of this concept are:

1. Each instrument is of simplest construction consistent with its basic function and covers the entire frequency range of its waveguide size.
2. An integrated set of instruments is available for each commonly-used waveguide frequency from S to R band.
3. Simple mechanical design, incorporating novel electrical circuitry, insures high accuracy, stability, and quality; and yet makes possible quantity production at low cost.

With 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, Noise Figure, Measurements

General information and techniques for the use of Hewlett-Packard microwave test equipment in making power measurements are presented on pages 131 to 133. A similar discussion concerning microwave impedance measurements appears on pages 141 to 143. A discussion on noise figure measurements appears on page 127. 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.

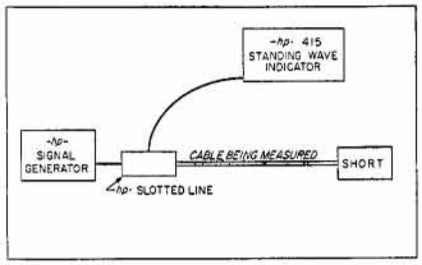


Figure 1. Suggested instrument arrangement for measuring small values of cable attenuation. Unknown cable is placed between slotted line and short.

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:

$$\text{Tanh } \alpha L = \frac{1}{SWR} \text{ Nepers}$$

If αL is much smaller than 1, Tanh αL 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 146). 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.

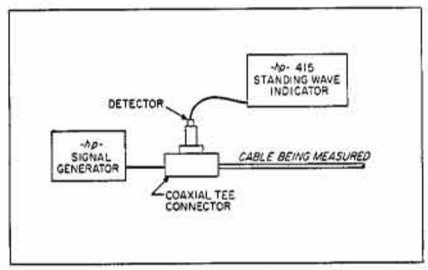


Figure 2. Arrangement of instruments for measuring velocity of propagation.

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:

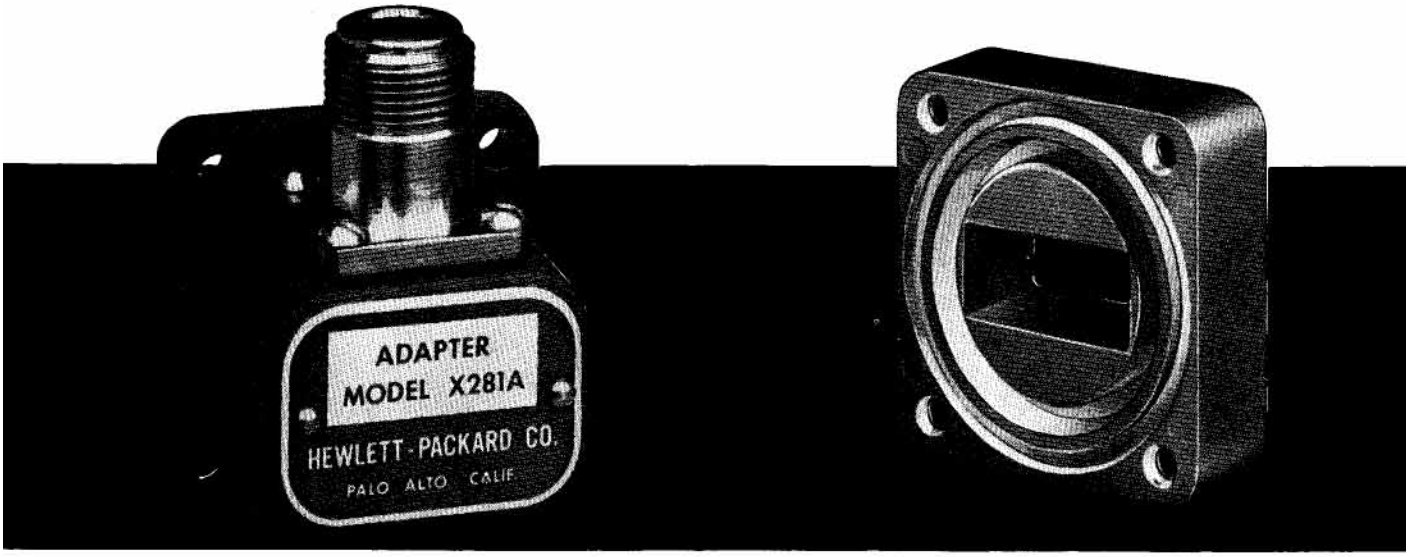
$$V = \frac{Lf_1}{2.46K}$$

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 receptacle 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.

-hp- 292A Waveguide to Waveguide Adapter

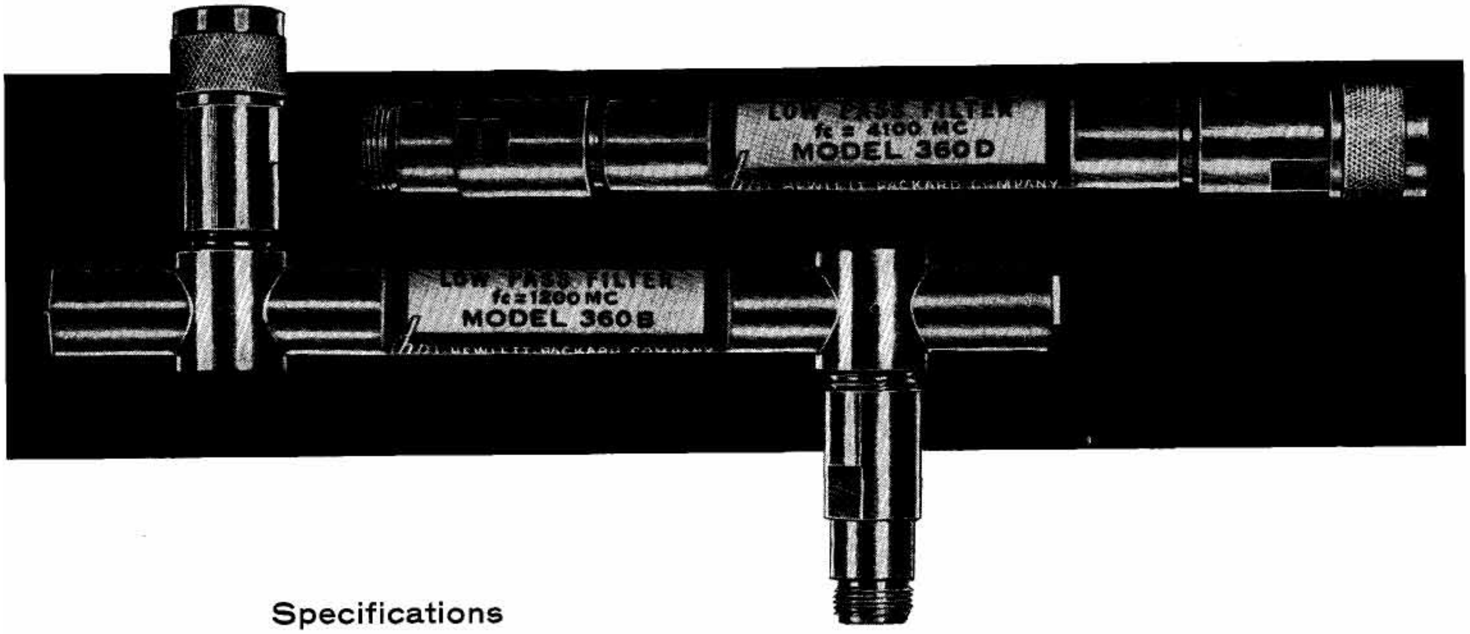
Model 292A Adapters are tapered lengths of waveguide employed to connect a given size of waveguide with the next size larger or smaller. Five models are offered, providing band interchange between the "H" and "X" bands, "M" and "X" bands, and others as indicated in the table below. Flanges at opposite ends of these shortwave guide sections mate respectively with one or the other bands as indicated by the prefix letters in the instrument model number.

Specifications

-hp- 281A Adapters		-hp- 290A Adapters		Frequency Range KMC	Fits Waveguide Size (in.)	-hp- 292A Adapters				
Model	Price	Model	Price			Model	SWR	Price	Length (in.)	Frequency Range KMC
S281A	$50.00	S290A	$65.00	2.60 - 3.95	3 x 1½	HX292A	1.05	$25.00	5¾	8.2 - 10.0
G281A	40.00	G290A	50.00	3.95 - 5.85	2 x 1	MX292A	1.05	40.00	2⅜	10.0 - 12.4
J281A*	35.00	J290A	35.00	5.30 - 8.2	1½ x ¾	MP292A	1.05	40.00	2⅜	12.4 - 15.0
H281A	30.00	H290A	30.00	7.05 - 10.0	1¼ x ⅝	NP292A	1.05	40.00	2⅜	15.0 - 18.0
X281A	25.00	X290A	15.00	8.2 - 12.4	1 x ½	NK292A	1.05	40.00	2⅜	18.0 - 22.0
		P290A	25.00	12.4 - 18.0	.702 x .391					

*SWR 1.30 from 5.3 to 5.5 KMC.

Data subject to change without notice.



Specifications

Cut-Off Frequency: Model 360A, 700 MC; 360B, 1,200 MC; 360C, 2,200 MC; 360D, 4,100 MC.

Insertion Loss: Not over 3 db throughout pass band.

Rejection: 50 db or more attenuation at 1.25 x (Cut-Off Frequency).

Nominal Impedance: 50 ohms through pass band. Should be matched for optimum performance.

SWR: Less than 1.6:1 to within 100 MC of cut-off. Less than 3:1 at cut-off.

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, $12.00; AC-16C rf Cable Assembly, $10.50.

Price: $40.00.

Data subject to change without notice.

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.

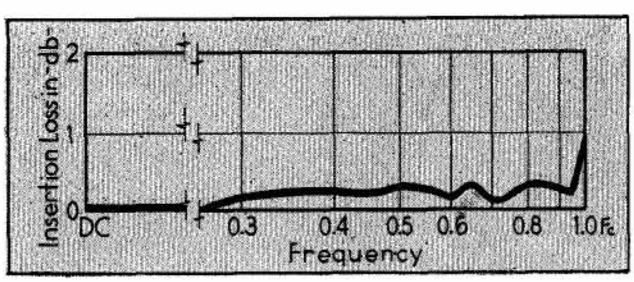


Figure 1. Typical band pass characteristics.

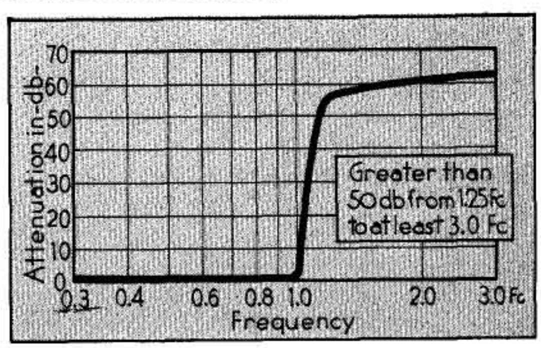


Figure 2. Typical rejection characteristics.

NOISE FIGURE

In microwave communications, the weakest signal that can be used is usually determined by the amount of noise added by the receiving system. Thus, any decrease in the amount of noise generated in the receiving system will produce an increase in the output signal-to-noise ratio equivalent to a corresponding increase in received signal. From a performance standpoint, an increase in the signal-to-noise ratio by reducing the amount of noise in the receiver is more economical than increasing the received signal level by raising the power of the transmitter. For example, a 5 db improvement in receiver noise figure is equivalent to increasing the transmitter power by 3:1.

The noise appearing at the output of a receiver or an amplifier is the sum of the noise arising from the input termination (source) and the noise contributed by the receiver or amplifier itself. The noise factor is the ratio of the actual output noise power of the device to the noise power which would be available if the device were perfect and merely amplified the thermal noise of the source rather than contributing any noise of its own. Noise figure is this power ratio expressed in db.

The noise factor (F) of a device (amplifier or mixer, for example) can be defined as:

$$F = \frac{N}{kT_oB \times G} \qquad (1)$$

where:

N = the noise output of the device
k = Boltzman's constant
T_o = 290° K (standard temperature)
B = Bandwidth of the device in MC
G = Power gain of the device

kT_o is equivalent to the available thermal noise per MC from the input resistor or resistive network. A theoretically perfect device adds no noise to the signal passing through it and thus the noise output equals the noise input per MC from the source resistor, times the bandwidth in MC, times the gain. Substituting this value for N in (1), the noise factor of a perfect device would be:

$$F = \frac{kT_oB \times G}{kT_oB \times G} = 1 \qquad (2)$$

and the noise figure (power ratio expressed in db) would be 0 db.

The noise figure of a receiver may be measured using a signal generator and an output power (square law) detector. However, this method is time-consuming and has the added disadvantage that the effective power gain bandwidth must be determined. Moreover, the available signal power may be difficult to determine accurately at the low levels involved.

Another method which overcomes these drawbacks is used in the Hewlett-Packard Noise Figure Meters to provide a dynamic, continuous display of noise figure. In place of a signal generator, this method uses a standard white noise source to supply a noise spectrum of known power which is flat with frequency. At intermediate and low radio frequencies temperature-limited diodes are suitable sources, while at microwave frequencies argon gas discharge tubes in suitable waveguide sections are both accurate and reliable.

Hewlett-Packard Models 340B and 342A Noise Figure Meters measure noise figure as a function of the ratio between the noise output of the device under test when a known amount of noise is introduced at the input, to the noise output when the device is terminated in its normal load.

To make noise figure measurements, the 340B or 342A, the appropriate noise source and the receiver or amplifier under test are connected as shown in the diagram. The noise figure meter squarewave modulates the noise source at about a 500 cps rate and measures noise figure by comparing the noise output of the device under test when the noise source is off to the noise output when the noise source is on.

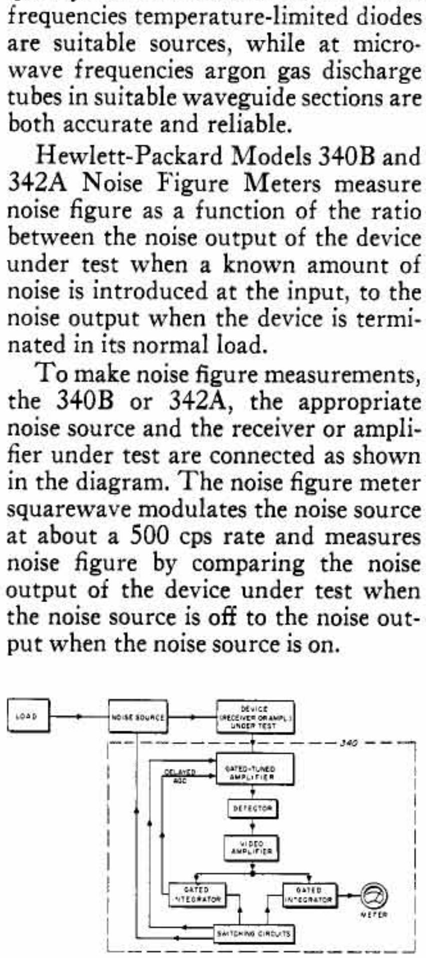


Figure 1. Simplified block diagram of ⓗ Model 340B.

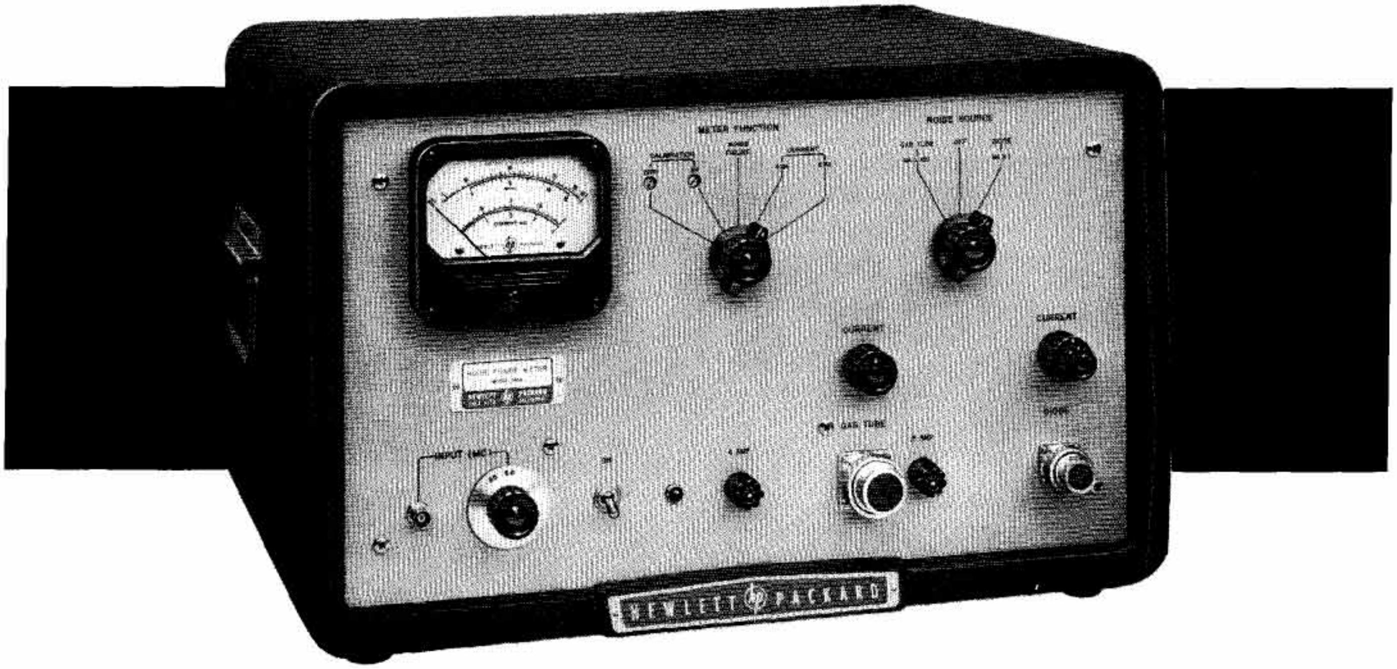
The input circuitry of the 340B consists of a gated-tuned amplifier which operates at two frequencies, 30 or 60 MC, selected by a front panel switch. The input circuitry of the 342A consists of a 30 MC gated-tuned amplifier preceded by a four channel mixer-local oscillator combination which, depending upon the position of the front panel switch, will convert four frequencies —60, 70, 105 and 200 MC—to 30 MC. The output from the 340B/342A tuned amplifier is detected, amplified, and alternately applied to two gated integrators. When the noise source is on, the combined noise power from the noise source and the device under test is amplified by the tuned amplifier, detected, and passed through the AGC integrator. The time constant of the AGC voltage applied to the amplifier is long enough to hold the gain of the amplifier the same whether the noise source is on or off.

When the noise source is turned off, the combined noise power from the source impedance (load) and the device under test is amplified, detected, and passed through the meter integrator and displayed on the meter. Because of the AGC action, the meter deflection is proportional to the ratio of the noise powers, (source on and source off) and, since the additional noise from the noise source (excess noise) is accurately known, the meter face is calibrated directly in db of noise figure.

The AGC action, in addition to establishing a reference against which noise figure measurements can be made, provides a wide (50 db) input operating range and also eliminates the necessity for periodic recalibration of the Noise Figure Meter. AGC voltages appear on a pair of terminals at the rear of the instrument to facilitate measurements which require an indication of the gain of the system in relation to changes in noise figure.

The meter face is provided with two noise figure scales—a "Noise Diode" scale for use with the ⓗ 343A vhf Noise Source and 345B IF noise source and a "Gas Tube" scale for use with 347A Waveguide Noise Sources. Current scales indicate the current supplied to the noise sources. Special circuitry is included to enable offsetting the Noise Figure Meter scale so that low values of noise figure can be read on a more sensitive external meter. A phone jack is provided on the rear of the Noise Figure Meter to drive a remote meter or galvanometer recorder.

340B/342A NOISE FIGURE METER



Advantages:

- Gives direct, noise figure readings while equipment is being operated
- Cuts receiver alignment time to minutes
- Completely automatic measurement
- Easily used by non-technical personnel
- No periodic recalibration needed
- Fast response; ideal for recorder operation

Uses:

- Measure noise figure and optimize performance in microwave or radar receivers, rf and IF amplifiers
- Select components, crystals, T-R cells and local oscillators for minimum noise
- Compare unknown noise sources against known noise levels
- Design IF amplifiers, crystal mixing circuits, wide band traveling wave tubes, etc.

New Instrument Speeds Noise Figure Measurements

Receiver and component alignment jobs that once took skilled engineers a full hour are now done in 5 minutes by a semi-skilled worker. Receiver noise figure can often be improved over the best adjustment previously possible. For instance, a 3 db improvement in receiver noise figure equals doubling transmitter output. Since accurate alignment is easy, equipment is better maintained and peak performance enjoyed regularly.

Above are some of the time-saving, cost cutting advantages of new Hewlett-Packard noise figure measuring equipment which includes two new Noise Figure Meters, Models 340B and 342A, plus a variety of coaxial and waveguide noise sources.

New Model 340B Noise Figure Meter, when used with a noise source such as ⓗ 345B described on the opposite page, automatically measures and continuously displays the noise figure of IF or rf amplifiers tuned to 30 or 60 MC. The noise figure of radar or microwave receivers with intermediate frequencies of 30 and 60 MC can be similarly measured and displayed. Receiver ranges of from 10 to 600 MC are covered with the use of the new ⓗ 343A vhf Noise

Source and receiver ranges from 2.6 to 18.0 KMC are covered with the new ⓗ 347A Waveguide Noise Source. These Noise Sources are described and specifications given below.

Five-Frequency Operation

New Model 342A Noise Figure Meter is similar to ⓗ 340B except that it operates on five frequencies between 30 and 200 MC. Four of these frequencies are 60, 70, 105 and 200 MC; the fifth is the basic 342A tuned amplifier frequency of 30 MC.

In operation, a noise source such as a gas discharge tube is connected to the input of a receiver under test. The receiver's IF amplifier input is connected to the 340B or 342A. The Noise Figure Meter pulses the gas discharge tube. When the tube is ignited the noise level is that of the receiver *plus* the discharge tube. When the tube is off, the noise level is that of the receiver and its termination. The Noise Figure Meter automatically compares these two conditions and presents noise figure directly on a front panel meter. Rate of response is such that changes in noise figure are constantly indicated on the meter.

New ⓗ Noise Sources

ⓗ 343A vhf Noise Source. Designed specifically for IF and rf amplifier noise measurement, Model 343A is a temperature-limited diode source with broadband noise output from 10 to 600 MC.

ⓗ 345B IF Noise Source. This source operates at either of two frequencies between 30 or 60 MC, as selected by a switch, and another selector permits matching 50, 100, 200 and 400 ohm impedances.

ⓗ 347A Waveguide Noise Source. These instruments are Argon gas discharge tubes mounted in waveguide sections. Available for all frequencies 2.6 through 18.0 KMC, they provide a uniform noise level throughout range and have a maximum SWR of 1.2.

Specifications

ⓗ 340B Noise Figure Meter

Frequency Range: Depends on noise source used.

Noise Figure Range: 3 to 30 db, indication to ∞ with Waveguide Noise Source. 0 to 15 db, indication to ∞ with IF Noise Source.

Zero Offset: Permits low values to be read on sensitive external meter.

Accuracy: ±0.5 db, 10 to 25 db; ±1 db, 3 to 10 db; 25 to 30 db with Waveguide Noise Source. ±0.5 db, 0 to 15 db with IF Noise Source.

Input Requirements: —60 dbm to —10 dbm. Corresponds to system gain before 340B of approximately 40 to 90 db; with Waveguide Noise Source approximately 50 to 100 db with vhf or IF Noise Source.

Input Frequency: 30 and 60 MC. Other frequencies between 10 and 60 MC on special order.

Bandwidth: 1 MC minimum.

Input Impedance: 50 ohms, nominal.

Power Input: 115/230 v, ±10%, 50/60 cps, 185-435 watts depending on line voltage and noise source connected.

Power Output: Sufficient to operate ⓗ 347A Waveguide Noise Source, ⓗ 345A IF Noise Source, or ⓗ 343A vhf Noise Source.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 13½" deep behind panel.

Weight: Cabinet Mount: Net 40 lbs. Shipping 63 lbs. Rack Mount: Net 35 lbs. Shipping 74 lbs.

Price: $715.00 (cabinet); $700.00 (rack). Add $25.00 for special frequencies between 10 and 60 MC. (Note: This instrument available only in the U.S.A. and Canada.)

ⓗ 342A Noise Figure Meter

(Same as 340B except as shown below)

Input Frequency: 30, 60, 70, 105 and 200 MC. 30 MC plus any four frequencies between 38 and 200 MC on special order. Frequency selector switch.

Price: $815.00 (cabinet); $800.00 (rack mount). (Note: This instrument available only in the U.S.A. and Canada.)

ⓗ 343A vhf Noise Source

Frequency Range: 10 to 600 MC.

Excess Noise: 5.2 ±0.1 db, 10 to 200 MC.
5.2 ±0.25 db, 200 to 400 MC.
5.2 ±0.35 db, 400 to 600 MC.

Source Impedance: 50 ohms, SWR less than 1.1, 10 to 400 MC; less than 1.3, 400 to 600 MC.

Dimensions: 2¾" wide, 2½" high, 5" deep.

Weight: Net ¾ lb. Shipping 2 lbs.

Price: $100.00.

ⓗ 345B IF Noise Source

(Same as 343A except as shown below)

Spectrum Center: 30 or 60 MC, selected by switch. Other frequencies between 10 and 60 MC on special order.

Excess Noise: Nominally 5.2 db into conjugate load.

Source Impedance: 50, 100, 200 and 400 ±4% ohms as selected by switch.

Price: $75.00. Add $25.00 for special frequencies.

Specifications

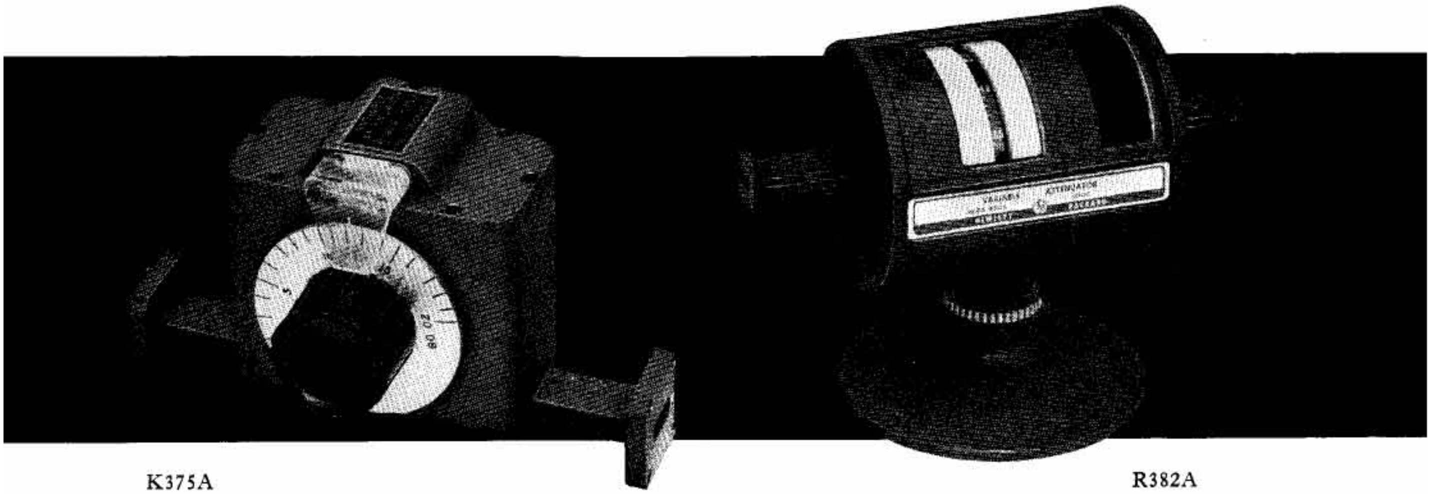
ⓗ 347A Waveguide Noise Source

Model	Range, KMC	Excess Noise, db	Approx. Length	Price
S347A	2.6 - 3.95	15.2 ± 0.5	22½"	$250.00
G347A	3.95 - 5.85	15.2 ± 0.5	19"	190.00
J347A	5.3 - 8.2	15.2 ± 0.5	19"	190.00
H347A	7.05 - 10	15.2 ± 0.5	16"	190.00
X347A	8.2 - 12.4	15.2 ± 0.5	14¾"	190.00
P347A	12.4 - 18	15.2 ± 0.5	14¾"	250.00

SWR all models, on or off, 1.2 max., less than 1.1 average.

Data subject to change without notice.

370/375/380/382A WAVEGUIDE ATTENUATORS



K375A R382A

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. 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.

375A Variable Flap Attenuators

Variable flap attenuators provide a simple, convenient means of adjusting waveguide power level, or isolating source and load. They consist of a slotted section in which a matched resistive strip is inserted a variable amount. The degree of strip penetration determines attenuation. A dial shows average reading over the frequency band, and a dust cover with shielded braid reduces external radiation and eliminates hand capacity effects. Attenuation is variable 0 to 20 db. Dial calibration is accurate within ±1 db from 0 to 10 db, ±2 db from 10 to 20 db.

S380A Calibrated Variable Attenuator

Model S380A, for setting exact power level or measuring attenuation, consists of a waveguide section with an attenuating plate parallel to the narrow face of the waveguide. A micrometer adjustment moves the plate across the waveguide, increasing attenuation from 0 to 10 db. Maximum average power is 1 watt, peak power, 1 kilowatt; frequency range 2.60 to 3.95 KMC, insertion loss less than 0.5 db. Calibration accuracy is ±0.3 db at 3 KMC. Calibration for other frequencies available on request. Price $260.00.

382A Broadband Attenuators

Operation of these direct-reading precision attenuators depends on mathematical law instead of resistivity of attenuating material. Accurate, stable attenuation, 0 to 50 db is insured full range, despite varying temperature and humidity. High power handling capacity, large, easily read dial. Attenuation at 0 setting less than 1 db, SWR less than ~~1.5~~, accuracy ±2% of reading or 0.1 db, whichever is greater.

Specifications, 370, 375, 382 Attenuators

-hp- Model 370*					-hp- Model 375A				-hp- Model 382A				Frequency Range KMC
Model	Calib. Freq. KMC	Power Dissipation Watts	Length (in.)	Price	Model	Power Dissipation Watts	Length (in.)	Price	Model	Capacity, Watts	Length (in.)	Price	
S370	3.0	1.0	12	$ 75.00	S375A	1.0	14¼	$120.00					2.60 - 3.95
G370	5.0	1.0	10⅛	75.00	G375A	1.0	13	110.00	G382A	15	31⅝	$500.00	3.95 - 5.85
J370	7.0	1.0	7⅜	65.00	J375A	1.0	13	100.00	J382A	10	25	350.00	5.30 - 8.2
H370	8.6	1.0	6⅜	60.00	H375A	1.0	7¼	90.00	H382A	10	19⅞	350.00	7.05 - 10.0
X370	10.0	1.0	5¼	55.00	X375A	0.5	7⅜	90.00	X382A	10	15 19/32	275.00	8.2 - 12.4
P370	15.0	1.0	4⅛	60.00	P375A	0.5	7¼	100.00	P382A	5	12⅛	275.00	12.4 - 18.0
K370	22.0	0.5	3¼	100.00	K375A	0.5	4⅝	140.00	K382A	2	7¾	425.00	18.0 - 26.5
R370	33.0	0.5	3	100.00	R375A	0.5	4½	180.00	R382A	1	6½	450.00	26.5 - 40.0

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.

POWER MEASUREMENT

IN THE microwave region, power measurements are considered to be more basic than current or voltage measurements. This is because power is invariant with position of measurement, while current and voltage (because of the distributed nature of the transmission system at these frequencies) are not.

In the range 0.1 to 10 milliwatts, power measurements are customarily made through the use of a bolometer which operates in a bridge circuit and changes rf energy into heat energy. This causes the resistance of the bolometer to change, unbalancing the bridge. The audio power which is substituted to rebalance the bridge and keep the bolometer resistance constant is then measured.

In the range 10 watts and above, power measurements are generally made directly, using conventional calorimeters.

Between these two ranges, however, measurement has been clumsy, time-consuming and expensive until the development of the hp 434A Calorimetric Power Meter. This unique new instrument fills the need for a convenient measuring device in the range 10 mw to 10 watts.

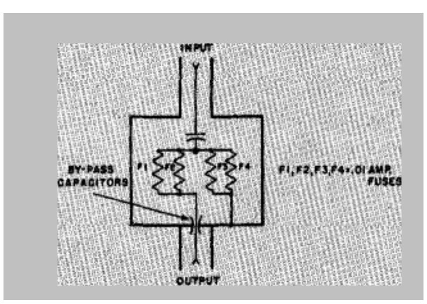


Figure 1. Arrangement for using four instrument fuses in series parallel combination in hp 476A.

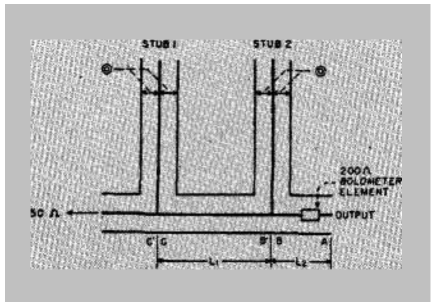


Figure 2. Diagram of Tunable Bolometer Mount (hp 475B).

A discussion of power measurements below 10 milliwatts follows. On page 133, the discussion takes up the precision and convenience of power measurements between 10 mw and 10 watts using proper techniques and the high-accuracy 434A. A description of Model 434A itself appears on pages 134 and 135.

0.1 to 10 Milliwatts

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 temperature coefficient bolometers. Barretters consist of a short length of very fine platinum wire suitably capsulated. Negative temperature coefficient bolometers (thermistors) consist of a small bit of semi-conductive material suspended between two fine wires.

In general, barretters are delicate, and readily burned out by too much power. Even if the overload is insufficient to burn out a barretter, it may still increase its cold resistance to the point where a self-balancing bridge meter cannot be zero set. Thermistors are much more rugged. Although they are rated at 25 mw maximum, they generally burn out at about 400 mw 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 with a low SWR through their operating range are available for coaxial and waveguide systems. Barretters are usually operated at 200 ohms, while thermistors usually operate at 100 or 200 ohm levels. Series-parallel combinations of the bolometer 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.

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 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. Er-

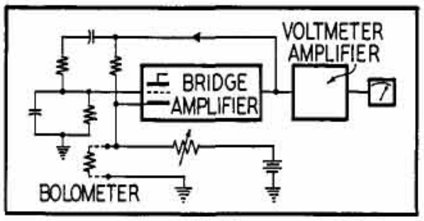


Figure 3. Basic Circuit of Power Meter.

rors that result from generator and load mismatch have been discussed under the section of this catalog dealing with Signal Generators.

hp 430C Microwave Power Meter will give direct instantaneous readings of microwave power when connected with a suitable bolometer mount. The bias current necessary to bring the bolometer to the correct operating resistance is furnished by the 430C Power Meter. This power meter circuit includes a self-balancing bridge and an audio voltmeter to indicate the magnitude of the bridge amplifier output, (Figure 3). 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 almost 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 40.0 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, or barretter—and whether the mount is untuned (broadbanded) or tunable.

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 40.0 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 detector element (barretter or crystal). In general, their SWR is less than 1.25 over the rated frequency range when using barretters.

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 more accurate microwave power measurements.

In general, squarewave or pulse modulated power can be measured accurately with either a barretter, fuse, or thermistor, subject to certain limitations which depend upon the characteristics of the bolometer elements in conjunction with the bridge oscillator. However, in hp 430C Power Meter, these limitations are not serious.

When using barretters or fuses, precautions should be taken if the modu-

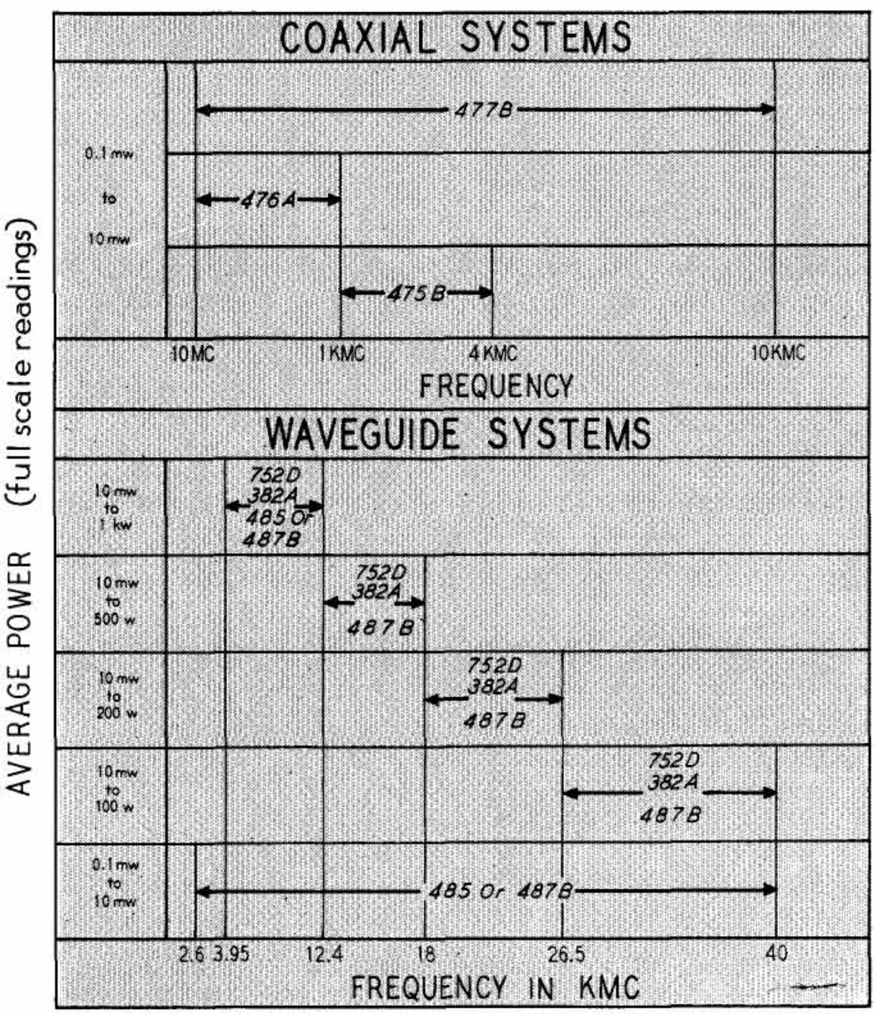


Figure 4. hp equipment for use with hp 430C Microwave Power Meter.

lation frequency is below about 200 cps. For sine and squarewave modulated power, the meter reading will tend to increase at such low modulated frequencies. For use with thermistor, precautions should be taken for frequencies less than 100 cps.

Furthermore, with barretters or fuses, 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 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 4.

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.

10 mw to 10 Watts

The new Model 434A Calorimetric Power Meter *(see also pages 134, 135)* automatically measures average power from 10 milliwatts to 10 watts. The instrument operates from dc to 12.4 KMC. The operator simply connects the source to the 434A and reads the power. Power above 10 watts may be measured by reducing it to the range acceptable to the 434A with calibrated attenuators or directional couplers.

The Model 434A, shown simplified in Figure 5, consists of a self-balancing bridge which has identical temperature-sensitive resistors (gauges) in two legs, an indicating meter and two load resistors, one for the unknown input power and one for the comparison power. The input load resistor and one gauge are in close thermal proximity so that heat generated in the input load resistor heats the gauge and unbalances the bridge. The unbalance signal is amplified and applied to the comparison load resistor which is in close thermal proximity to the other gauge so that the heat generated in the comparison load resistor is transferred to its gauge and nearly rebalances the bridge.

The meter measures the power supplied to the comparison load to rebalance the bridge. The characteristics of the gauges are the same and the heat transfer characteristics from each load are the same, so the power dissipated in each load is the same, and the meter may be calibrated directly in input power.

An efficient heat transfer from the loads to the temperature gauges is accomplished by immersing the components in an oil stream.

The power measurement is accurate, because the flow rates through the two heads are the same and the head characteristics are the same. To insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger just prior to entering the heads. Identical flow rates are obtained by placing all elements of the oil system in series as shown in the figure.

The accuracy of Model 434A is one of its unique attributes. Since the new power meter represents the most accurate method available for measuring high-frequency power the 434A may find much use as a laboratory standard power meter. Nominal accuracy is 5%. However, higher accuracies can be achieved by employing techniques to minimize frequency and impedance mismatch effects.

For example, accuracy can be improved by applying an efficiency correction to compensate for the internal power loss in the rf termination. Also, accuracy can be improved by accurately matching the 434A to the source. For this purpose it is desirable that the power be carried in a waveguide rather than a coaxial cable. This not only reduces line loss but permits a waveguide slide-screw tuner to be used ahead of the wave guide-coax transition at the instrument connector. Such waveguide tuners normally give less loss than coaxial tuners.

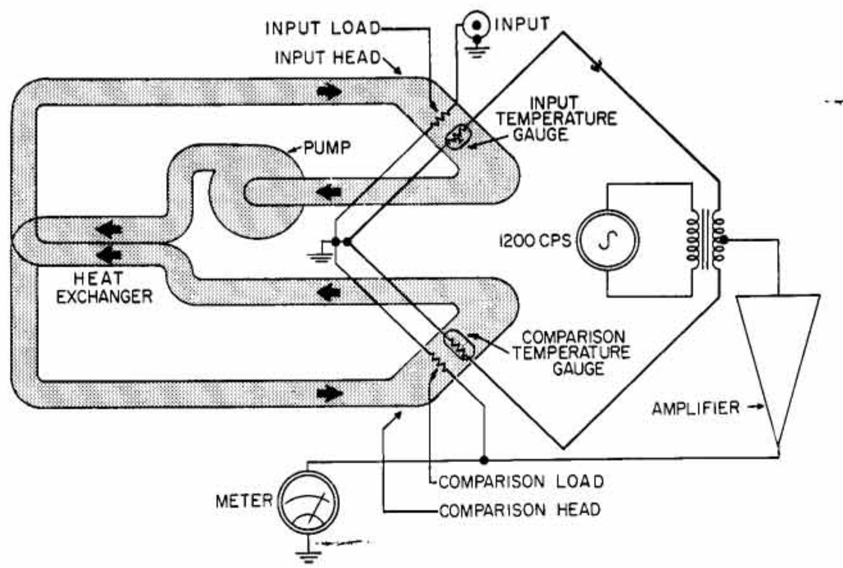
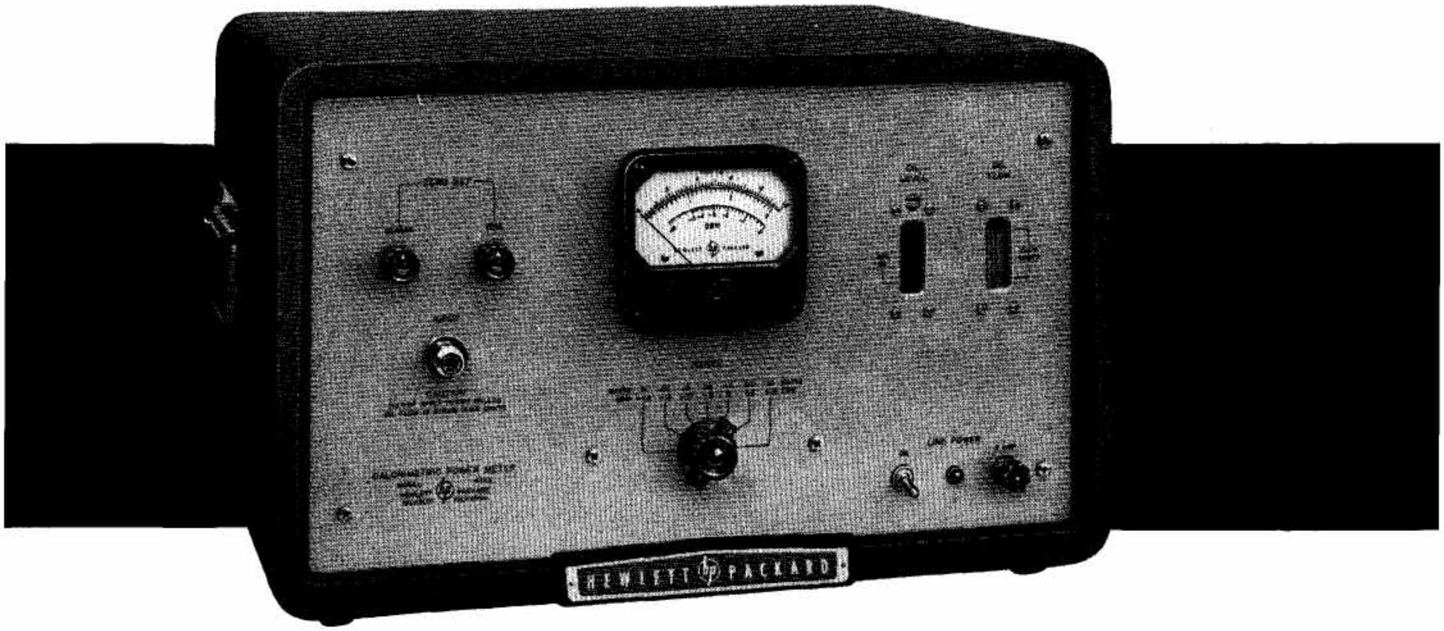


Figure 5. Simplified diagram, hp 434A Calorimetric Power Meter.

ⓗ 434A CALORIMETRIC POWER METER



Just Connect, Read Powers
10 mw to 10 Watts

Advantages:

- Simplest power measurements, 10 mw to 10 watts, dc to 12.4 KMC
- No barretter or thermistor needed
- No external terminations or plumbing
- Compact, entirely self-contained
- Direct reading in watts and DBW

Uses:

- Measures power to 10 watts average, 1 Kw peak
- AM power measurement
- Pulsed, ac and video power
- Measure dc powers

STATED simply, the new ⓗ434A Calorimetric Power Meter offers you this:

The fastest, easiest means yet devised to measure powers accurately from 10 milliwatts to 10 watts between dc and 12.4 KMC.

With the new 434A, measurement is literally as simple as connecting to a 50 ohm type N front panel terminal and reading power directly. The instrument has only two simple front panel controls, and is ideal for use by non-technical personnel.

Model 434A fills the important range between bolometer-type microwave power meters such as ⓗ430C (pages 136, 137) and conventional calorimeters whose lower range is approximately 10 watts. But unlike previous cumbersome and costly equipment suggested for its range, the ⓗ434A is completely self-contained and requires no external detectors or plumbing of any type.

Rapid Response Time

Model 434A employs a self-balancing bridge and a high-efficiency heat transfer system to and from an oil stream to provide a full scale response time of 5 seconds or less. This fast reaction, a fraction of the response time needed by ordinary calorimeters, means the 434A quickly follows small adjustments in input tuning circuits. Further, the use of twin power sensitive elements in one oil stream plus a feedback system makes the accuracy virtually independent of variations in oil flow rate or ambient temperature, and prevents fluctuations due to changes in oil flow rate or oil temperature.

Circuit Description

Basically the Model 434A consists of a self-balancing bridge which has identical temperature-sensitive resistors (gauges) in two legs, an indicating meter and two load resistors, one for the unknown input power and one for the comparison power. The input load resistor and one gauge are in close thermal proximity so that heat generated in the input load resistor heats the gauge and unbalances the bridge. The unbalance signal is amplified and applied to the comparison load resistor which is in close thermal proximity to the other gauge so that the heat generated in the comparison load resistor is transferred to its gauge and nearly rebalances the bridge.

The meter measures the power supplied to the comparison load to rebalance the bridge. The characteristics of the gauges are the same and the heat transfer characteristics from each load are the same, so the power dissipated in each load is the same, and the meter may be calibrated directly in input power.

The power measurement is accurate, because the flow rates through the two heads are the same and the oil enters the heads at nearly the same temperature. To insure constant temperature and to bring the streams to nearly the same temperature, they are passed through a parallel-flow heat exchanger just prior to entering the heads. Identical flow rates are obtained by placing all elements of the oil system in series.

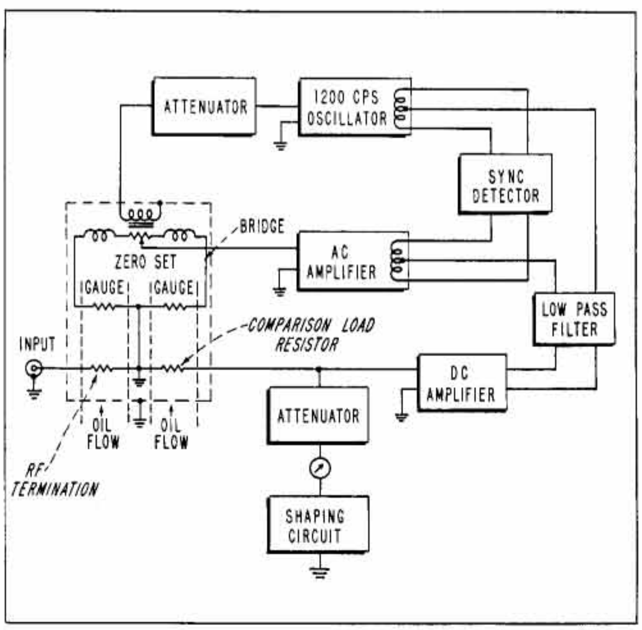


Figure 1. Basic arrangement of instrument circuitry.

Specifications

Input Power Range: Seven meter ranges. Full-scale readings of 0.01, 0.03, 0.1, 0.3, 1.0, 3.0 and 10 watts. Meter scale also calibrated from −10 to 0 DBW, providing continuous readings from −30 to +10 DBW. Power range can be extended upward with attenuators or directional couplers.

Peak Input Power: 1 kilowatt, maximum.

Frequency Range: Dc to 12.4 KMC.

Dc Input Impedance: 50 ohms ±5 ohms at type N input jack.

Input SWR: Dc to 5 KMC, less than 1.3. 5 to 10 KMC, less than 1.5. 10 to 12.4 KMC, less than 1.7.

Meter Response Time: Less than 5 seconds for full scale deflection.

Accuracy: Within ±5% of full scale. Includes dc calibration and rf loss. Greater accuracy can be achieved through appropriate techniques.

Estimated Attainable Accuracy:

Dc	Upper Ranges	½%
	Two Lowest Ranges	2%
0 to 1 KMC	Upper Ranges	1%
	Two Lowest Ranges	3%
1 to 4 KMC	Upper Ranges	2%
	Two Lowest Ranges	4%
4 to 10 KMC	Upper Ranges	3%
	Two Lowest Ranges	5%
10 to 12.4 KMC	Upper Ranges	4%
	Two Lowest Ranges	5%

Power Supply: 115/230 volts ±10%, 50/60 cycles, approximately 155 watts with no input, 175 watts with 10 watts input.

Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14¾" deep. Rack Mount: 19" wide, 10½" high, 13½" deep behind panel.

Weight: Net 49 lbs. Shipping 71 lbs. (cabinet mount). Net 44 lbs. Shipping 66 lbs. (rack mount).

Price: $1,400.00 (cabinet); $1,385.00 (rack mount).

Data subject to change without notice.

-hp- 430C MICROWAVE POWER METER

Advantages:

Reads direct in dbm or mw; no tedious calculations

Wide power range; nominal range extendable with directional couplers and attenuators

Automatic operation; usable with many different bolometers

Highest quality; unique stability and accuracy

Uses:

Instantaneous microwave power measurements, pulsed or CW

Use on waveguide or coaxial systems

Direct, Automatic, Instantaneous Pulsed or CW Power Readings

THIS -*hp*- Microwave Power Meter gives you instantaneous rf power readings direct in dbm or mw—and completely eliminates tedious computation and troublesome adjustments during operation. The instrument may be used at any frequency for which there are bolometer mounts—and measurements are entirely automatic.

In measuring 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 40.0 KMC for certain thermistors.

Hewlett-Packard waveguide bolometer mounts are now available covering, collectively, the frequency spectrum from 2.6 KMC to 40.0 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 -hp- 430C

Power Range: 5 ranges, front panel selector. Full scale readings of 0.1, 0.3, 1, 3 and 10 mw. Also continuous readings from -20 to $+10$ dbm. (0 dbm $=$ 0.001 watt). Power range may be extended with attenuators or directional couplers 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, 90 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). Net 17 lbs. Shipping 35 lbs. (rack mount).

Accessories Available: AC-16K Video Cable Assembly, \$5.00; AC-16D Cable Assembly, \$2.65.

Price: \$250.00 (cabinet); \$255.00 (rack mount).

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 -hp- 477B

Frequency Range: 10 MC to 10 KMC.

SWR: Less than 1.5 (less than 1.3—50 MC to 7 KMC).

Power Range: 0.01 to 10 mw (with -*hp*- 430C Microwave Power Meter).

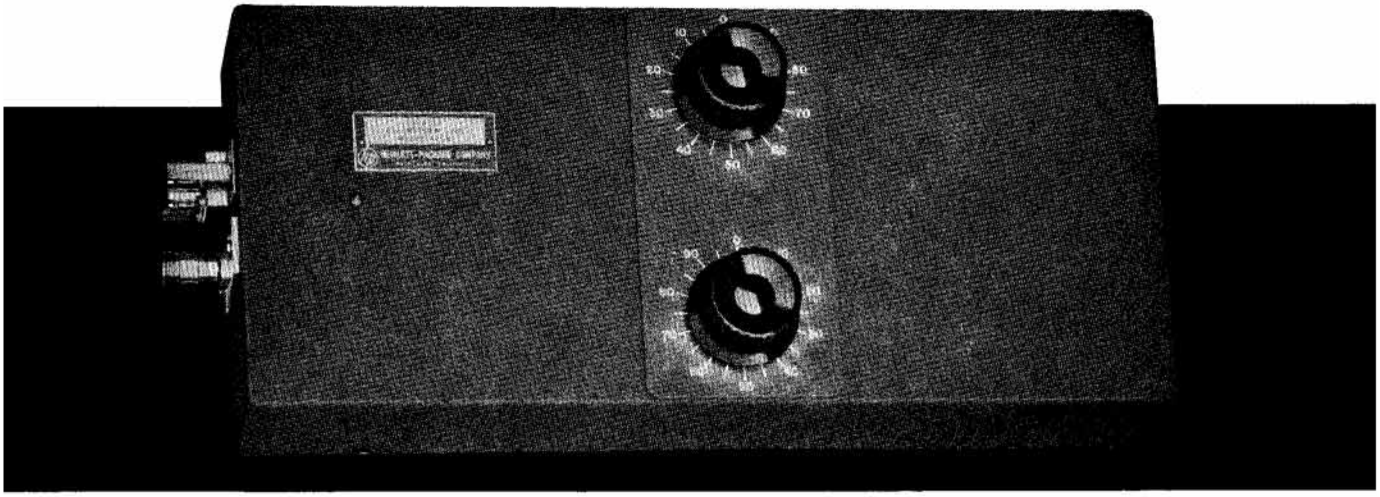
Element: 200 ohm, negative temperature coefficient thermistor included.

Accessories Available: AC-16K Video Cable Assembly, \$5.00.

Price: \$75.00.

Data subject to change without notice.

hp 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 136)*.

Specifications hp 475B

Frequency: Approx. 1,000 to 4,000 MC. (Varies with SWR, phase of source and value of bolometer load.)

Power Range: 0.1 mw to 10 mw full scale (with hp 430).

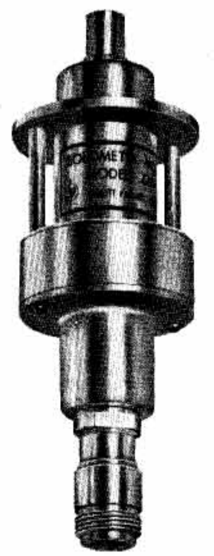
Power Sensitive Element: hp G-28A instrument fuse, specially selected and installed. May also be used with Sperry 821, Narda N821 Barretter or Western Electric Type D166382 Thermistor.

Dimensions: Cabinet Mount: $7\frac{3}{8}''$ 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, $12.00. AC-16K Video Cable Assembly, $5.00; spare G-28A Fuse, $2.00.

Price: $300.00.



hp 476A UNIVERSAL BOLOMETER MOUNT

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 hp 476A

Nominal Impedance: 50 ohms.

Maximum SWR: Less than 1.15, 20 to 500 MC.
Less than 1.25, 10 to 1,000 MC.

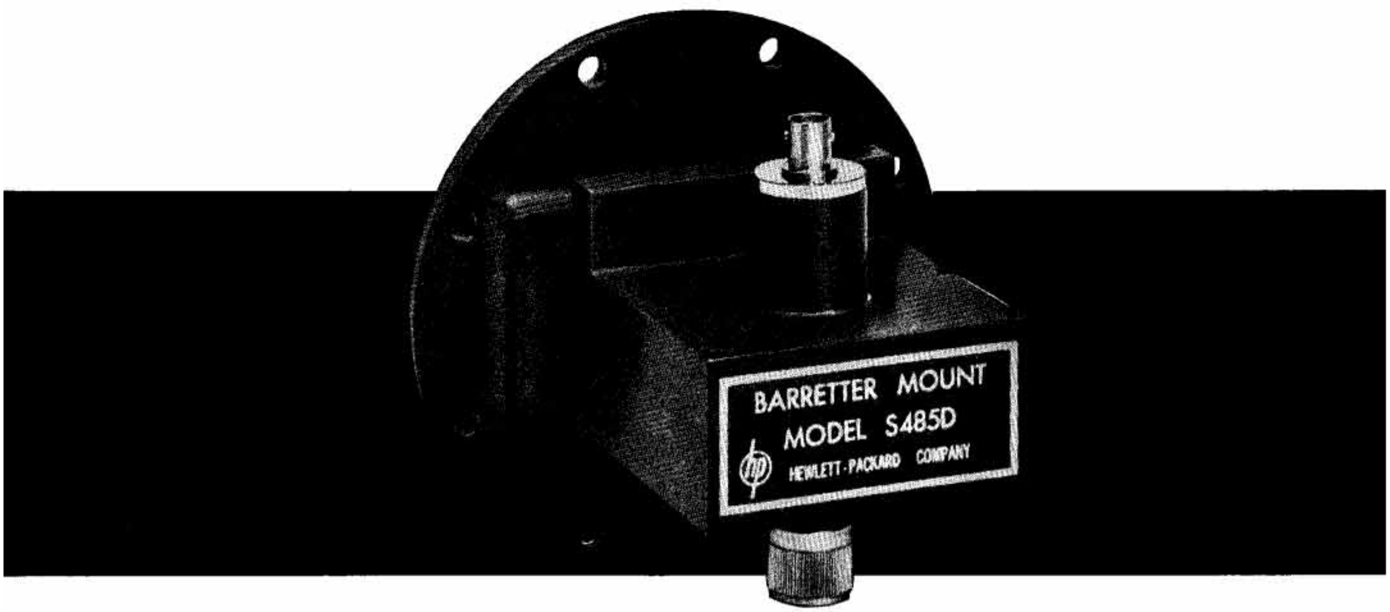
Maximum Power: 10 milliwatts.

Bolometer Element: Four 1/100 ampere instrument fuses, specially selected and treated. (hp G-28B.)

Accessories Available: AC-16F rf Cable Assembly, $12.00; AC-16K Video Cable Assembly, $5.00.

Price: $85.00.

Data subject to change without notice.



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 KMC, is offered in the S band range only. This instrument uses a Sperry 821 or Narda N821 barretter and requires no tuning. SWR is less than 1.35 over the entire waveguide band.

-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 Sperry 821 or Narda N821 barretter. Or, for maximum sensitivity a 1N21 or a 1N23 silicon crystal may be used. Detector elements can be quickly interchanged.

-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 0.02 v/0.1 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. *-hp-* AC-60K Barretter Matching Transformer is required to interconnect the 485D with *-hp-* 416A Ratio Meter (pages 144, 145).

All models have BNC output connectors mating with UG88/U plugs.

Specifications

Model	Maximum SWR	Frequency Range KMC	Fits Waveguide Size (In.)	Length (In.)	Price
S485A	1.35	2.60 - 3.95	3 x 1½	4⅝	$140
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	5.20 - 5.50			
H485B	1.25	7.05 - 10.0	1¼ x ⅝	5⅞	$ 85
X485B	1.25	8.20 - 12.4	1 x ½	5⅞	$ 75
S485D	1.35	2.60 - 3.95	3 x 1½	4½	$170
G485D	1.5	3.95 - 5.85	2 x 1	3⅛	$170
J485D	1.5*	5.20 - 8.20	1½ x ¾	4¼	$170

All mounts accept either barretter or crystal except *-hp-* S485A, which employs barretter only.

*From 5.2 to 7.5 KMC. Increases to approximately 2.0 at 8.2 KMC.

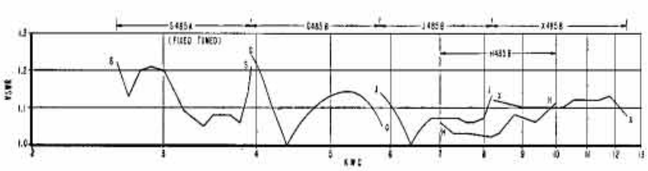
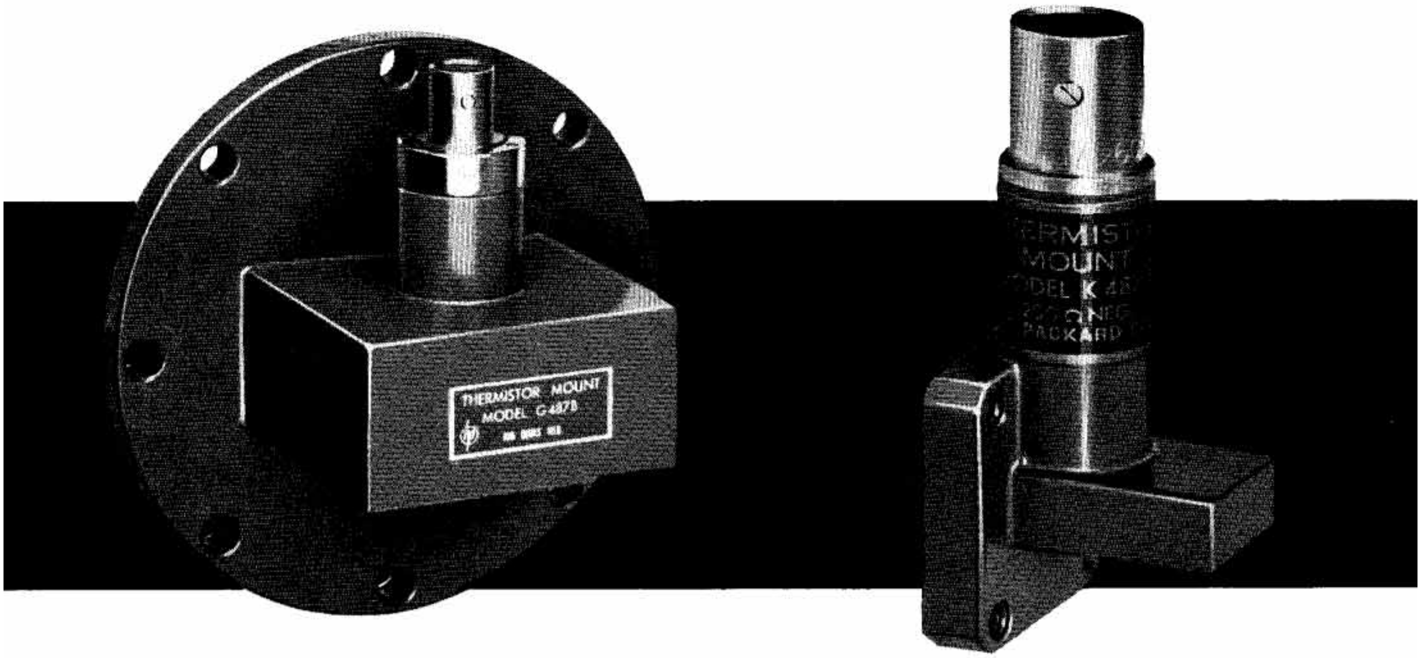


Figure 1. Typical SWR vs. Frequency, *-hp-* 485, when used with barretter.

Data subject to change without notice.

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 40.0 KMC.

Each 487 series mount covers the full frequency range of its waveguide band and requires no tuning. The long time constant of the mount makes it ideal for measuring average power of low duty cycle pulses. Since thermistors have inherent overload protection, and since the majority of power is reflected during overload conditions, burnouts are virtually impossible.

Model 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 136 and 137), or other instruments responsive to negative temperature coefficient bolometers operating at the 100 or 200 ohm level.

Specifications

Model	Maximum Power	Maximum SWR	Frequency Range (KMC)	Fits 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
P487B	10 mw	1.5	12.4 - 18.0	0.702 x 0.391	110.00
K487B	10 mw	2.0	18.0 - 26.5	½ x ¼	150.00
R487B	10 mw	2.0	26.5 - 40.0	0.360 x 0.220	225.00

Thermistor: Permanently installed 100-ohm negative coefficient thermistor. (K487B and R487B use 200-ohm thermistors.)

Thermistor Time Constant: Approximately 1 second when cooling on an open circuit.

Accessories Available: AC-16K Cable Assembly, $5.00.

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 determines 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.

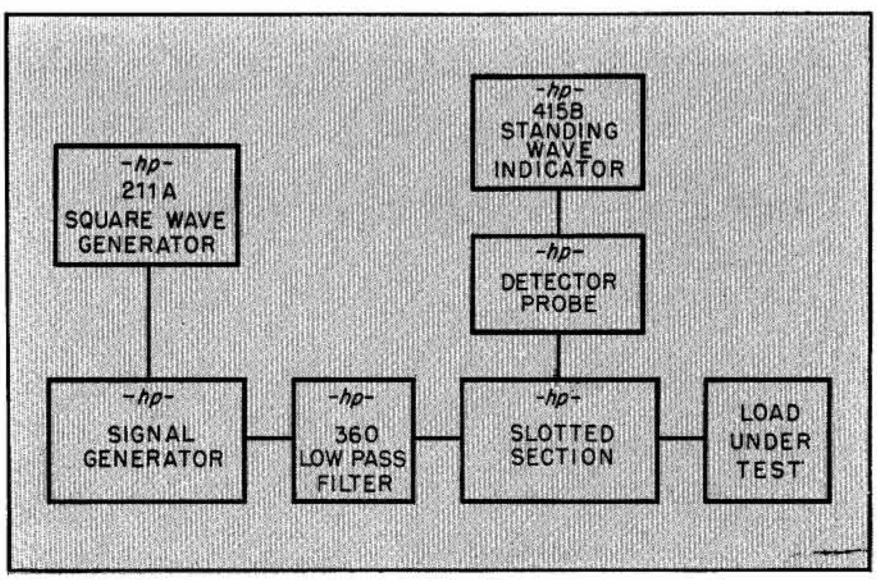


Figure 1. Typical setup for impedance measurements.

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 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 98-101). 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.

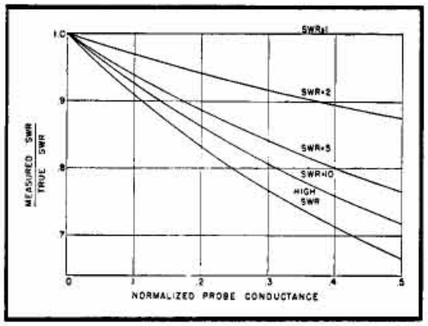


Figure 2. Effect of probe penetration on measured SWR.

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.

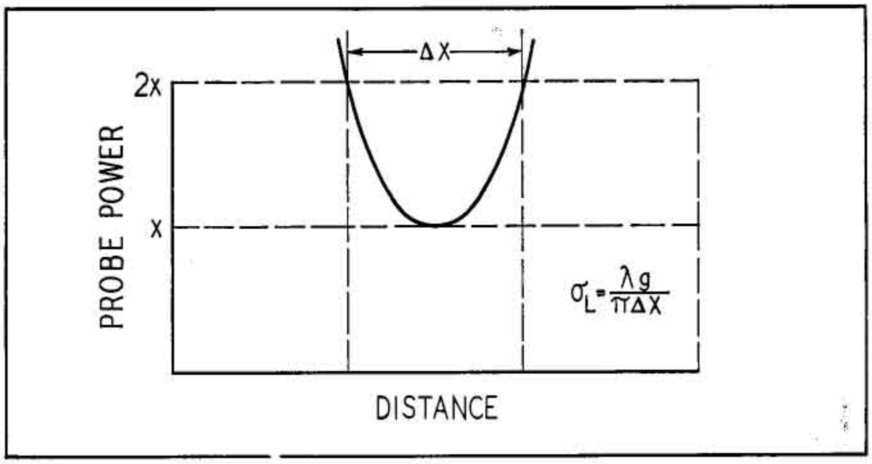


Figure 3. Twice minimum power method for measuring SWR.

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,

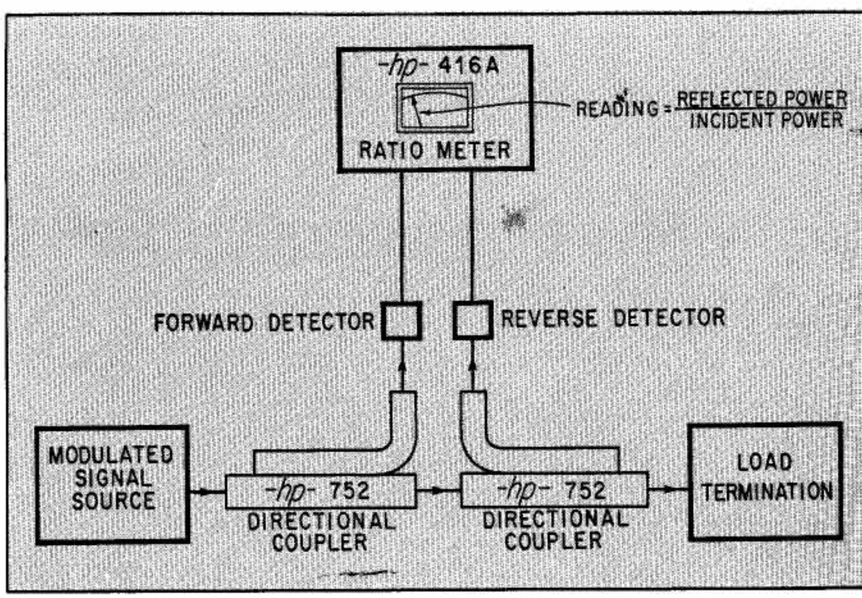


Figure 4. Typical Reflectometer setup.

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, pages 144, 145) 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.

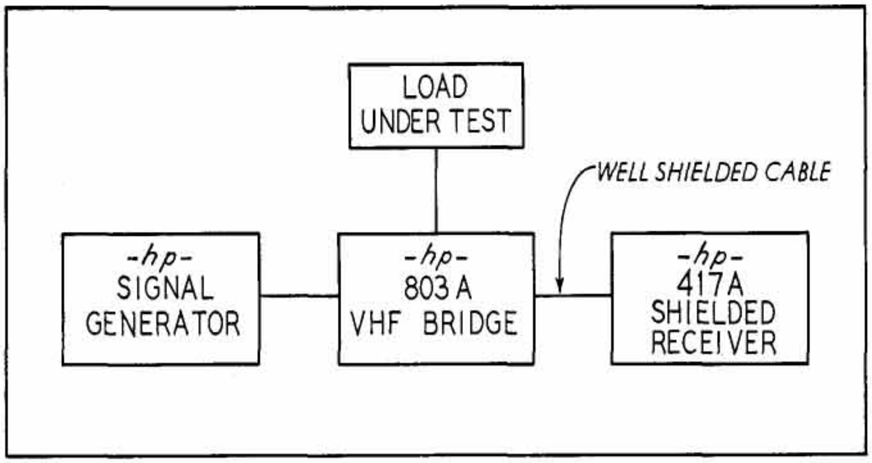


Figure 5. Impedance measurements for frequencies below 500 MC.

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.

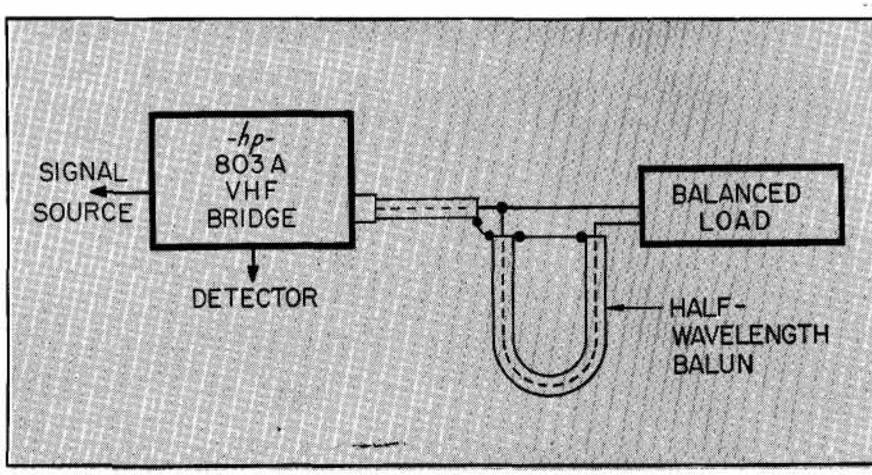


Figure 6. Measurement setup using balun with balanced load.

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-* 683A-687A Electronic Sweep Oscillators, pages 116, 117), 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.

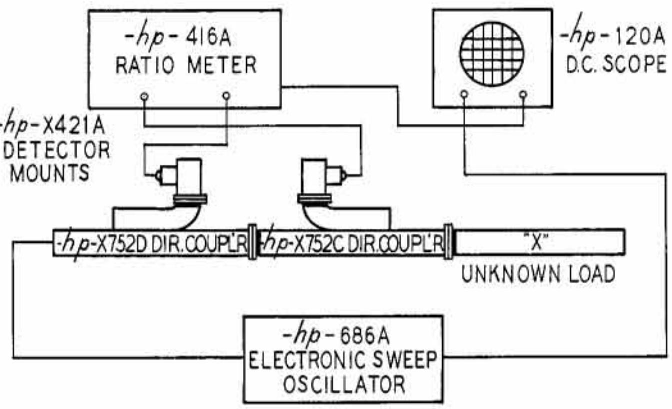


Figure 1. Typical Reflectometer Setup. Note use of two directional couplers back-to-back, with individual detectors, for simultaneous evaluation of incident and reflected powers.

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*- 916 (see page 160) 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 157) 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: 3.0 μv to 100 mv rms for full scale deflection. (Square or sine-wave.)

Input Impedance: Approximately 75 K ohms, both channels.

"Excess Coupler Loss": Includes provision for increasing sensitivity of Incident Channel by 10 db for reflectometer setups employing couplers with different coefficients.

Output: Connectors for oscilloscope and high impedance recorder.

Adjustments: "Set to Full Scale" control for initial calibration with 100% reflection, or at SWR peak.

Internal Check: "Eye" tube continuously monitors input amplitude (and frequency indirectly) to assure proper operating range for instrument and crystal detectors.

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

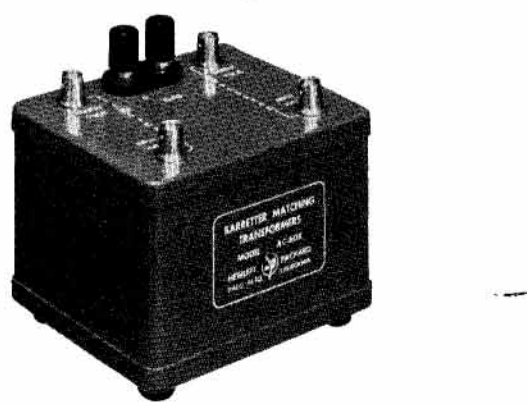
Dimensions: Cabinet Mount: 20½" wide, 12½" high, 14½" deep. Rack Mount: 19" wide, 10½" high, 14½" deep.

Weight: Net 36 lbs. Shipping 47 lbs. (cabinet mount). Net 28 lbs. Shipping 41 lbs. (rack mount).

Accessories Available: AC-16K Video Cable Assembly, $5.00. AC-60K Barretter Matching Transformer, $80.00.

Price: $475.00 (cabinet); $460.00 (rack mount).

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 matches 200 ohm barretters such as Sperry 821 or Narda N821B. An 8.75 ma bias is supplied from the 416A Ratio Meter. The AC-60K measures 4¾" x 4", and is 3½" high. Weight is 2 lbs. The instrument is supplied with three cable assemblies for connection to -*hp*- 416A. $80.00.

Data subject to change without notice.

803A VHF BRIDGE

Advantages:

Direct reading,
- 2 to 2,000 ohm impedances
- $-90°$ to $+90°$ phase angle

Wide range, 52 to 500 megacycles

Simple, easy operation

Faster than slotted lines

Compact size

Standard Type N connector

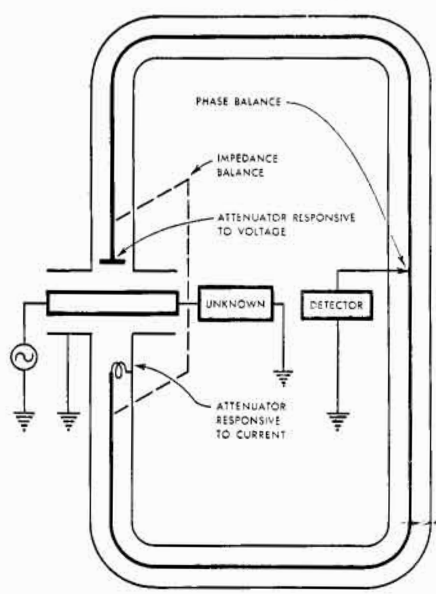
Uses:

Determines characteristics of:
- Antennas
- Transmission lines
- Rf chokes
- Resistors
- Condensers

Measures:
- Connector impedances
- Standing wave ratios
- % reflected power
- Vhf system flatness

Reads Any Impedance Directly Between 52 and 500 MC

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 $-8.8°$ to $+8.8°$.

External rf Generator: Requires an AM signal source of at least 1 mw. High signal level is desirable. (*-hp-* Model 608C vhf Signal Generator 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.)

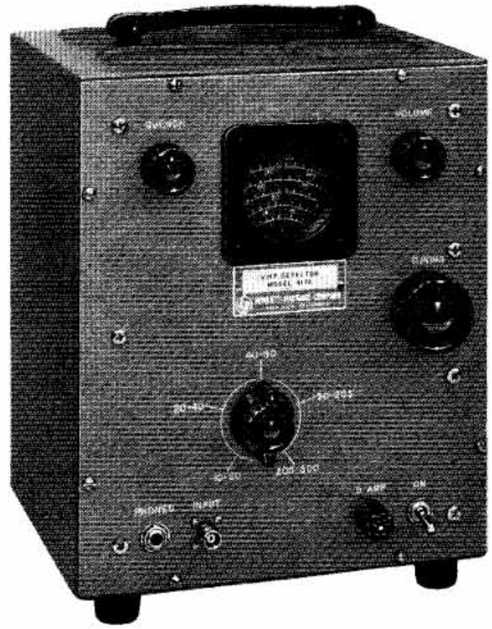
Dimensions: Cabinet Mount: 14¼" wide, 15¼" high, 9" deep.

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: $800.00.

-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: 115/230 v $\pm 10\%$, 50/60 cps, 35 watts.

Dimensions: Cabinet Mount: 9¼" wide, 12½" high, 9" deep.

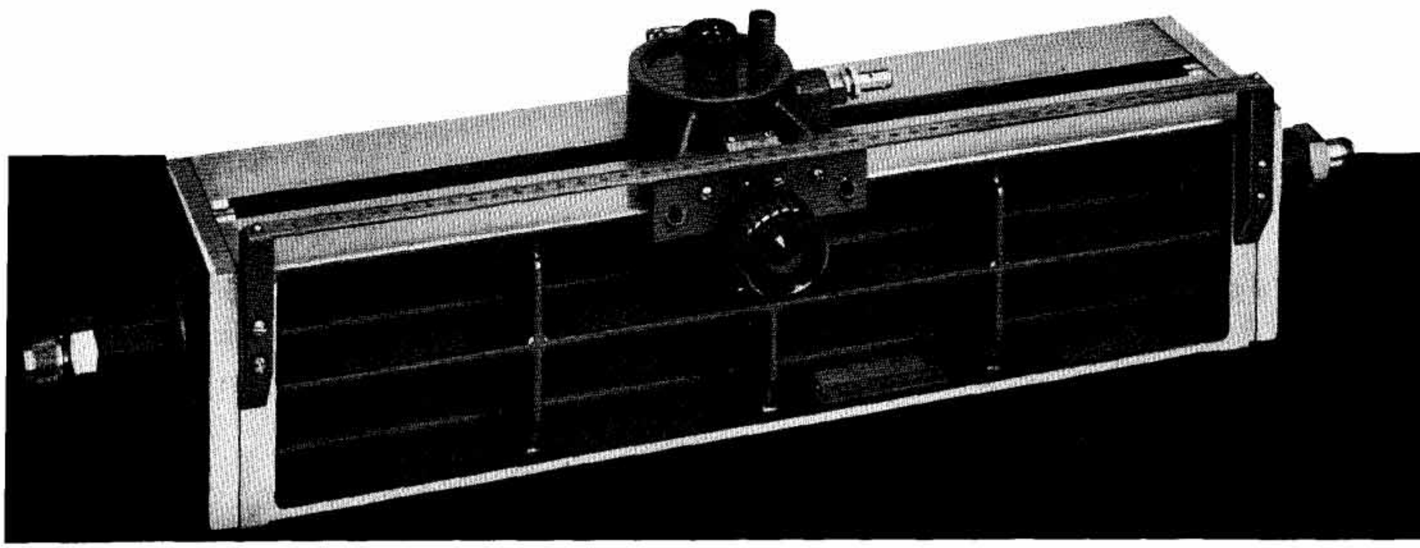
Weight: Net 18 lbs. Shipping 31 lbs.

Accessories Available: AC-16B Cable Assembly, $5.00; AC-16K Cable Assembly, $5.00; 803A-16E Input Cable Assembly, $8.75.

Price: $350.00.

Data subject to change without notice.

805A/B SLOTTED LINES



Specifications

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.

Weight: Net 18 lbs. Shipping 30 lbs.

Accessories Furnished: 1 803A-76G shorting plug; 1 8A-76H shorting jack.

Accessories Available: AC-16F rf Cable Assembly, $7.50; 475B-34V Barretter Adapter, $1.50; AC-16K Cable Assembly, $5.00. 8A-45 Carrying case 29" wide, 9½" high, 9½" deep, $25.00.

Price: $450.00.

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.

Accessories Furnished: 1 8B-76G shorting plug.

Accessories Available: 8B-76H shorting jack, $4.50; AC-16K; 475B-34V; 8A-45, as described above.

Price: $450.00.

(Other specifications same as -*hp*- 805A)

Data subject to change without notice.

"Parallel-Plane" Design Gives Utmost Electrical Stability

THE 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 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.

415B STANDING WAVE INDICATOR

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.

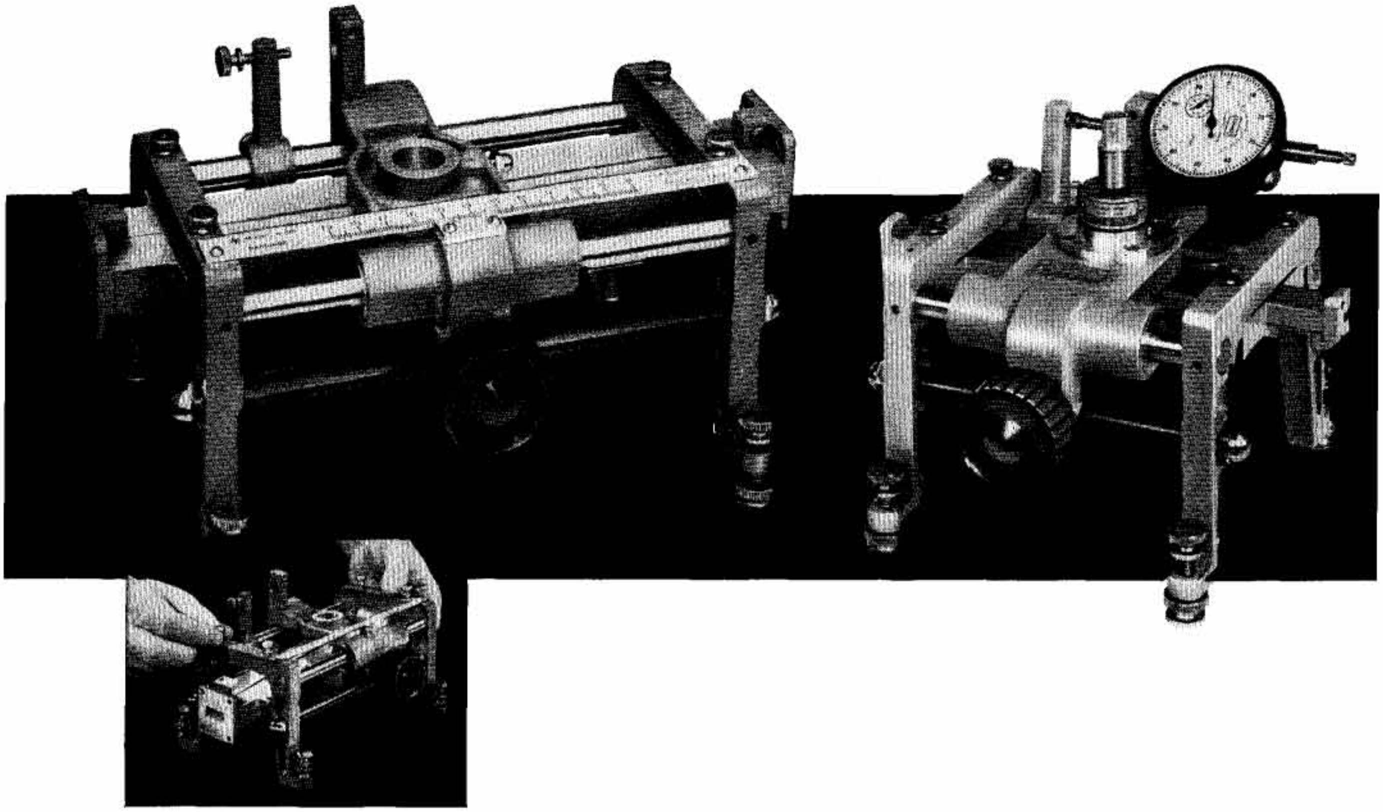
The instrument is normally supplied for operation at 1,000 cps. However, on special order it is available equipped for operation at any filter frequency from 315 to 2,020 cps. (should not be harmonically related to power line frequency). Units for converting the 415B to operation at any frequency in the above range can be obtained at nominal charge and installed in the field.

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 μv ref. to input operated from a 200 ohm resistor.
Amplifier Q: 25 ±5.
Calibration: Square law. Meter reads SWR, db.
Range: 70 db. Input attenuator provides 60 db in 10 db steps. Accuracy ±0.1 db per 10 db step. Cumulative error ±0.2 db max.
Scale Selector: "Normal," "Expand," and "−5 db."
Meter Scales: SWR: 1–4; SWR: 3–10; Expanded SWR: 1–1.3; db: 0–10; Expanded db: 0–2.
Gain Control: Adjusts to convenient reference level. Range at least 10 db.
Input: "Bolo" (200 ohms). Bias provided for 8.4 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.
Power: 115/230 v ±10%, 60 cps (50 cps model available on request), 55 watts.
Dimensions: Cabinet Mount: 7½" wide, 11½" high, 12¼" deep. Rack Mount: 19" wide, 7" high, 11" deep.
Weight: Net 13 lbs. Shipping 21 lbs. (cabinet mount). Net 18 lbs. Shipping 30 lbs. (rack mount).
Accessories Furnished: 1 41A-16E Cable Assembly.
Accessories Available: 415B-42B Plug In Filter (315-700 cps, $45.00; 700-2020 cps, $32.00). AC-16K Video Cable Assembly, $5.00. AC-16D Cable Assembly, $2.65.
Price: $200.00 (cabinet); $205.00 (rack).

Data subject to change without notice.

hp 809B/814B 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 814B Universal Probe Carriages are precision-built mechanical assemblies designed to operate, respectively, with hp 810B series and 815B series slotted sections. The combination of 809B Carriage and 810B series sections covers 3.95 to 18.0 KMC. Model 814B Carriage and 815B series sections cover 18.0 to 40.0 KMC.

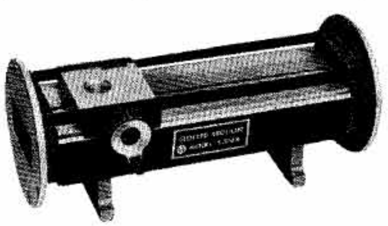
These Universal Probe Carriages greatly simplify measurements involving a number of waveguide bands, and eliminate the cost of a special probe for each band. There is an appreciable saving on engineering time since waveguide sections can be interchanged in seconds. Manufacture of both carriages is of highest quality throughout to assure maintenance-free service, positive mechanical positioning of interchangeable waveguides, and precise installation of the mating hp probes *(see page 152)*. hp 809B has a vernier scale permitting readings to 0.1 mm and provision for mounting a dial gauge for greater accuracy. hp 814B has a dial indicator which may be read directly to 0.01 mm.

hp 810B Waveguide Slotted Sections (for 809B) are accurately machined sections of waveguide in which a small

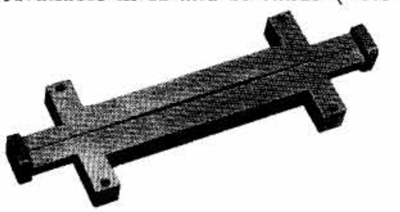
longitudinal slot is cut. They fit the 809B Carriage in a precisely indexed position. A traveling probe mounted on the 809B samples the waveguide's electric field along the slot, and permits precise plotting of variations throughout the length of probe travel. Slotted sections are accurately machined 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.

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.

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 Broadband Probes and Detector Mounts shown on page 152.



815B Waveguide Slotted Sections (for 814B). Available in K and R bands (18.0 to 40.0 KMC), these waveguide slotted sections are carefully machined for timesaving accuracy in measurement.



Specifications

809B Universal Probe Carriage

Carriage: Mounts all 810B Waveguide Slotted Sections and 806B Coaxial Slotted Section.

Probe Required: 442B Broadband Probe in combination with 440A Detector or 444A Untuned Probe (see page 152).

Probe Travel: 10 centimeters.

Calibration: Metric. Vernier permits readings to 0.1 mm. Provision for dial gauge installation.

Accuracy: When used with waveguide sections, SWR of 1.02 can be easily read. Slope error of slotted sections may be eliminated by adjustment.

Dimensions: 8″ long, 6¼″ wide, 5″ high.

Price: $160.00.

S810A Waveguide Slotted Section

Conventional waveguide slotted section with probe carriage mounted directly on waveguide. Will accept 442B or 444A Probes.

Frequency Range: 2.6 to 3.95 KMC.

Waveguide Size: 3″ x 1½″.

Length: 12¾″.

Price: $450.00.

806B Coaxial Slotted Section

Carriage: Fits 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.

814B Universal Probe Carriage

Carriage: Mounts all 815B Waveguide Slotted Sections.

Probe Required: 446B Untuned Probe *(see page 152)*.

Probe Travel: 4 centimeters.

Calibration: Metric. Dial indicator reads direct to 0.01 mm.

Accuracy: SWR of 1.02 can be read.

Dimensions: 6¼″ long, 6¼″ wide, 6¼″ high.

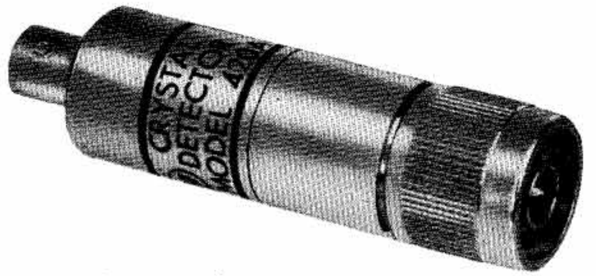
Price: $200.00.

810B/815B Slotted Sections

Model	Frequency Range KMC	Fits Waveguide Size (in.)	Overall Length (in.)	Price
G810B	3.95 - 5.85	2 x 1	10¼	$110.00
J810B	5.20 - 8.20	1½ x ¾	10¼	110.00
H810B	7.05 - 10.0	1¼ x ⅝	10¼	110.00
X810B	8.20 - 12.4	1 x ½	10¼	90.00
P810B	12.4 - 18.0	.702 x .391	10¼	110.00
K815B	18.0 - 26.5	.500 x .250	4½	265.00
R815B	26.5 - 40.0	.360 x .220	4½	265.00

Discontinuity due to slot results in SWR of less than 1.01.

Data subject to change without notice.



420A/B Crystal Detectors

-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 0.01 v/0.1 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, similar to 420A, but having a selected video load, is available in matched pairs whose frequency response difference is within ±1 db from 1 to 4 KMC. *-hp-* 420A, $50.00; *-hp-* 420B, $150.00 per pair.

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 0.01 v/0.1 mw, 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. *-hp-* H421A, $95.00; *-hp-* X421A, $75.00; *-hp-* P421A, $105.00.

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. Price (matched pairs): H421A, $210.00; P421A, $230.00; X421A, $170.00.

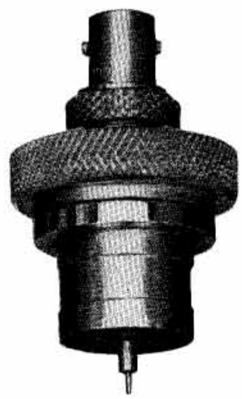
440A Detector Mount

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.

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, the 442B forms a sensitive detector for slotted waveguides sections. Probe is shielded and provided with poly-iron inserts to prevent spurious resonances. $40.00.

444A Untuned Probe

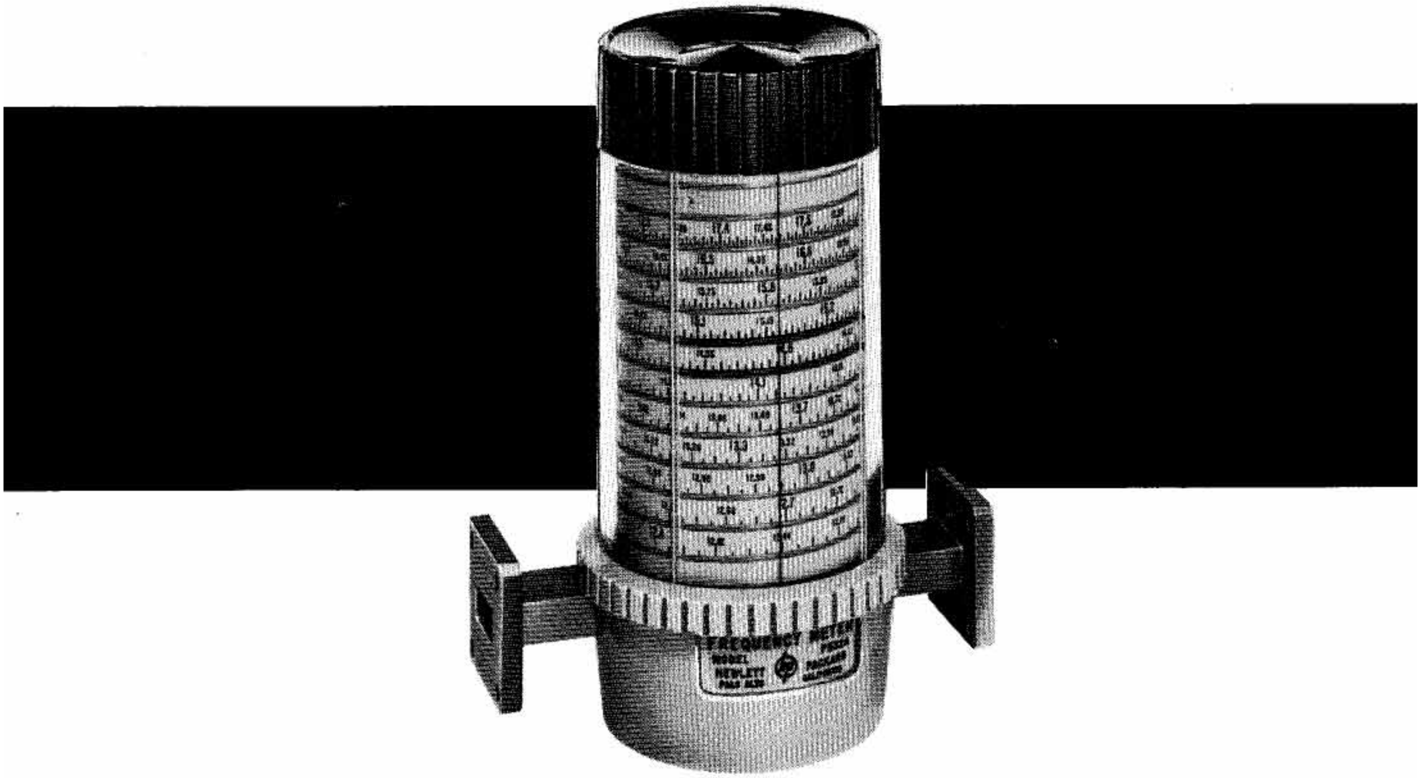


A modified crystal (1N76 or 1N26) plus a small antenna in a convenient housing permitting probe penetration to be varied quickly and easily. Probe position is fixed by a locking ring. Requires no tuning; and sensitivity surpasses most elaborate single and double-tuned probes (particularly between 8 and 18 KMC). Poly-iron inserts damp spurious resonances. Frequency coverage 3 to 18 KMC; BNC output jack. For ¾″ mounting hole as on *-hp-* 809B Carriage (page 150). $40.00.

446B Untuned Probe

New Model 446B is a broadband detector and probe designed for use with *-hp-* 814B Universal Probe Carriage and *-hp-* 815B Waveguide Slotted Sections. *(See pages 150, 151.)* It covers K and R band frequencies, 18.0 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 532A Frequency Meters are wide band, direct reading instruments offering quality construction, convenience and outstanding value at low cost. Frequency is read directly in KMC with high accuracy as indicated on the adjoining table. 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 dip in output indicates resonance. Tuning is by a precision lead screw, spring-loaded to eliminate backlash. Readability is enhanced by a long, effective spiral scale length and a scale calibrated in small frequency increments. For example, Model X532A has an effective scale length of 77″ and is calibrated in 5 MC increments. Resetability is 0.01% (1 MC at 10 KMC).

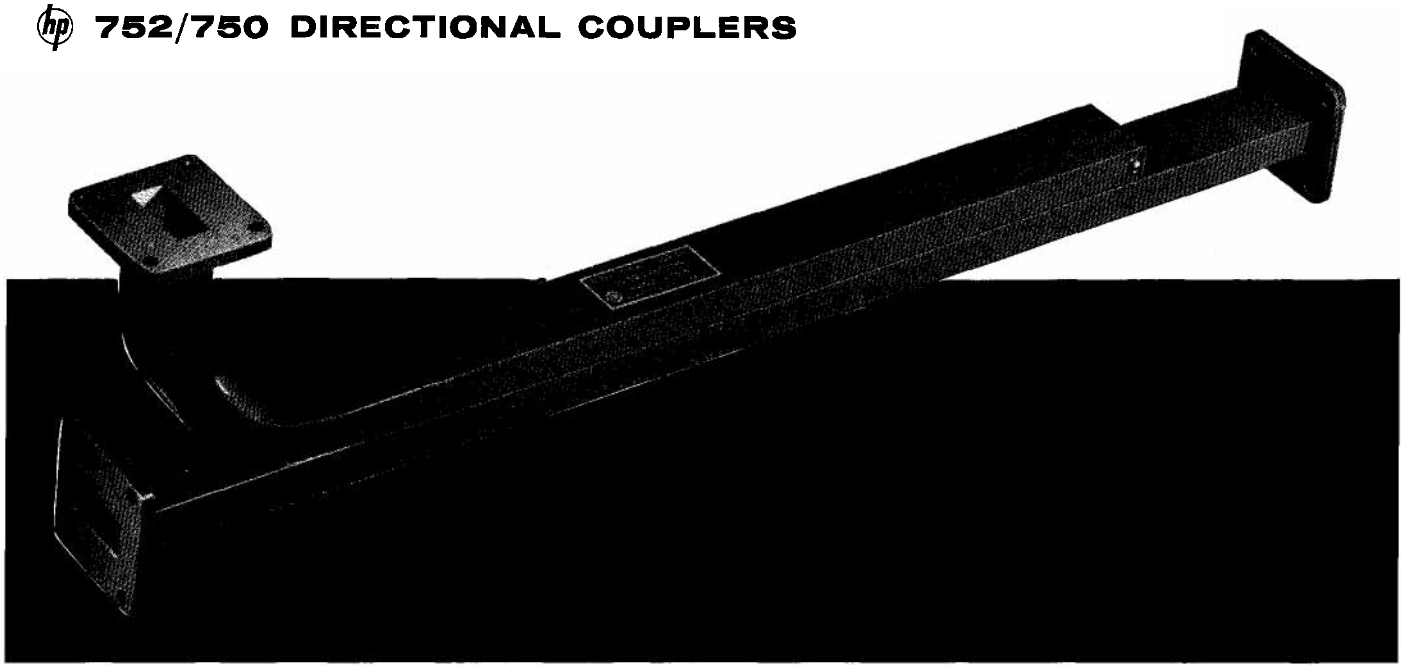
Model 532A Frequency Meters are supplied for H, X, P, K and R bands, covering frequencies 7 to 40.0 KMC. For J band work (5.2 to 8.2 KMC), Model 530 Frequency Meter (not direct reading) is supplied *(see table)*. Model 530 is tuned by a micrometer unit, and readings are quickly converted to frequency by a calibration chart on the instrument.

Specifications

Model	Accuracy	Frequency Range KMC	Fits 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
H532A	0.1%	7.05 - 10.0	1¼ x ⅝	6¼	195.00
X532A	0.08%	8.20 - 12.4	1 x ½	4½	150.00
P532A	0.1%	12.4 - 18.0	.702 x .391	4½	210.00
K532A	0.1%	18.0 - 26.5	½ x ¼	4½	230.00
R532A	0.2%	26.5 - 40.0	.360 x .220	4½	250.00

Other specifications, Models 532A: Resetability 0.01%, backlash 0.005%, SWR at resonance 1.3:1 approximately, dip at resonance 1 db or more.

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."

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.

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.

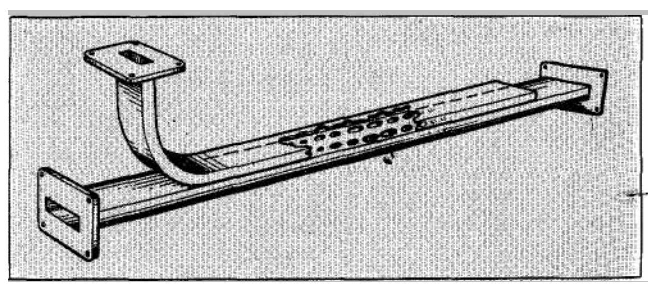


Figure 1. Construction, -*hp*- 752 Directional Couplers.

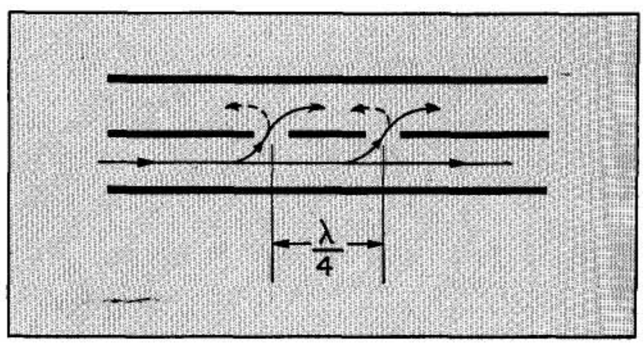
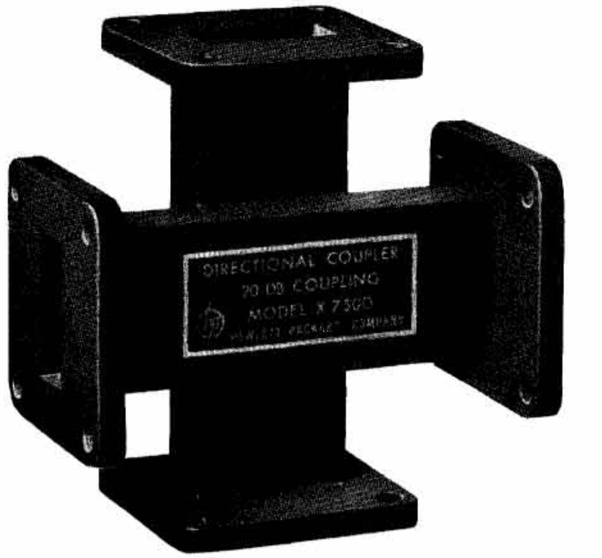


Figure 2. Cross-section, two-aperture coupler.

-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 141-143 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 inex-

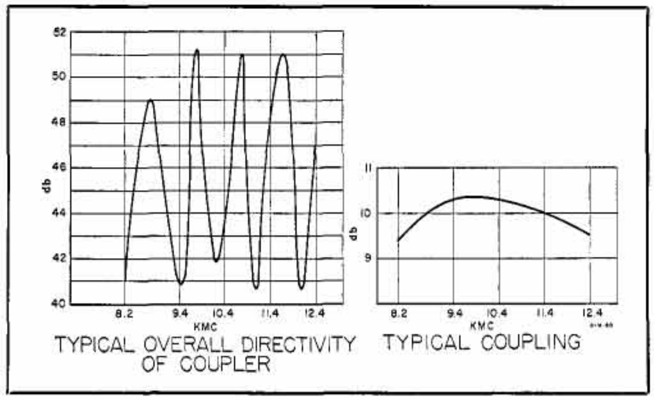


Figure 3. Characteristics, *-hp-* 752 Coupler - 10 db model.

pensive 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.

Specifications

-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	$150.00
S750E	30	2.6 - 3.95	3 x 1½	9 x 9	18	150.00
G750D	20	3.95 - 5.85	2 x 1	6 x 6	7	120.00
G750E	30	3.95 - 5.85	2 x 1	6 x 6	7	120.00
J750D	20	*5.85 - 8.20	1½ x ¾	5 x 5	4	80.00
J750E	30	*5.85 - 8.20	1½ x ¾	5 x 5	4	80.00
H750D	20	7.05 - 10.0	1¼ x ⅝	4 x 4	3	70.00
H750E	30	7.05 - 10.0	1¼ x ⅝	4 x 4	3	70.00
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.

-hp- 752 Multi-Hole Couplers

Band[1] (Prefix)	Frequency KMC	Fits Waveguide Size (in.)	Mean Coupling Accuracy (db) 2, 3	SWR Main Guide 752A	SWR Main Guide 752C/D	Average Power Aux. Guide Load (w)	Length (in.) A	Length (in.) C	Length (in.) D	Shipping Weight (lbs.)	Price
S	2.6 - 3.95	3 x 1½	±0.4	1.1	1.05	2	50¼	48	48	40	$375.00
G	3.95 - 5.85	2 x 1	±0.4	1.1	1.05	2	34⅝	33	33	19	250.00
J*	5.85 - 8.2	1½ x ¾	±0.4	1.1	1.05	1	26½	25 9/16	25 9/16	16	140.00
H	7.05 - 10	1¼ x ⅝	±0.4	1.1	1.05	1	18⅝	17½	17½	5	120.00
X	8.2 - 12.4	1 x ½	±0.4	1.1	1.05	1	16 11/16	15 11/16	15 11/16	4	100.00
P	12.5 - 18.0	.702 x .391	±0.4	1.1	1.05	1	13¾	12¼	12¼	3	115.00
K‡	18.0 - 26.5	.500 x .250	±0.7	1.1	1.05	½	10⅜	9 15/16	9 15/16	3	175.00
R‡	26.4 - 40.0	.360 x .220	±0.7	1.1	1.05	½	11⅝	8⅝	7⅝	2	200.00

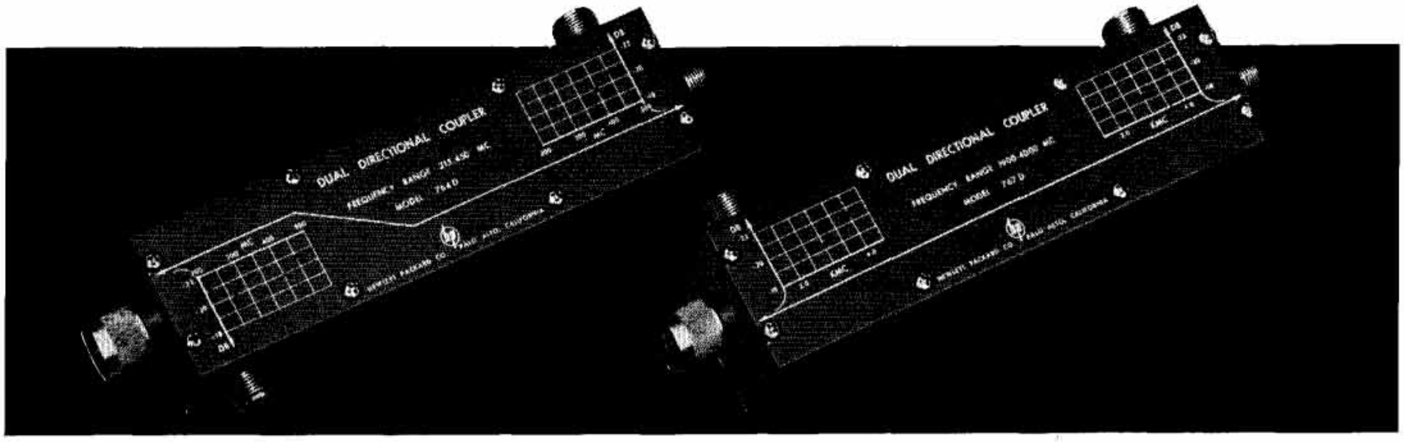
1. When ordering, specify suffix letter to indicate nominal coupling: A for 3 db, C for 10 db, D for 20 db. (Example: S-band, 3 db coupling, Model S752A.)
2. Mean coupling is the average of the maximum and minimum coupling values in the rated frequency range.
3. Coupling variation over rated frequency range is not more than ±0.5 db about mean coupling.
4. Directivity is at least 40 db.

* J752 couplers operate to 5.2 KMC with reduced performance.
Directivity: Greater than 40 db, 5.85 to 5.5 KMC; greater than 36 db, 5.5 to 5.2 KMC.
Variation of Coupling from nominal value: not more than —1.2 db at 5.5 KMC, not more than —2 db at 5.2 KMC.

‡ Circular flange model available.

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.

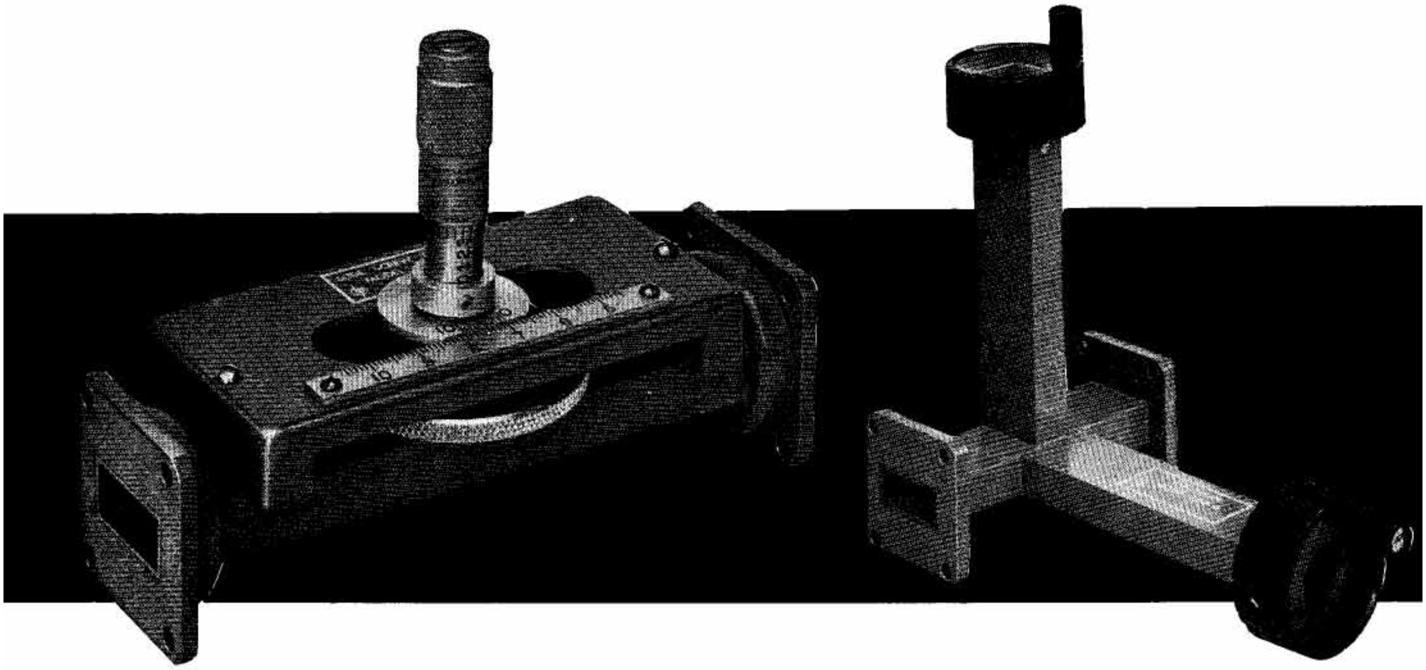
The new couplers have a very flat frequency response and high directivity so that reflectometer accuracy is adequate for system checks and alignment. Their high power handling capacity and low insertion loss means they may be installed permanently in coaxial lines for power monitoring. They are dual 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	$160.00
765D	20 db	450 - 945 MC	1.15	1.20	30 db	±1 db	160.00
766D	20 db	940 - 1975 MC	1.20	1.30	26 db	±1 db	150.00
767D	20 db	1900 - 4000 MC	1.25	1.50	26 db	±1 db	150.00
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.



-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 a reflection which is used to cancel out existing reflection in a system. Probe insertion may be varied by means of a calibrated micrometer screw except on S, K and R870A which employ a micrometer 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.

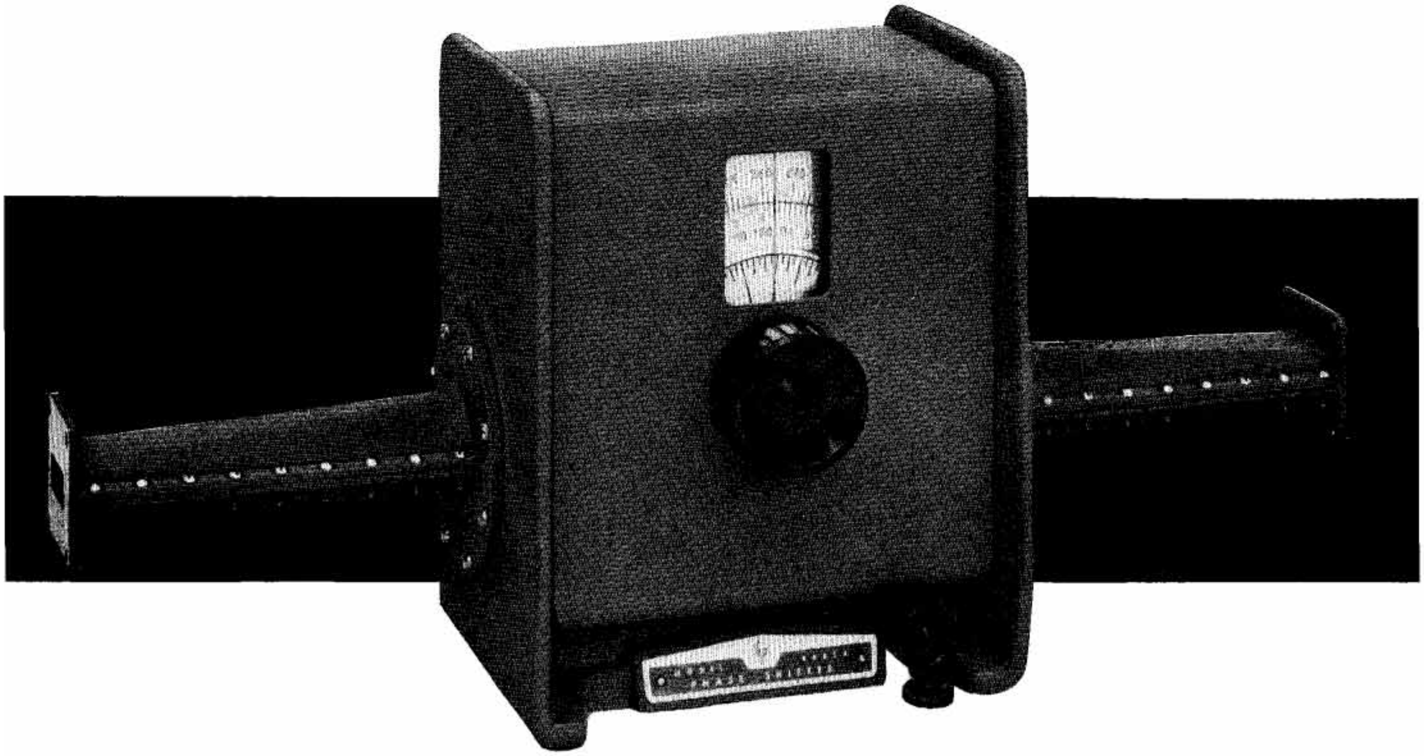
-hp- 880A Tuners consist of a straight section of waveguide to which series and shunt tuning arms are attached. Each arm has a movable short circuit which may be adjusted by a fine tuning control.

Data subject to change without notice.

Specifications

-hp- 870A Slide-Screw Tuner				-hp- 880A E-H Tuner				Frequency Range KMC	Fits Waveguide Size (in.)
Model	Approx. Length (in.)	Shipping Weight (lbs.)	Price	Model	Approx. Length (in.)	Shipping Weight (lbs.)	Price		
S870A	9⅞	15	$225.00	—	—	—	—	2.60 - 3.95	3 x 1½
G870A	8¼	7	185.00	—	—	—	—	3.95 - 5.85	2 x 1
J870A	8⅛	7	150.00	—	—	—	—	5.30 - 8.20	1½ x ¾
H870A	6	4	130.00	—	—	—	—	7.05 - 10.0	1¼ x ⅝
X870A	5½	3	125.00	X880A	3½	3	$130.00	8.20 - 12.4	1 x ½
P870A	5	3	130.00	P880B	2¼	3	150.00	12.4 - 18.0	.702 x .391
K870A	3½	3	250.00	—	—	—	—	18.0 - 26.5	.500 x .250
R870A	2⅞	3	300.00	—	—	—	—	26.5 - 40.0	.360 x .220

885A WAVEGUIDE PHASE SHIFTERS



Precision Phase Variation for J, X and P-Band Systems

HEWLETT-PACKARD 885A Phase Shifters provide accurate, controllable phase variation in the J, X and P-band frequency ranges. They are particularly useful in measurement of transmission, attenuation and impedance in a microwave system, in introducing differential phase shift and in otherwise studying design of microwave systems and antennas. For example, the 885A Phase Shifter can be used to optimize performance of an antenna array, or to vary the directivity characteristics.

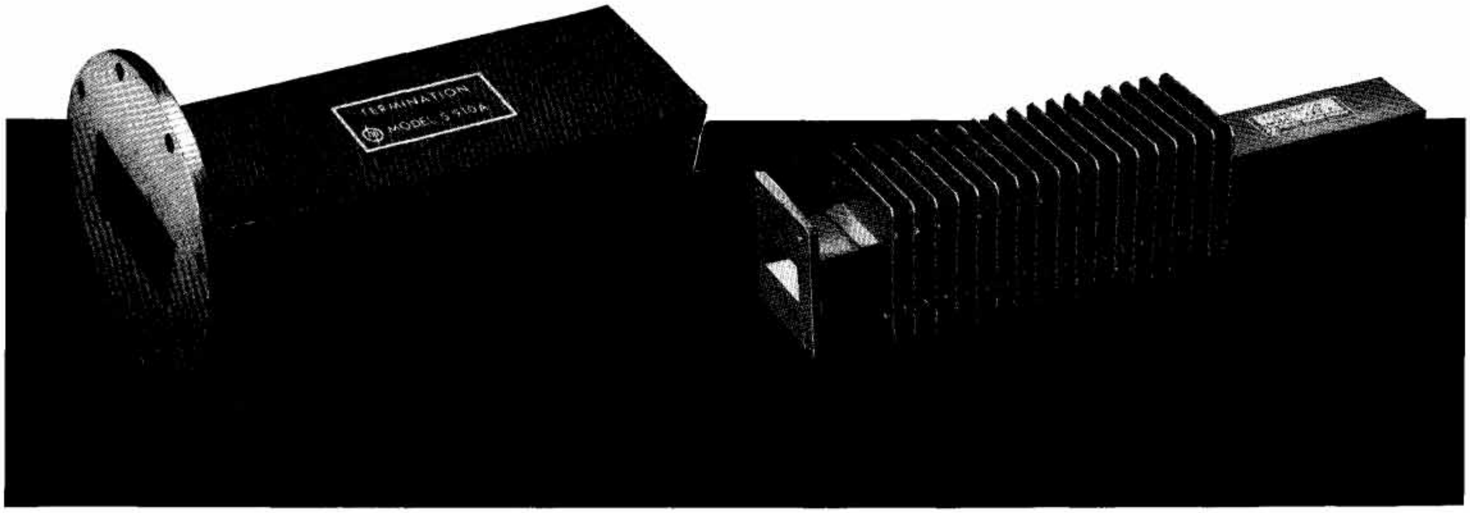
The instrument has a high accuracy over its entire phase range of —360 to +360 electrical degrees, has low power absorption, is simple to operate, and requires no charts or interpolation. It is sturdily built, comprising two rectangular-to-circular waveguide transitions with a dial-driven circular waveguide mid-section. The instrument is housed in a cast-aluminum container for rigidity and durability.

Specifications

Model	Frequency (KMC)	Accuracy	Insertion Loss	Loss Variation with Phase Setting	Max. Average Input Power	Approx. Length	Price
J885A	5.3 - 8.2	3°	2 db max.	0.4 db max.	10 watts	25"	$500.00
X885A	8.2 - 12.4	2° 8.2 - 10 KMC 3° 10 - 12.4 KMC	2 db max.	0.4 db max.	10 watts	15½"	400.00
P885A	12.4 - 18.0	4°	3 db max.	0.5 db max.	5 watts	12¼"	550.00

All models. SWR (maximum): 1.35. Accuracy (phase difference <30°): 10%. Power handling capacity: Approximately 10 watts.

Data subject to change without notice.



hp 910A/B Low Power Termination

Model 910A is designed for terminating waveguide systems operating at average powers of about 1 watt. The terminations are carefully designed to absorb virtually all of the applied power and assure a low SWR. They may be used wherever a matched load is required, as in the measurements of reflection, discontinuities or obstacles in waveguide systems. They are also for use with directional couplers or hybrid tees.

hp 912A High Power Termination

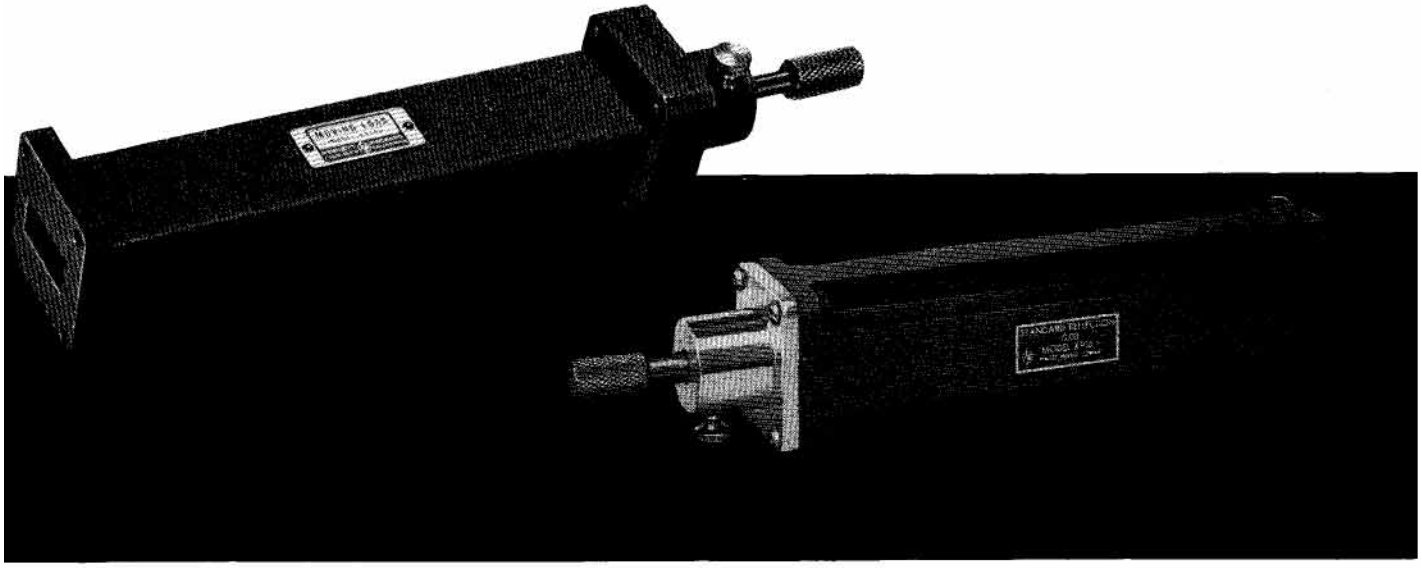
This termination is similar to Model 910A but is designed for waveguide systems operating at high powers. Since these terminations readily absorb large amounts of power, they are useful as dummy loads in testing vacuum tube characteristics, transmitter output, etc. Model 912A Terminations contain a high 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	Fits 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	$60.00	S912A	1.1	100	100	15¼	$200.00	2.60 - 3.95	3 x 1½
G910A	1.06	1	6⅝	50.00							3.95 - 5.85	2 x 1
J910A	1.02	1	8 3/16	35.00							5.30 - 8.20	1½ x ¾
H910A	1.02	1	5⅝	30.00							7.05 - 10.0	1¼ x ⅝
X910B	1.02	1	6⅞	25.00	X912A	1.1	50	50	8¼	75.00	8.20 - 12.4	1 x ½
P910A	1.02	½	4¼	30.00							12.4 - 18.0	.702 x .391

Data subject to change without notice.

WAVEGUIDE LOADS



914A/B Moving Loads

Model 914 Moving Load consists of a section of waveguide in which is mounted a sliding, tapered, low-reflection load. A plunger controls the position of the load which is variable at least ½ wavelength at the lowest waveguide frequency. This permits reversing the phase of the residual reflection so that this reflection can be separated from the other small reflections in the waveguide system.

In Model 914A the reflection of the load is less than 0.5% (1% for K and R bands) over the full frequency range of the waveguide. The X914B, K914B, R914B are similar to the 916 series.

Specifications

Model	Frequency Range KMC	Fits 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
X914B	8.20 - 12.4	1 x ½	8¼	3	50.00
P914A	12.4 - 18.0	.702 x .391	8	1	55.00
K914B	18.0 - 26.5	.500 x .250	6½	1	250.00
R914B	26.5 - 40.0	.360 x .220	5¼	1	250.00

916 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 0.05 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

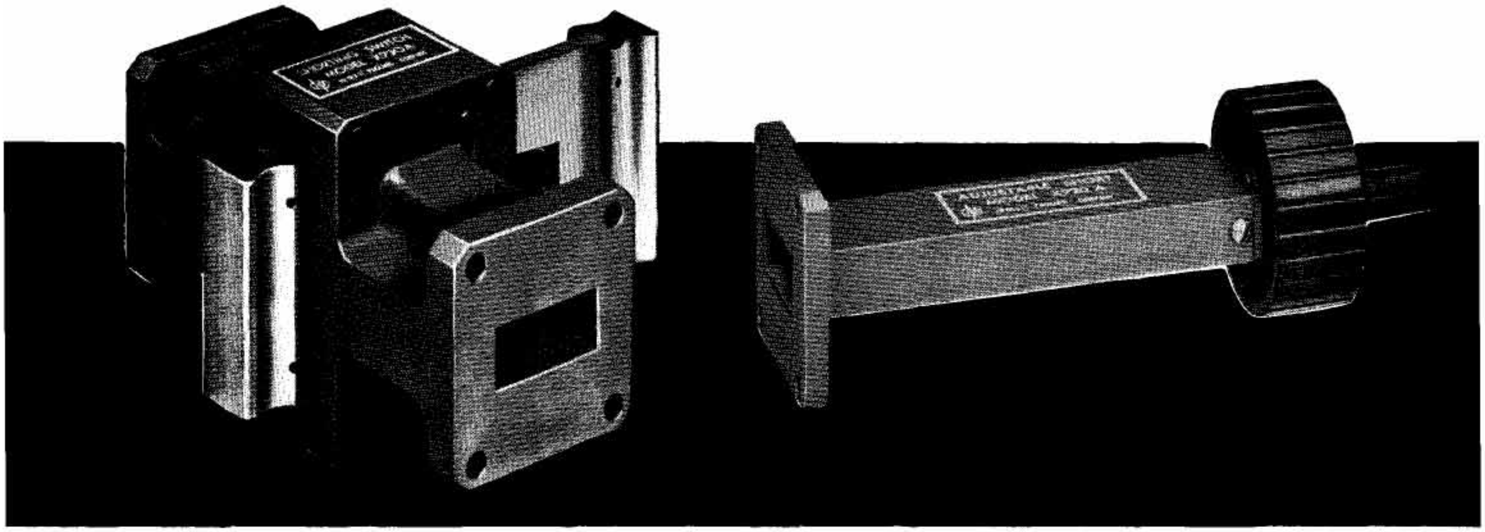
Model*	Nominal Reflection Coefficient	Accuracy (Reflection Coefficient)	Price
X916B	0.05	±0.0025	$100.00
X916C	0.10	±0.0035	100.00
X916D	0.15	±0.0045	100.00
X916E	0.20	±0.007	100.00

*X916A is replaced by the X914B (see table opposite).

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.

WAVEGUIDE SHORTS



X930A Shorting Switches

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: $100.00.

Data subject to change without notice.

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 containing a movable low loss contacting finger wiper.* Position of the short is varied by a fine tuning control.

Specifications

Model	Approx. Length (in.)	Frequency Range KMC	Fits Waveguide Size (in.)	Shipping Weight (lbs.)	Price
S920A	10½	2.60 - 3.95	3 x 1½	10	$150.00
G920A	7½	3.95 - 5.85	2 x 1	4	125.00
J920A	3¼	5.30 - 8.20	1½ x ¾	3	100.00
H920A	3½	7.05 - 10.0	1¼ x ⅝	2	75.00
X920A	4½	8.20 - 12.4	1 x ½	2	75.00
P920B	5½	12.4 - 18.0	.702 x .391	2	75.00
K920A/BC**	4½	18.0 - 26.5	.500 x .250	2	140.00
R920A/BC**	4	26.5 - 40.0	.360 x .220	2	150.00

*In the P, K, and R bands a choke-type short is employed. Position of the choke is varied by a micrometer adjustment. **Suffix "C" in model number indicates also available with circular flanges.

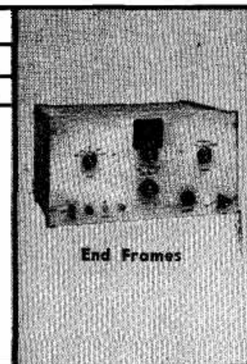
-hp- CABINETS AND MOUNTING METHODS

Most -hp- instruments are available either factory-mounted in -hp- portable cabinets or ready for mounting in standard EIA (RETMA) relay racks.

Extremely light in weight, and equipped with carrying handles, -hp- cabinets are designed for both bench and field use where instrument portability is important. Rugged resistance-welded, all-metal construction insures maximum protection and shielding for the instruments. Sharp sheet-metal edges and corners are eliminated and the clean, business-like appearance of the cabinets reflects the quality of the instrument itself and does credit to any laboratory or test area.

In lieu of regular cabinets, many -hp- instruments may be equipped with -hp- AC-17 End Frames, sturdy frames adapting a rack-mount configuration to bench use and fitted with carrying handles (see photo below). Instruments which will accept AC-17 End Frames are listed in the table immediately below and are the same as those fitting the "205AG" cabinet.

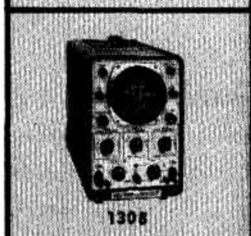
205AG



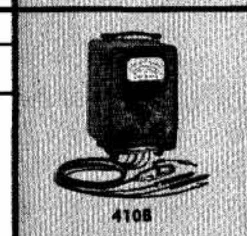
End Frames

Height 12.500" Width 20.500"							
Depth 13.750"			Depth 17.750"				
AC-44A	AC-44C	AC-44D	AC-44G	AC-44H	AC-44J	AC-44E	AC-44F
100D	212A	340B	606A	302A	434A	560A*	684A*
202A/B	520A*	342A				561A*	685A*
205A/AG	624C	522B					686A*
206A							687A*
330B/C/D							
416A							
540A							
650A							
712B							

*Instrument will not fit -hp- AC-17 End Frames.



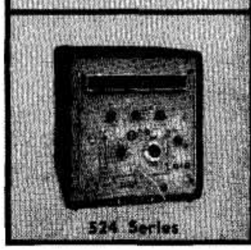
130B



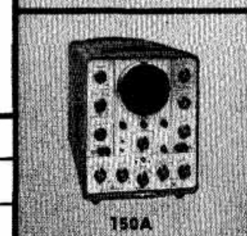
410B

Height 15.000" Width 9.750"	
Depth 13.500"	Depth 20.000"
211A	120A
521A	122A
521C/D	130A/B

Height 11.250" Width 7.500"			
Depth 7.250"	Depth 11.000"	Depth 13.000"	Depth 19.000"
410B	200AB	200CD	490B
412A	201C	200J	491A
	400D	202C	492A
	400H	207A	494A
	400L		
	415B	711A	
	425A	715A	
		428A	
		430C	
		500B/C	



524 Series



150A

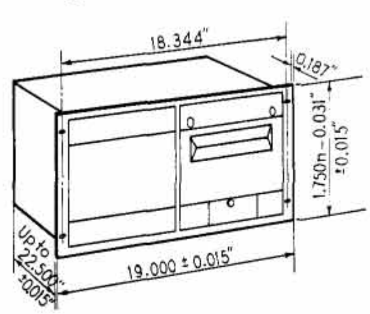
Height 21.250" Width 20.000"	
Depth 22.750"	
524B	524D
524C	

Height 17.000" Width 13.750"			
Depth 19.500"	Depth 20.000"	Depth 21.000"	Depth 24.000"
608C/D	523B	612A	150A

Nominal tolerance on decimal dimensions ±0.015"

EIA* Modular (Rack) Mounting

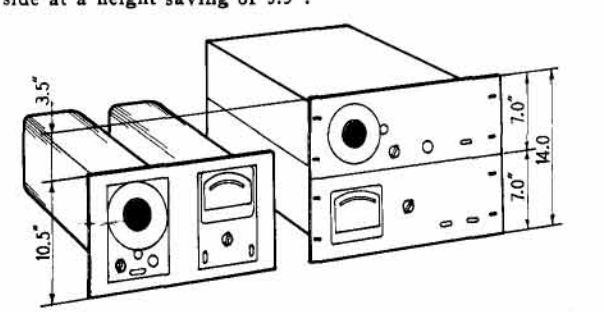
For the user desiring to assemble a composite testing system of some permanence, most -hp- instruments are available in modular, building-block form for rack mounting. Basic dimensions are indicated below. Rack-mounting models are also available with telescoping slides at slight additional cost.



*Electronics Industries Association (formerly RETMA).

-hp- AC-2A/B Dual-Mounting Modular Adapter

-hp- Instruments which are normally supplied with either 7" x 19" control panels (for standard EIA modular mounting) or 9.875" x 7" panels (for small portable cabinets) can also be mounted side-by-side in -hp- AC-2A/B Adapter Panels. These panels measure 10.5" high x 19" wide. Thus instead of the 14" height of two conventional 7" high rack mount instruments, the same two -hp- instruments in "cabinet" configuration can be rack-mounted side by side at a height saving of 3.5".



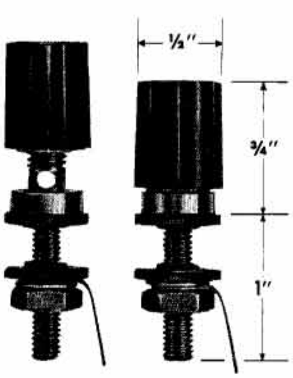
AC-60A/B Line Matching Transformers

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. $45.00.

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 45 KC; maximum level is +15 dbm. Shipping weight 6 lbs. $60.00.

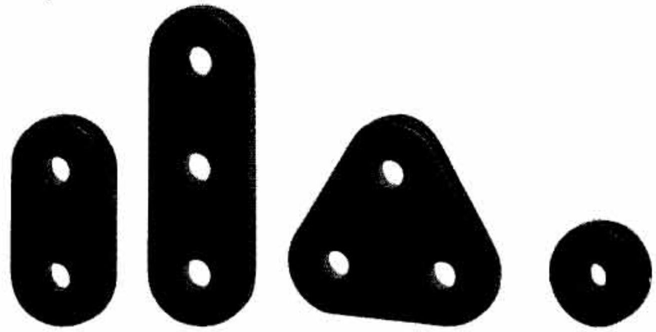
AC-10C/D Binding Posts



Designed by *-hp-*, these posts insure a positive connection that can be changed quickly and easily. The recess for "banana" plugs is in the main body of the post to eliminate excessive contact resistance. The cross-hole for permanent connection may be used even when a plug is inserted. The posts have a nylon insulated ferrule. AC-10C (black), $.35; AC-10D (red), $.35.

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

Model 25

Model 24

24 Waveguide Stand

Model 24 Waveguide Stands are cast and machined from aluminum alloy. They are designed for *-hp-* 25 Waveguide Clamps and lock the clamps at any height from 2¾" to 5¼". Model 24 is 2½" high and its base measures 4¾" in diameter. $3.00 each.

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.

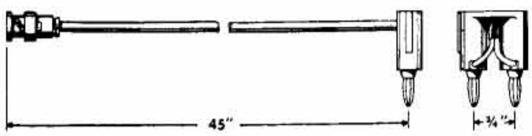
AC-76A BNC-to-Binding-Post Adapter

This new *-hp-* adapter mates with a BNC receptacle, providing an easy method of connecting clip leads, banana plugs or wires to instruments having BNC receptables. The nylon ferrule of the center conductor binding post is colored red; the other ferrule is black. Spacing between the banana plug is ¾". $5.00 each.

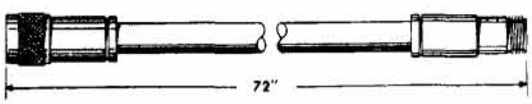
Data subject to change without notice. Prices f.o.b. factory.
Quantity discount prices on request.
Instruments finished in -hp- grey baked enamel.

ACCESSORY CABLE ASSEMBLIES, TEST LEADS

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.



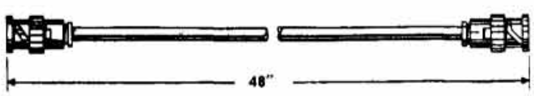
AC-16B Cable Assembly. Identical with AC-16A except has dual banana plug (¾ inch center) on one end and UG-88/U Type BNC male connector on other end. Length overall, 45 inches. Each, $5.00.



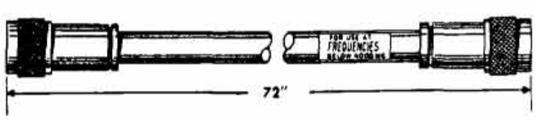
AC-16C Cable Assembly. This cable consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on one end with UG-21B/U Type N male connector and UG-23B/U Type N female connector at opposite end. For use at frequencies below 4,000 MC. Each, $10.50.

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.

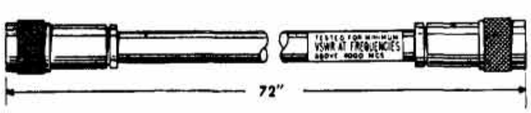
AC-16E Cable Assembly. A short cable of 9 inches length consisting of RG-58/U 50 ohm coaxial cable terminated on both ends with UG-88/U Type BNC male connectors. Each, $4.50.



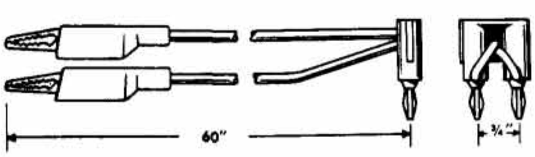
AC-16K Cable Assembly. This cable consists of 4 feet of RG-58/U 50 ohm coaxial cable terminated on each end with UG-88/U Type BNC male connectors. Each, $5.00.



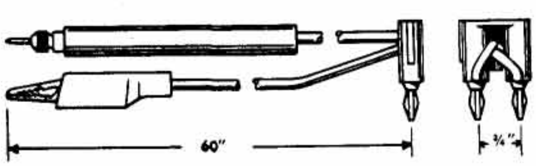
AC-16F Cable Assembly. For use at frequencies below 4,000 MC. Consists of 6 feet of RG-9A/U 50 ohm coaxial cable terminated on each end with UG-21B/U Type N male connectors. Each, $12.00.



AC-16Q Cable Assembly. For use at frequencies above 4,000 MC. Consists of 6 feet of specially treated RG-9A/U 50 ohm coaxial cable terminated on each end with UG-21D/U Type N male connectors. Each cable tested and selected for minimum SWR at frequencies above 4,000 MC. Each, $14.00.



AC-16S Test Leads. Dual banana plug to alligator clips. Five feet long, one red lead, one black lead. Each, $5.50.



AC-16T Test Lead. Dual banana plug to probe and alligator clip. Five feet long. Each, $6.00.

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	0.500
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.

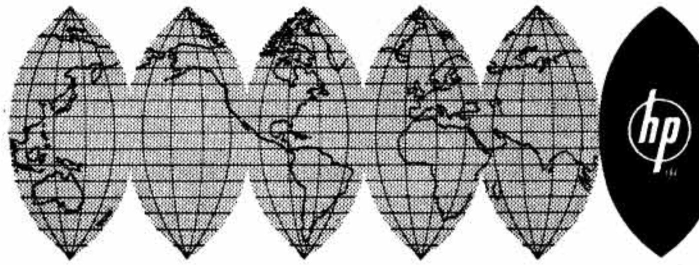
(2) All *-hp-* flanges are plain contact type. Where choke type connection is required, use *-hp-* 290A Cover to Choke Flange Adapter.

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 almost 400 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

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✛ Indicates Instrument Repair Stations

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MOhawk 4-8345

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Middlesex Turnpike
BRowning 2-9000

✛ **Bridgeport 8, Connecticut**
Yewell Associates, Inc.
1101 East Main Street
FOrest 6-3456

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The I. E. Robinson Company
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REgent 7-6791

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R. M. C. Associates
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LOwell 7-3933

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TRafalgar 9-2023

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7404 West Chester Pike
SHerwood 8-1294

Pittsburgh 27, Pennsylvania
S. Sterling Company
4024 Clairton Boulevard
TUxedo 4-5515

Poughkeepsie, N. Y.
Yewell Associates, Inc.
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GRover 1-3456

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HAzelwood 7-7560

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CEdar 3-7522

✛ **High Point, North Carolina**
Bivins & Caldwell, Inc.
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Tel.: 2-6873

Huntsville, Alabama
Bivins & Caldwell, Inc.
JEfferson 2-5733
(Direct line to Atlanta)

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GArden 5-5541

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ELgin 5-7931

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HIllcrest 2-8080

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AXminster 9-3594

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EDison 2-6667

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HUnter 6-8166

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ACademy 3-8106

✛ **San Francisco Area**
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Neely Enterprises
501 Laurel Street
LYtell 1-2626

✛ **Seattle 9, Washington**
ARVA
1320 Prospect Street
MAin 2-0177

Tucson, Arizona
Neely Enterprises
232 So. Tucson Blvd.
MAin 3-2564

CANADA

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Atlas Instrument Corporation, Ltd.
3333 Cavendish Blvd.
HUnter 9-8495 and 8496

✛ **Toronto 10, Ontario**
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RUssell 1-6174

Vancouver 2, British Columbia
Atlas Instrument Corporation, Ltd.
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frequency coverage from 50 KC to 21,000 MC; hp voltmeters from 10 to 700,000,000 cps, oscillators from 0.008 to 10,000,000 cps.

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Tel: Palae 1369 and Palae 1343

Finland
INTO O/Y
11 Meritullinkatu, Helsinki
Tel: 62 14 25 and 35 125

• France
Radio Equipements
65 rue de Richelieu, Paris 2ème
Tel: RIChelieu 49-88

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Hewlett-Packard S.A.
Verkaufsbüro
Frankfurt am Main
Holzhausenstrasse 69
Telefon 55 47 27

Greece
K. Karayannis
Karitsi Square, Athens
Tel: 23-213 (9 Lines)

India
The Scientific Instrument
Company, Ld.
6, Tej Bahadur Sapru Road
Allahabad 1

The Scientific Instrument
Company, Ld.
240, Dr. Dadabhai Naoroji Road
Bombay 1

The Scientific Instrument
Company, Ld.
11, Esplanade East, Calcutta 1

The Scientific Instrument
Company, Ld.
B-7, Ajmeri Gate Extn.
New Delhi 1

The Scientific Instrument
Company, Ld.
30, Mount Road, Madras 2

Israel
Electronic & Engineering Ltd.
6 Feierberg St., Tel-Aviv
Phone 4288

+ Italy
Dott. Ing. Mario Vianello
Via. L. Anelli 13, Milano
Telef. 553-081

Japan
Seki & Company, Ltd.
Daini Taihei Building
No. 1 Kanda Higashi-Fukudacho
Chiyoda-Ku, Tokyo
Tokyo (866) 3136 - 8

+ Netherlands
C. N. Rood, N.V.
11 - 13 Cort Van Der Lindenstraat
Rijswijk (Z.H.)
Tel. The Hague - 98 - 51 - 53 (6 Lines)

New Zealand
Geo. H. Sample & Son (N.Z.) Ltd.
431 Mount Albert Road
Mount Roskill S.1, Auckland
Tel: 89-439

Norway
Morgenstierne & Co.
Colletts Gate 10, Oslo
Tel. 60 17 90

Portugal
Senatejo Industrial, Lda.
Rua do Alecrim, 46-S/Loja
Lisbon
Tel: 3 44 46 - Expediente
36 86 43 - Gerencia

Union of South Africa
F. H. Flanter & Co. (Pty.), Ltd.
Rosella House
Buitencingle Street, Cape Town
Tel. 3-3817

Spain
ATAIO, Ingenieros
A. Aguilera, No. 8
Madrid
Tel: 23 27 42
57 84 51

+ Sweden
Erik Ferner AB
Snörmakarvägen 35
Bromma
Tel: 252870

+ Switzerland
Max Paul Frey
Hangweg 27
Köniz - Bern
Tel: (031) 63 36 44

Taiwan (Formosa)
Far-Eastern Company
No. 6 Nanyang Street
Taipei, Taiwan
Telephone: 27876
31868

+ United Kingdom
Livingston Laboratories
Retcar Street
London N. 19, England
Tel: Archway 6251

Yugoslavia
Belram Electronics
43 Ch. de Charleroi
Brussels, Belgium
Tel: 38.12.40